Astron. Astrophys. 354, 411–422 (2000)

ASTRONOMY AND ASTROPHYSICS

Research Note

X-ray emission/absorption mechanisms of 4 NLSy-1-like AGN and a radio quasar

QSO 0117-2837, RX J0134.3-4258, NGC 4051, Mrk 1298, 4C +74.26

Stefanie Komossa[1] **and Janek Meerschweinchen**[2]

[1] Max-Planck-Institut für Extraterrestrische Physik, Postfach 1603, 85740 Garching, Germany
[2] Weststrasse 19, 31683 Obernkirchen 2, Germany

Received 8 April 1999 / Accepted 5 November 1999

Abstract. We present a study of the X-ray variability properties and spectral shapes of five active galaxies all of which show extreme or enigmatic X-ray properties. We focus on QSO 0117-2837, RX J0134-4258, and NGC 4051, and briefly comment on Mrk 1298 and 4C +74.26. The individual objects were originally partly selected as candidates to host warm absorbers on the basis of (i) characteristic X-ray absorption features (NGC 4051, Mrk 1298, 4C +74.26), (ii) extreme X-ray spectral steepness (QSO 0117-2837; this object is found to be located in the 'zone of avoidance' when plotted in the Γ_x–FWHM$_{H\beta}$ diagram), and (iii) drastic spectral variability (RX J0134-4258). The temporal analysis reveals large-amplitude variability by a factor $\sim$30 in the long-term X-ray lightcurve of NGC 4051, very rapid variability of Mrk 1298, constant X-ray flux of the NLSy1 galaxy QSO 0117-2837, and constant mean countrate of RX J0134-4258 despite huge spectral changes. Besides the warm absorber, several further mechanisms and their merits/shortcomings are investigated to explain the spectral characteristics of the individual objects. Different models are favored for different sources. Consequences for Narrow-line Seyfert 1s in general are discussed and we present results from photoionization models to distinguish between different suggested NLSy1 scenarios.

Key words: galaxies: active – galaxies: nuclei – galaxies: quasars: general – galaxies: Seyfert – X-rays: galaxies

1. Introduction

1.1. Narrow-line Seyfert 1 galaxies

X-ray and optical observations of the last decade revealed a new sub-class of active galaxies that shows a number of unusual properties which are still not well understood. The subgroup of Narrow-line Seyfert 1 galaxies (NLSy1s hereafter) was recognized by Osterbrock & Pogge (1985) based on optical properties, namely, the small widths of the lines emitted from the broad line region (BLR). Puchnarewicz et al. (1992) made the interesting observation that many optical spectra of a sample of ultrasoft X-ray AGN discovered during the Einstein survey turned out to be NLSy1s, confirming the suggestion of Stephens (1989) that 'X-ray selection may be an efficient way to find NLSy1 galaxies'. Many more galaxies of this type were identified in the course of optical follow-up observations of ROSAT X-ray sources (e.g., Bade et al. 1995, Greiner et al. 1996, Becker et al. 1996, Moran et al. 1996, Wisotzki & Bade 1997, Grupe et al. 1998, Xu et al. 1999).

Correlation analyses performed in the last few years confirmed and quantified the trend that was already present in the study of Puchnarewicz et al. (1992): the correlation of *steep* X-ray spectra (measured at soft X-ray energies) with *small* widths of the BLR Balmer lines (e.g., Laor et al. 1994, 1997, Boller et al. 1996 (BBF96 hereafter), Brandt et al. 1997, Grupe et al. 1999a).[1] Further, there are some correlations between the optical emission line properties in the sense that *small* widths of BLR lines appear to go hand in hand with *strong* FeII complexes and *weak* [OIII]/Hβ ratios (e.g., Gaskell 1985, Puchnarewicz et al. 1992, Boroson & Green 1992, Laor et al. 1994, Lawrence 1997, Lawrence et al. 1997, Grupe et al. 1998).

A detailed analysis of the UV spectra of a number of NLSy1 galaxies was carried out by Rodriguez-Pascual et al. (1997) who detected a broad component in the permitted UV lines (FWHM $\gtrsim 5000$ km/s) but its absence in optical lines and favored an optically thin BLR à la Shields et al. (1995) as explanation. They also collected IR $-$ X-ray fluxes and conclude that Seyferts and NLSy1s are generally very similar concerning luminosities in different energy bands except that NLSy1s tend to be underluminous in the UV.

The causes for (a) the very soft X-ray spectrum in the ROSAT energy band, and for (b) the correlations among the optical emission lines and with the X-ray properties are still

[1] More precisely, the clearest trend is that *large*-FWHM BLR lines always appear in combination with *flat* X-ray spectra whereas NLSy1s show a rather large scatter in spectral slope and many are as flat as 'normal' Seyfert 1s (see particularly Xu et al. 1999).

Send offprint requests to: St. Komossa (skomossa@xray.mpe.mpg.de)

under discussion. Whereas most of the spectral steepness in, e.g., the NLSy1 galaxy NGC 4051 is caused by the presence of a warm absorber, strong soft excesses have been observed in other sources (e.g., TON S180; Fink et al. 1997, Comastri et al. 1998). In particular, a model that explains in detail *all* properties of NLSy1s within one scenario seems to be still lacking. Several suggestions have been made to explain individual aspects, e.g., (i) a special geometry, i.e., a disk-like BLR that is viewed face-on (Osterbrock & Pogge 1985, Stephens 1989, Puchnarewicz et al. 1992) or (ii) selective absorption of the high-velocity component of the BLR by dust (Halpern & Oke 1987) to account for the small width of Hβ; (iii) partial shielding of the NLR by a thick BLR (Boroson & Green 1992) to explain the anti-correlation of FeII and [OIII]; (iv) a removal or hindrance of a multi-phase BLR equilibrium by a steep X-ray spectrum à la Guilbert et al. (1983) (Brandt et al. 1994, see also Komossa & Fink 1997d) or (v) a scaling of BLR radius with X-ray spectral slope as in Wandel (1997) to explain the correlation of $\Gamma_{\rm x}$ with FWHM$_{\rm H\beta}$. BBF96 tentatively favored (vi) *low-mass* central black holes to produce a 'hot' soft excess in combination with a shielded NLR as suggested by Boroson & Green (1992). Komossa & Greiner (1995) and Komossa & Fink (e.g., 1997a,d,e) studied the possibility that (vii) the steep X-ray spectra in the ROSAT band and/or the optical high-ionization iron lines are predominantly caused by the presence of warm absorbers, and find, for the case of NGC 4051, that warm absorber and coronal line region are likely of different origin. Komossa & Janek (1999) examined the influence of various EUV-X-ray spectral shapes on the optical emission line ratios of NLSy1s.

1.2. Warm absorbers

Warm absorbers, highly ionized matter in the central region of active galaxies (AGN), are an important new diagnostic tool for investigating the conditions within the nuclei of AGN (see Fabian 1996, Komossa & Fink 1997d for overviews). The presence of an ionized absorber was first discovered in Einstein observations of the quasar MR 2251-178 (Halpern 1984). With the improved spectral resolution of ROSAT and ASCA, many more were found. They have been observed in $\sim$50% of the well-studied Seyfert galaxies as well as in some quasars (e.g., Pan et al. 1990, Nandra & Pounds 1992, Turner et al. 1993, Fiore et al. 1993, Mathur 1994, Done et al. 1995, Cappi et al. 1996, Ulrich-Demoulin & Molendi 1996, Komossa & Fink 1997b,c, Schartel et al. 1997a). Signatures of ionized absorbers have also been detected in quite a number of NLSy1 galaxies (e.g., Brandt et al. 1994, Pounds et al. 1994, Leighly et al. 1996, 1997, Guainazzi et al. 1996, Brandt et al. 1997, Komossa & Fink 1997a, Hayashida 1997, Iwasawa et al. 1998).

1.3. The present study

Given the enigmatic properties of NLSy1s, their detailed study is important. The sources discussed below all show some particularly extreme behavior in terms of spectral slope or variability. X-ray analyses of them were either not published previously, or with different emphasis (for details see below).

Part of the original selection criterion also was to check for the presence of a warm absorber (WA), since WAs suggest themselves as explanation for both extreme spectral steepness in the soft X-ray band and strong spectral variability.[2] However, we do not only focus on this scenario. Alternatives are discussed in some detail. In particular, we examine the influence of different EUV-X-ray spectral shapes on BLR multi-phase equilibrium following the suggestion of Brandt et al. (1994).

This paper is organized as follows: The data reduction is described in Sect. 2. In the next two sections we present the general assumptions on which the data analysis is based (Sect. 3) and results for the individual objects (Sect. 4). In Sects. 5.1-5.5 we give a discussion of the properties of the individual galaxies while in Sects. 5.6-5.7 consequences for NLSy1s in general are addressed. The concluding summary is given in Sect. 6. Throughout this paper, we assume H_0 = 50 km/s/Mpc and the galaxies to follow the Hubble flow.

2. Data reduction

We used all-sky survey (RASS) as well as archival and pointed serendipitous ROSAT (Trümper 1983) PSPC (Pfeffermann et al. 1987, Briel et al. 1994) observations of the galaxies. The observations are summarized in Table 1.

For further analysis, the source photons were extracted within a circular cell centered on the target source. The background was determined in a source-free ring around the target source and subtracted. The data were corrected for vignetting and dead-time, using the EXSAS software package (Zimmermann et al. 1994). In case of RASS data the background was determined in a source-free region along the scanning direction of the telescope.

To carry out the spectral analysis source photons in the amplitude channels 11-240 were binned according to a constant signal/noise ratio of at least 3σ, and higher for brighter sources.

Details on the standard procedures for the reduction of ROSAT data can be found in, e.g., Zimmermann et al. (1994) and Briel et al. (1994).

3. Data analysis: general assumptions

Several models were applied to the X-ray spectra of the galaxies: (i) a single powerlaw of the form $\Phi \propto E^{\Gamma_{\rm x}}$ (which, even if not the correct description, always provides a useful means

[2] Given that WAs are unambiguously detected in Seyferts, one would naturally expect the existence of objects with *deeper* absorption complexes that recover only beyond the ROSAT energy range (unless an as yet unknown fine-tuning mechanism is at work, that regulates the optical depths in the important metal ions to a very narrow range); whether WAs are indeed present requires a careful examination on an object-by-object basis which is presented below. (Note that some early arguments against WAs in ROSAT spectra simply mixed up some of the basic physical properties of warm absorbers and thus led to erroneous conclusions).

Table 1. Log of observations. $t_{\rm exp}$ gives the exposure time in ksec, CR the countrate in cts/s. The data for NGC 4051 are separately listed in Table 3. 'S' refers to RASS data, 'P' to PSPC observations in the pointed mode.

object	date	$t_{\rm exp}$	CR	obs.
QSO 0117	Dec. 28-29, 1991	4.5	0.44	P
RXJ 0134	Dec. 1990	0.55	0.30	S
	Dec. 28, 1992 - Jan. 3, 1993	5.9	0.24	P
Mrk 1298	June 1-15, 1996	21.3	0.01	P
4C +74.26	June 23-34, 1993	19.4	0.65	P

of judging the steepness of the spectrum), (ii) a powerlaw plus soft excess parameterized either as black body emission or by the accretion disk model available in EXSAS (Zimmermann et al. 1994), and (iii) a warm absorber model. The latter was calculated with Ferland's (1993) code Cloudy (see Komossa & Fink 1997a,b for details). The following assumptions were made: The warm absorber is assumed to be of constant density $\log n_{\rm H} = 9.5$, of solar abundances according to Grevesse & Anders (1989) (if not mentioned otherwise), and to be illuminated by the continuum of the central point-like energy source. The spectral energy distribution from the radio to the gamma-ray region consists of our mean AGN continuum (Komossa & Schulz 1997) of piecewise powerlaws with, in particular, an energy index $\alpha_{\rm uv-x} = -1.4$ in the EUV and an X-ray photon index $\Gamma_{\rm x}$ which is either directly determined from X-ray spectral fits or fixed to –1.9. The fit parameters of the warm absorber are its column density $N_{\rm w}$ and the ionization parameter $U = Q/(4\pi r^2 n_{\rm H} c)$. In case of the dusty warm absorber models the dust composition and grain size distribution were chosen like in the Galactic diffuse interstellar medium (Mathis et al. 1977) as incorporated in *Cloudy* (Ferland 1993), and the metal abundances were depleted correspondingly (see Komossa & Fink 1997b,c for details).

4. Data analysis results: individual objects

Below, we first provide a brief review of the multi-wavelength properties of the individual sources and then report the results from our analysis of the X-ray data.

4.1. QSO 0117-2837

QSO 0117-2837 (1E 0117.2-2837) was discovered as an X-ray source by Einstein and is at a redshift of z=0.347 (Stocke et al. 1991). Grupe (1996) classified it as NLSy1. It is serendipitously located in one of the ROSAT PSPC pointings; the steep X-ray spectrum was briefly noted by Schwartz et al. (1993) and Ciliegi & Maccacaro (1996). We present here the first detailed analysis of the ROSAT observations of this AGN.

When the X-ray spectrum is fit by a single powerlaw continuum with Galactic cold absorption of $N_{\rm Gal} = 1.65\,10^{20}$ cm^{-2} (Dickey & Lockman 1990), we derive a photon index $\Gamma_{\rm x} \simeq -3.6$ (-4.3, if $N_{\rm H}$ is treated as free parameter). The overall quality of the fit is good ($\chi^2{}_{\rm red} = 0.8$), but there are slight systematic residuals around the location of absorption edges.

A successful alternative description is a warm-absorbed flat powerlaw of canonical index. We find a very large column density $N_{\rm w}$ in this case, and the contribution of emission and reflection is no longer negligible; there is also some contribution to Fe Kα. For the pure absorption model, the best-fit values for ionization parameter and warm column density are $\log U \simeq 0.8$, $\log N_{\rm w} \simeq 23.6$ ($N_{\rm H}$ is now consistent with the Galactic value), with $\chi^2{}_{\rm red}$ = 0.74. Including the contribution of emission and reflection for 50% covering of the warm material as calculated with *Cloudy* gives $\log N_{\rm w} \simeq 23.8$ ($\chi^2{}_{\rm red}$ = 0.65). We note that for these large column densities, the optical depth to electron scattering becomes significant. The main purpose of the present study was to check under which conditions a warm absorber model fits at all; more detailed modelling should await the availability of deeper observations and improved spectral resolution. Several strong EUV emission lines are predicted to arise from the warm material. Some of these are: FeXXIλ2304/H$\beta_{\rm wa}$ = 10, HeIIλ1640/H$\beta_{\rm wa}$ = 16, FeXXIλ1354/H$\beta_{\rm wa}$ = 37, FeXVIIIλ975/H$\beta_{\rm wa}$ = 16, NeVIIIλ774/H$\beta_{\rm wa}$ = 9, and FeXXIIλ846/H$\beta_{\rm wa}$ = 113. No absorption from CIV and NV is expected to show up. Both elements are more highly ionized.

Alternatively, the spectrum can be fit with a flat powerlaw plus soft excess (Table 2). E.g., assuming a black body shape we derive $KT_{\rm bb} = 0.1$ keV for $N_{\rm H} = N_{\rm Gal}$ ($\chi^2{}_{\rm red} = 0.7$).

An analysis of the temporal variability reveals constant source flux within the 1σ error during the observation.

4.2. RX J0134-4258

Discovered in the ROSAT survey (Greiner 1996), the object was optically identified as NLSy1 galaxy (Grupe 1996) with redshift z=0.237. The later pointed PSPC observation led to the detection of strong spectral variability (Greiner 1996, Grupe 1996, Mannheim et al. 1996, Komossa & Fink 1997d). Here, we present the first detailed analysis of the X-ray properties of this peculiar source.[3] The kind of variability of RX J0134-4258 is rare, and provides important constraints on the intrinsic X-ray emission mechanisms and/or the properties of surrounding reprocessing material.

RASS. When fit by a single powerlaw, the spectrum of RX J0134-4258 turns out to be one of the steepest among NLSy1s with $\Gamma_{\rm x} \approx$ –4.4 (absorption was fixed to the Galactic value in the direction of RX J0134-4258, $N_{\rm Gal} = 1.59\,10^{20}$ cm^{-2}). A warm-absorbed, intrinsically *flat* powerlaw provides a successful alternative fit to the RASS data. Due to the low number of available photons, a range of possible combinations of U and $N_{\rm w}$ explains the data with comparable success. A large column density $N_{\rm w}$ (of the order 10^{23} cm^{-2}) is needed to account for the

[3] First results of the present study were reported by Komossa & Fink (1997d), Komossa & Greiner (1999), and Komossa et al. (1999a). Another study by Grupe et al. (1999b) in underway who also report the detection of RX J0134-4258 at radio wavelengths.

Table 2. Comparison of different spectral fits to QSO 0117-2837, RX J0134-4258 and Mrk 1298: (i) single powerlaw (pl), (ii) accretion disk model after Shakura & Sunyaev (1973), and (iii) warm absorber. Γ_x was fixed to –1.9 in (ii) and (iii), except for RX J0134-4258, where Γ_x = –2.2 (see text). Instead of individual error bars we provide several models that successfully describe the data.

name	powerlaw$^{(1)}$			acc. disk + pl$^{(2)}$			warm absorber$^{(2)}$		
	$N_H^{(3)}$	Γ_x	χ^2_{red}	$M_{BH}^{(4)}$	$\frac{\dot{M}}{\dot{M}_{edd}}$	χ^2_{red}	log U	log N_w	χ^2_{red}
QSO 0117-2837	0.30	–4.3	0.8	6	0.6	0.7	0.8	23.6	0.7
RX J0134–4258$^{(5)}$	0.16	–4.4	0.5	1	0.1	0.6	0.5	23.1	0.6
RX J0134–4258$^{(6)}$	0.16	–2.2	1.3						
Mrk 1298	0.44	–2.6	4.3	1	0.02	3.5	–0.3	22.2	0.95

$^{(1)}N_H$ free, if $> N_H^{Gal}$ $^{(2)}N_H$ fixed to N_H^{Gal} $^{(3)}$in 10^{21}cm^{-2} $^{(4)}$in 10^5M$_\odot$, fixed $^{(5)}$survey obs. $^{(6)}$pointed obs.

ultrasoft observed spectrum. When we fix $\Gamma_x = -2.2$, the value observed during the later pointing, and use $N_H = N_{Gal}$, we obtain $\log N_w = 23.1$ and $\log U = 0.5$. This model gives an excellent fit ($\chi^2{}_{red} = 0.6$).

A number of further models were compared with the observed spectrum. E.g., an accretion disk model was fit. Again, we fixed Γ_x =-2.2. The black hole mass is not well constrained by the model and was fixed (10^5 M$_\odot$). We find $\frac{\dot{M}}{\dot{M}_{edd}} \simeq$ 0.1 and, again, a very good fit is obtained (Table 2). If instead the spectrum is fit by a single black body, one derives a temperature $kT \simeq 0.07$ keV.

Pointed observation. The fit of a single powerlaw to the spectrum of RX J0134-4258 yields a photon index Γ_x = -2.2 (χ^2_{red} = 1.4), *much flatter* than during the RASS observation. The amount of cold absorption was fixed to the Galactic value (if treated as free parameter, the Galactic value is underpredicted). For this model fit, two kinds of residuals are visible: (i) the first data point (below 0.15 keV) indicates a higher countrate than predicted by the model. This data point significantly influences the value of χ^2_{red}, and if it is excluded from spectral fitting, we obtain χ^2_{red} = 1.0 and $\Gamma_x = -2.1$. Formally, a very low-temperature soft excess could be present in the spectrum of RX J0134-4258. Indeed, such a model can be fit with $kT \simeq 0.1$ keV. Hints for a similar very soft excess have been found in the ROSAT spectra of TON S180 (Fink et al. 1997) and NGC 4051 (Komossa & Fink 1997d). However, since such a component is essentially only constrained by the first few data bins we do not discuss this possibility in further detail. Another possibility is uncertainties in the calibration at these low energy channels. The second deviation from the powerlaw is (ii) an underprediction of the countrate in the energy range ~0.4–0.9 keV (Fig. 2) indicative of the presence of absorption edges, as observed in AGNs where warm absorbers are present. However, again, the deviations from the powerlaw are only defined by few bins, and we thus assume in the following that the spectrum during the pointed observation essentially represents the intrinsic, un-distorted continuum (a complete description might invoke both, a weak soft excess and weak warm absorption, but fitting such models would definitely be an overinterpretation of ROSAT data).

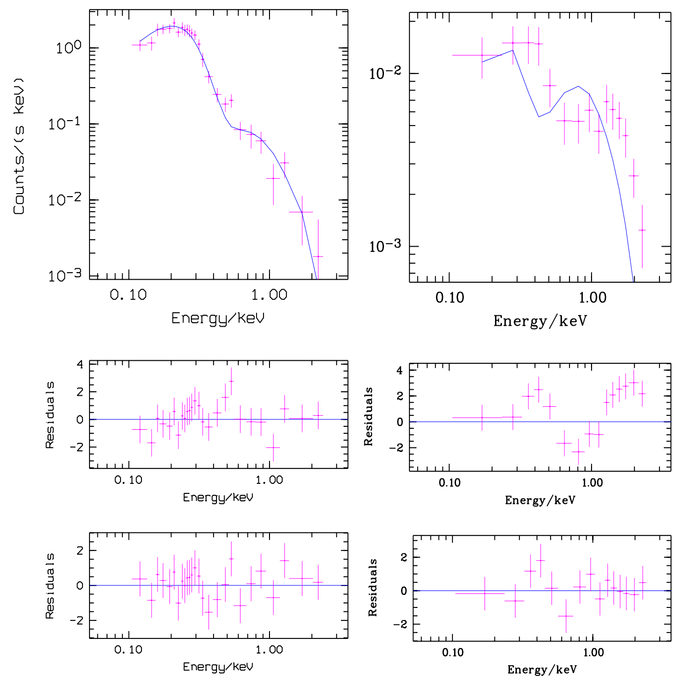

Fig. 1. X-ray spectra and residuals of the fit for QSO 0117-2837(left) and Mrk 1298(right). The upper panel gives the observed X-ray spectrum of each galaxy (crosses) and the model fit (solid line). The lower panel shows the residuals. QSO 0117-2837 (left): upper panels: single powerlaw, lowest panel: warm-absorbed flat powerlaw. Mrk 1298 (right): upper panels: single powerlaw, lowest panel: warm-absorbed flat powerlaw.

Temporal analysis: The countrate during the pointed observation turns out to be variable by about a factor 2. The lightcurve is displayed in Fig. 3.

4.3. NGC 4051

NGC 4051 has been classified as Seyfert 1.8 (e.g., Rosenblatt et al. 1992) or NLSy1 (e.g., Malkan 1986) and is at a redshift of z = 0.0023. This galaxy has been been observed with all major X-ray satellites (e.g., Marshall et al. 1983, Lawrence et al. 1985, Matsuoka et al. 1990, Mihara et al. 1994, McHardy et al. 1995, Guainazzi et al. 1996, Komossa & Fink 1997a; for

Table 3. Log of ROSAT PSPC observations of NGC 4051 and warm absorber fit results. $t_{\rm exp}$ = effective exposure time, CR = mean count rate, $L_{\rm x}$ = mean (0.1–2.4 keV) luminosity corrected for cold and warm absorption.

date	$t_{\rm exp}$ [s]	CR [cts/s]	log U	log $N_{\rm w}$	$\Gamma_{\rm x}$	$L_{\rm x}$ [10^{41} erg/s]
Nov. 15, 1991	2705	1.0	0.2	22.52	-2.2	3.5
Nov. 16, 1991	28727	1.6	0.2	22.45	-2.2	5.4
Dec. 15 - 19, 1991	4783	1.0	0.1	22.35	-2.2	3.7
Nov. 11 - 17, 1992*	20815	6.0	0.2	22.35	-2.2	19.5
Nov. 11 - 12, 1993	12261	2.9	0.4	22.67	-2.3	9.5

* results of model fits uncertain due to off-axis location of source

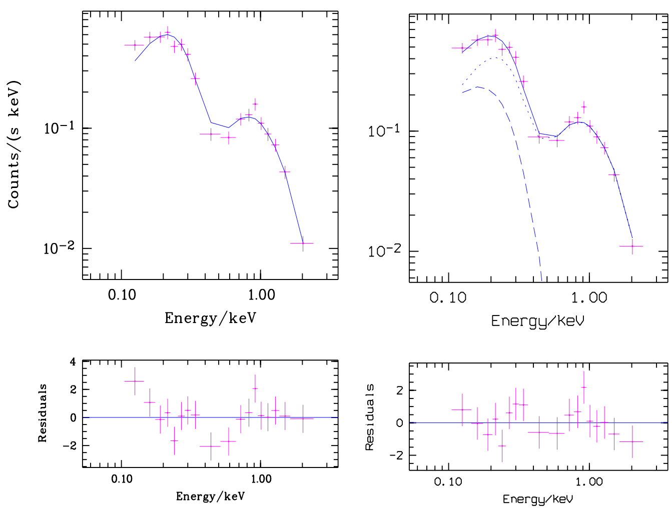

Fig. 2. X-ray spectrum (pointed obs.) of RX J0134-4258 and residuals. *Left*: The upper panel gives the observed X-ray spectrum (crosses) and powerlaw model fit (solid line), the lower panel the residuals. *Right*: The same for a powerlaw plus black body fit (the quality of the fit is improved, but some systematic residuals around 0.4-0.9 keV remain). The spectrum was binned to a signal/noise of 8σ per bin. The amount of cold absorption was fixed to the Galactic value.

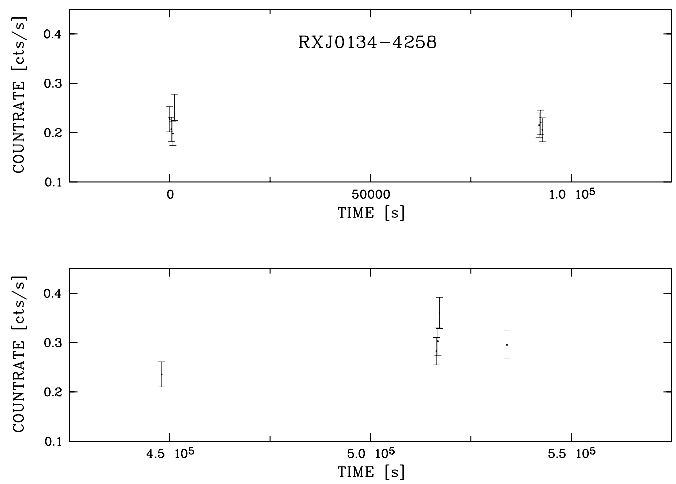

Fig. 3. X-ray lightcurve of RX J0134-4258 (pointing) binned to time intervals of 400s. The time is measured in seconds from the start of the observation.

brief summaries of these papers see Sects. 1 and 5 of Komossa & Fink 1997a). Recently, first BeppoSAX results have been presented by Guainazzi et al. (1998a), who report the detection of a strong drop in source flux which lasted the whole observing interval of ~2 d.

Here, we present an analysis of all ROSAT PSPC data of this source, including previously unpublished observations and a homogeneous re-analysis of published ones (McHardy et al. 1995). Since NGC 4051 is strongly variable in X-rays, the large set of ROSAT data is very valuable to create a long-term lightcurve of this source and to study variability mechanisms. It also provides an excellent data base to study long-term spectral changes due to the presence of the warm absorber and places tight constraints on the ionization state of the warm material.

To investigate the long-term trend in the variability of NGC 4051, in countrate as well as in ionization parameter U and column density $N_{\rm w}$ of the warm absorber, we have fit our warm absorber model to the individual data sets. We find that in the long term all features are variable, except for the cold absorption which is always consistent with the Galactic value within the error bars. Ionization parameter U and column density $N_{\rm w}$ change by about a factor of 2. The slope of the powerlaw remains rather steep (Table 3).

The long-term lightcurve reveals large-amplitude variability by a factor ~30 in countrate within the total observing interval. The X-ray lightcurve is displayed in Fig. 5.

4.4. *Mrk 1298*

Mrk 1298 (PG 1126-041) is a luminous Seyfert 1 galaxy at redshift z = 0.06 (Osterbrock & Dahari 1983). Its optical spectrum (Rafanelli & Bonoli 1984, Miller et al. 1992) is characterized by strong FeII emission line complexes. Mrk 1298 was part of several studies of correlations between strength of FeII and other spectral properties (Boroson & Green 1992, Wang et al. 1996 (WBB96 hereafter)). A UV spectrum of Mrk 1298 was presented by Wang et al. (1999). The ROSAT PSPC X-ray spectrum was first analyzed by WBB96 who detected an absorption edge which they interpreted as arising from a warm absorber. We present here a more detailed analysis of the properties of the warm absorber (see also Komossa & Fink 1997d,e), including predictions of non-X-ray emission lines expected to arise from the warm material, and test for the presence of a *dusty* warm absorber. We also analyze the temporal behavior of the X-ray flux.

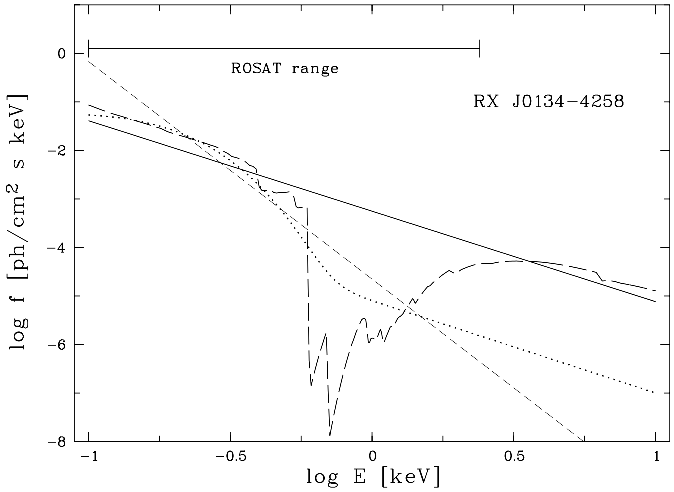

Fig. 4. Comparison of different X-ray spectral fits successfully applied to the ROSAT survey observation of RX J0134-4258 (broken lines) and the pointed observation (solid line). Short-dashed line: single powerlaw with $\Gamma_{\rm x} = -4.4$; long-dashed: warm-absorbed flat powerlaw; dotted: powerlaw plus soft excess, parameterized as a black body. All models are corrected for Galactic absorption.

A single powerlaw does not provide a successful X-ray spectral fit. We find $\chi^2_{\rm red}$=3.3 and the amount of cold absorption underpredicts the Galactic value in the direction of Mrk 1298, $N_{\rm H}^{\rm Gal} = 4.44\,10^{20}$ cm^{-2}. If Galactic absorption is enforced, the quality of the fit becomes worse ($\chi^2_{\rm red}$=4.3). Therefore, a number of further spectral models was fit, including an intrinsically flat powerlaw plus black-body like soft excess. The latter model gives $\chi^2_{\rm red}$=3.4 (Table 4), still unacceptable.

On the other hand, a warm absorber fits the X-ray spectrum well. We fixed the photon index of the intrinsic powerlaw to $\Gamma_{\rm x}$ =-1.9. In a first step, cold absorption was fixed to the Galactic value. We then obtain $\log U \simeq -0.3$ and $\log N_{\rm w} \simeq 22.2$ and the quality of the fit is acceptable ($\chi^2_{\rm red}$=0.95). Slight systematic residuals remain at very low energies. Thus, in a second step, $N_{\rm H}$ was treated as free parameter. In this case we find some excess absorption, the fit is further improved ($\chi^2_{\rm red}$=0.78), and the residuals disappear (Fig. 1). The warm absorber parameters change to $\log U \approx -0.1$ and $\log N_{\rm w} \approx$ 22.5. The cold absorption amounts to $N_{\rm H} \simeq 0.6 \times 10^{21}$ cm^{-2}.

Finally we note that the model of a *dusty* warm absorber does not give a successful X-ray spectral fit provided the intrinsic powerlaw spectrum is close to $\Gamma_{\rm x}$ =-1.9.

The X-ray temporal analysis (Fig. 6) reveals rapid variability of the source with repeated changes in countrate by a factor ~2 within 800 s.

4.5. 4C +74.26

4C +74.26 is a radio-loud quasar at z=0.104 (Riley et al. 1988). The RASS data of this source were analyzed by Schartel et al. (1996a) who derived $\Gamma_{\rm x} \simeq -1.3$. In a study of ROSAT and ASCA data, Brinkmann et al. (1998) confirmed the unusually flat soft X-ray ROSAT spectrum ($\Gamma_{\rm x} \simeq -1.3$ to -1.6; as compared to $\Gamma_{\rm x} \simeq -2.2$ typically seen in nearby radio-loud quasars), found a steeper ASCA powerlaw spectrum, and evidence for the presence of a warm absorber. We re-analyzed this source, since the description given in Brinkmann et al. was highly suggestive of the presence of a *dusty* warm absorber.

The fit of a single powerlaw model yields an acceptable fit ($\chi^2_{\rm red} = 1.0$) but an extremely flat spectrum with $\Gamma_{\rm x}$ =-1.4. Applying the model of a *dusty* warm absorber to the ROSAT spectrum we get a successful spectral fit with a steeper intrinsic powerlaw. In particular, we fixed the photon index to $\Gamma_{\rm x}$ =-2.2 since we wanted to test whether the data are consistent with the general expectation for radio quasars. In this case we obtain a column density of the dusty warm gas of $\log N_{\rm w}$ = 21.6 and an ionization parameter of $\log U = -0.1$ ($\chi^2_{\rm red}$ = 1.0).

5. Discussion

We first discuss the X-ray properties of the individual objects, in the context of other object-specific observations. Then, a more general discussion on NLSy1s is given.

5.1. QSO 0117-2837

Three models were found to fit the ROSAT X-ray spectrum of QSO 0117-2837 successfully. A single steep powerlaw with $\Gamma_{\rm x} \simeq -4.3$, a flat powerlaw plus soft excess, and a warm-absorbed flat powerlaw. In the latter case a rather large column density of the warm absorber is inferred, $\log N_{\rm w} \approx 23.6 - 23.8$. This would make the ionized absorber in QSO 0117-2837 the one with the largest column density known, and suggests that other spectral components contribute to, or dominate, its X-ray spectral steepness. Given the reported relations between X-ray and UV absorption, we note that we do not predict any UV absorption from NV and CIV for our best-fit warm absorber model. Both elements are more highly ionized; i.e., the absence of UV absorption alone could not be used as argument against a warm absorber.

Given the very steep rise towards the blue of QSO 0117-2837's optical spectrum (Grupe et al. 1999a; Fig. 1a of Komossa et al. 2000), it is tempting to speculate that a giant soft-excess dominates the optical-to-X-ray spectrum. We strongly caution, though, that simultaneous optical-X-ray variability studies in other Seyferts and NLSy1s (e.g., Done et al. 1995) do *not* favor a direct relation between optical and X-ray spectral components. Furthermore, such a giant optical-to-X-ray bump in QSO 0117-2837 and NLSy1s in general, would be inconsistent with the finding of Rodriguez-Pascual et al. (1997) that NLSy1s tend to be underluminous in the UV.

A most interesting peculiarity of QSO 0117-2837 is revealed, when combining its X-ray and optical properties: Whereas its X-ray spectrum is among the steepest observed among NLSy1s, its Hβ emission line is fairly broad. Fitting this line with Gaussian components it is best described by a two component Gaussian with a narrow component of similar width as [OIII] plus a broad component of FWHM$_{H\beta} \approx$ 4000 km/s (Komossa et al. 2000). This combination of $\Gamma_{\rm x}$ and

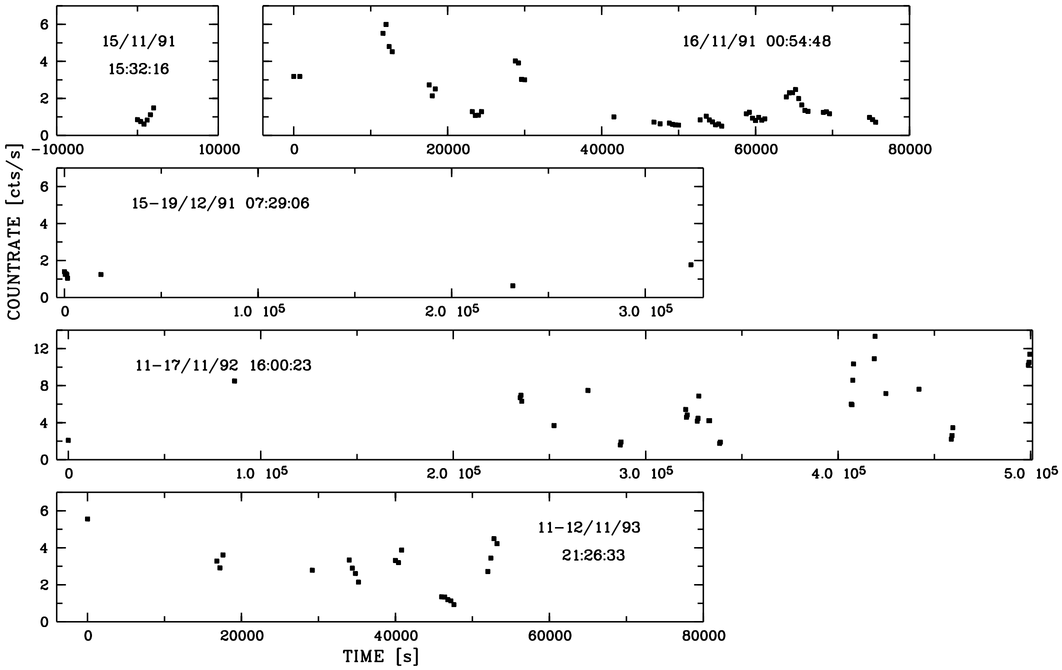

Fig. 5. Long-term X-ray lightcurve of NGC 4051, based on all pointed ROSAT PSPC observations of this source. NGC 4051 is variable by a factor ∼30 in countrate. The lightcurve of Nov. 16, 1991 was earlier shown in McHardy et al. (1995), the one of Nov. 1993 in Komossa & Fink (1997a). The time is measured in s from the beginnings of the individual observations; the insets in each panel give the starting times.

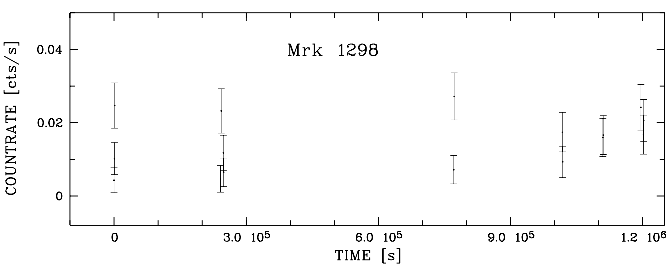

Fig. 6. X-ray lightcurve of Mrk 1298. Each point encloses a time interval of 800s. Rapid variability on short timescales is revealed.

FWHM$_{H\beta}$ places QSO 0117-2837 in a region in the popular $\Gamma_{\rm x}$ versus FWHM$_{H\beta}$ diagram (e.g., Fig. 8 of BBF96) which is barely populated by objects, therefore occasionally referred to as 'zone of avoidance'.

Its peculiar properties make QSO 0117-2837 a good target for follow-up X-ray spectral observations with XMM and AXAF, as well as for high-resolution optical observations of the Hβ complex.

Some NLy1s have been reported to show rapid X-ray variability. QSO 0117-2837 shows constant source flux during the observation, though.

5.2. RX J0134-4258

5.2.1. Comparison with similar objects

The drastic spectral variability of RX J0134-4258 is rather peculiar. Often, in AGN, the X-ray flux is variable but the spectral slope remains constant. Cases were a strong change in hard X-ray spectral shape was reported, are IRAS 13224 (Otani et al. 1996), NGC 4051 (Guainazzi et al. 1996), and Mrk 766 (Leighly et al. 1996). However, in all cases the spectral index varied mainly between $\Gamma_{\rm x} \simeq -2.0$ and *flatter* values. Further, these sources changed countrate when changing spectral shape. Recently, Guainazzi et al. (1998b) presented observations of the Seyfert galaxy 1H0419-577 which underwent a spectral transition from steep ($\Gamma_{\rm x} = -2.5$) to flat ($\Gamma_{\rm x} = -1.6$) between a ROSAT and a SAX observation. The most similar case to RX J0134-4258 we are aware of is the observation reported by Fink et al. (1997) who detected changes in spectral index of the NL quasar TON S180 that were not accompanied by a noticeable change of the total soft X-ray emission.

5.2.2. Variability mechanisms

Warm absorption. One natural mechanism to produce the spectral variability in RX J0134-4258 is warm absorption because this is an efficient method to produce steep X-ray spectra (e.g., by a change in ionization state of the warm absorber). Note, that Grupe (1996) argued against the presence of the warm absorber based on the erroneous statement that a warm absorber could not produce a steep soft X-ray spectrum.

Examination whether, and under which conditions, a warm absorber is indeed a viable description of the X-ray spectrum, and whether it is the only one, has to be based upon detailed modeling and careful consideration of alternatives.

Our modelling (Sect. 4.2) leads to the following results: The ultra-soft state is well fit by a warm absorber with column density $\log N \simeq 23$. This is a factor of about 2-3 larger than that of the well-studied warm absorber in the NLSy1 galaxy NGC 4051 (e.g., Pounds et al. 1994, Komossa & Fink 1997a, and our Table 3).

The most suggestive scenario within the framework of warm absorbers then is a change in the *ionization state* of ionized material along the line of sight, caused by *varying irradiation* by a central ionizing source. One problem arises immediately, though: In the simplest case, lower intrinsic luminosity would be expected, to cause the deeper observed absorption, in 1990. However, the source is somewhat brighter in the RASS observation. (Fig. 4). Some variability seems to be usual, though. The countrate changes by about a factor of 2 during the pointed observation (Fig. 3). If one wishes to keep this scenario, one would have to assume that the ionization state of the absorber still reflects a preceding (unobserved) low-state in intrinsic flux.

Alternatively, and more likely, gas heated by the central continuum source may have *crossed the line of sight*, producing the steep RASS spectrum, and has (nearly) disappeared in the 1992 observation. This scenario explains most naturally the nearly constant countrate from RASS to pointed observation, because the countrate is dominated by the soft energy part of the spectrum (below 0.7 keV) which is essentially unaffected by warm absorption. The transient passage of a BLR cloudlet would be consistent with the scenario proposed by Rodriguez-Pascual et al. (1997) who suggested a matter-bounded BLR in NLSy1s on the basis of emission line profiles and strengths. They derive a lower column density for the BLR clouds but since our best-fit X-ray warm absorber also has a higher ionization parameter, the hydrogen Strömgren sphere is shifted further out and thus the clouds remain matter-bounded.[4]

Alternatives: The short duration of the RASS observation has to be kept in mind, and both, an intrinsically steep powerlaw and a strong soft excess fit the X-ray spectrum as well. Variability in only one component seems to be problematic, though, since the nearly constant countrate has to be accounted for.

A spectral change with constant countrate is reminiscent of one class of Galactic black hole transients (the one in which both spectral components change simultaneously as to mimic constant countrate; e.g., Tanaka 1997). In fact, the potential similarity of NLSy1s with Galactic black hole candidates has been repeatedly mentioned (starting with Pounds et al. 1995), but has never been explored in more detail. We do not follow this one further, since the analogy between NLSy1s and Galactic black hole candidates does not seem to go very far (e.g., p. 411 of Brandt & Boller 1999).

Finally, it is also possible that the constant countrate is pure coincidence: Both, variable soft excesses (see, e.g., 1E1615+061 for an extreme example) *and* variable powerlaws (often of constant shape) have been observed in AGN and these two might have compensated each other to produce nearly constant total countrate (this seems to be the model favored by Grupe 1996; their Fig. 8.11).

[4] It is important to note that both these scenarios are consistent with the recent ASCA observation of Grupe et al. (1999b) who do not detect strong absorption edges in the ASCA spectrum of RX J0134-4258 (the upper limits they report are *not* very tight, though): In case of a non-equilibrium warm absorber the actual depths of absorption edges depend on the unknown flux history; in the more likely case of a transient cloud passage the absorber has simply *left our line-of-sight*.

5.3. NGC 4051

The variability amplitude of NGC 4051, a factor 30 over the measured time interval, is fairly large. During all individual ROSAT observations, the source is variable. No long-term very low state as recently reported by Guainazzi et al. (1998a) occurred.

The warm absorber properties, averaged over individual observations, are found to be quite constant, with changes less than about a factor of two in column density and ionization parameter. This is consistent with the finding of Komossa & Fink (1997a) that the bulk of the warm material in NCC 4051 does not react to short-timescale changes in the ionizing luminosity and thus the bulk of the ionized absorber must be of low density, or alternatively, the warm material is out of photoionization equilibrium. The latter possibility was also suggested by Nicastro et al. (1999) based on shorter-timescale variability behavior of NGC 4051. Recently, Contini & Viegas (1999) presented detailed multi-wavelength modelling of NGC 4051, including in their models the presence of shocks besides photoionization.

5.4. Mrk 1298

It is interesting to note that Mrk 1298 exhibits all characteristics of a NLSy1 galaxy except that its observed FWHM of Hβ, 2200 km/s, just escapes the criterion of Goodrich (1989).

A warm absorber fits well the X-ray spectrum of this galaxy, whereas a powerlaw plus black-body-like soft excess does not. This also holds for further possible shapes of the soft excess.

In the following, we give some predictions made by the warm absorber scenario, in terms of line emission and absorption. Depending on the covering factor of the warm absorber, the ionized material might contribute to high-ionization emission lines in the optical–EUV spectral region (e.g., Komossa & Fink 1997a,d,e). Among the strongest predicted lines are [FeXIV]λ5303/H$\beta_{\rm wa}$ = 3, (NVλ1240+FeXIIλ)/H$\beta_{\rm wa}$ = 13 and OVIλ1035/H$\beta_{\rm wa}$ = 284. However, the warm absorber is matter bounded and the total emissivity in Hβ is fairly small when compared to the observed Hβ-luminosity of $L_{\rm H\beta}^{\rm obs} \simeq 10^{42.86}$ erg/s (Rafanelli & Bonoli 1984; the value given in Miller et al. 1992 is a factor 1.6 lower). Scaled to observed Hβ, the strongest predicted line is OVI$_{\rm wa}$/H$\beta_{\rm obs}$ $\approx$ 0.4.

WBB96 mention the presence of UV absorption lines in an IUE spectrum of Mrk 1298. The following equivalent widths of UV absorption lines are predicted for the best-fit warm absorber model (see also the discussion in Wang et al. 1999): $\log W_\lambda/\lambda \simeq -2.9$ in CIV and Lyα and $\log W_\lambda/\lambda \simeq -3.0$ in NV (adopting a velocity parameter b = 60 km/s). This is assuming all spectral steepness is indeed caused by the warm absorber. If an additional soft excess is present (note that just a powerlaw plus black-body-like soft excess does *not* fit the ROSAT spectrum; but in case more than two spectral components are allowed, fits are not well constrained due to the limited PSPC spectral resolution) the contribution from the warm absorber would be less, since a lower column density would be inferred from spectral fits.

5.5. 4C +74.26

There is growing evidence that several (*but not all*) warm absorbers contain dust. The reported individual cases are IRAS 13349+2438 (Brandt et al. 1996, Komossa & Greiner 1999, Komossa et al. 1999b), NGC 3227 (Komossa & Fink 1997b, George et al. 1998), NGC 3786 (Komossa & Fink 1997c), MCG 6-30-15 (Reynolds et al. 1997), IRAS 17020+4544 (Leighly et al. 1997, Komossa & Bade 1998).

The advantage of invoking dust mixed with the warm absorber in 4C +74.26 is the steeper intrinsic powerlaw spectrum ($\Gamma_x \simeq -2.2$) required to compensate for the 'flattening effect' (Komossa & Fink 1997b) of dust, as compared to a single powerlaw fit which gives a peculiarly flat spectrum ($\Gamma_x \simeq -1.4$).

A steep intrinsic spectrum has the advantage of being close to the ASCA hard-energy value of Γ_x derived for this source (Brinkmann et al. 1998) and the general expectations for nearby radio-loud quasars in the ROSAT band ($\Gamma_x \simeq -2.2$; e.g., Schartel et al. 1996a, Brinkmann et al. 1997, Yuan 1998). Better spectral resolution soft X-ray data are needed to distinguish between both possibilities, an intrinsically flat powerlaw, or a dusty warm absorber.

5.6. X-ray spectral complexity in NLSy1 galaxies

Based on limited spectral resolution in the soft X-ray band, early models attempted to explain the X-ray spectral steepness of NLSy1s with one component only; either (i) a single steep powerlaw, or (ii) a strong soft excess on top of a flat powerlaw (e.g., Puchnarewicz et al. 1992, BBF96), in analogy to Seyferts (e.g., Walter et al. 1994) and quasars (e.g., Schartel et al. 1996a,b, 1997b) which were believed to have soft X-ray excesses, or (iii) heavily warm-absorbed flat powerlaws (e.g., Komossa & Greiner 1995, Komossa & Fink 1997a,d,e). One of the comfortable properties of both, the soft excess plus flat powerlaw and the warm-absorbed flat powerlaw interpretation, is the presence of enough X-ray photons to account for the strong observed FeII emission in NLSy1s. It does not immediately explain the occasionally observed trend of *stronger* FeII in objects with *steeper* X-ray spectra, but it is interesting to note that Wang et al. (1996) find a trend for stronger FeII to preferentially occur in objects whose X-ray spectra show the presence of absorption edges.

However, there were early indications of spectral complexity of NLSy1s (e.g., Brandt et al. 1994, Komossa & Fink 1997a,d; see also Vaughan et al. 1999). E.g., a detailed study of NGC 4051, a bright source for which several deep ROSAT observations were performed, revealed all three of the spectral components to be simultaneously present: The spectral steepness is dominated by the warm absorber, but the index of the underlying powerlaw can become as steep as $\Gamma_x \approx -2.3$[5] and an additional soft excess ist present in source high-states (Pounds et al. 1994, Komossa & Fink 1997a; the latter authors additionally provided evidence for an EUV bump component based on photon counting arguments). Further complications concerning the X-ray spectra of NLSy1s have emerged recently, via the suggestion of *dusty* warm absorbers in some NLSy1-like galaxies (Brandt et al. 1996, Leighly et al. 1997, Komossa & Bade 1998).

We have examined two further NLSy1s observed with ROSAT, 1ZwI and PHL 1092, and find that neither a flat powerlaw with soft excess nor a warm absorber can account for *most* of the spectral steepness. The sources are best described by a single steep spectral component.

As suggested by Komossa (1997) these spectral components of NLSy1s may be linked in the sense that a more polar view on the accretion disk (e.g., Fig. 3 of Madau 1988) causes the soft excess component to be more pronounced, while along the funnels of the disk outflows are driven which cause the characteristic absorption edges of warm absorbers if viewed along the line-of-sight against the continuum source.

Except for NGC 4051 the faintness of the objects of the present study (and many other ROSAT observed ultrasoft sources) does not allow to perform n-component spectral fits. However, the one-component models presented here still provide upper limits on the contribution of each single component (steepness of powerlaw, strength of soft excess, column density of warm absorber).

Given the few cases that have been observed with high X-ray spectral resolution and sufficient countrates, other approaches to distinguish between different EUV-X-ray spectral shapes are important. Such an approach is described in the following section.

5.7. EUV – soft X-ray spectral shape and stability of broad line clouds

One suggestion to link the apparently steep soft X-ray spectra with the small FWHM of the broad lines in NLSy1s was the influence of the X-ray spectral shape on multi-phase BLR cloud equilibrium, especially the hindrance of BLR formation due to illumination by a steep X-ray spectrum (Brandt et al. 1994). Here, we test this suggestion based on calculations carried out with the code *Cloudy*. In particular, we investigate how different EUV-X-ray spectral shapes change the range in which a multi-phase equilibrium is possible and attempt to distinguish, within the limits of this scenario, between different suggested spectral models.

[5] Given the recent reports of occasional discrepancies between the powerlaw indices derived from fitting ROSAT and ASCA data, in the sense that ROSAT spectra tend to be steeper, this might also affect NGC 4051's spectrum. We note, however, that during the Nov. 1992 ROSAT observation of this galaxy, the powerlaw was in its steepest observed state even when comparing with other ROSAT observations of this source.

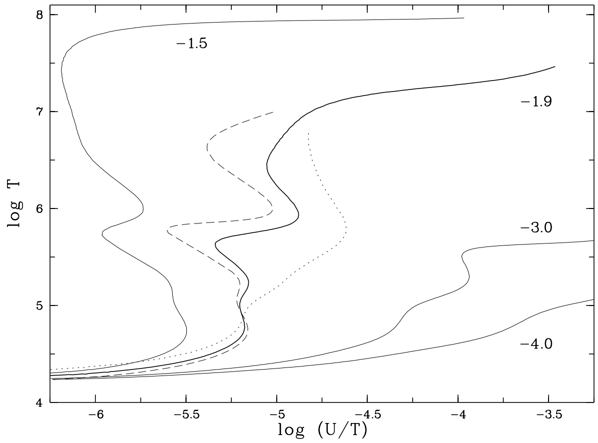

Fig. 7. Gas equilibrium curves. The X-ray spectral shape and the gas metal abundances were varied. The solid lines correspond to mean Seyfert continua with energy index $\alpha_{\rm uv-x}$=–1.4, varying photon index $\Gamma_{\rm x}$ as indicated in the figure and solar chemical abundances. Dotted line: metal abundances of Z=0.3×$Z_\odot$; dashed line: Z=3×$Z_\odot$.

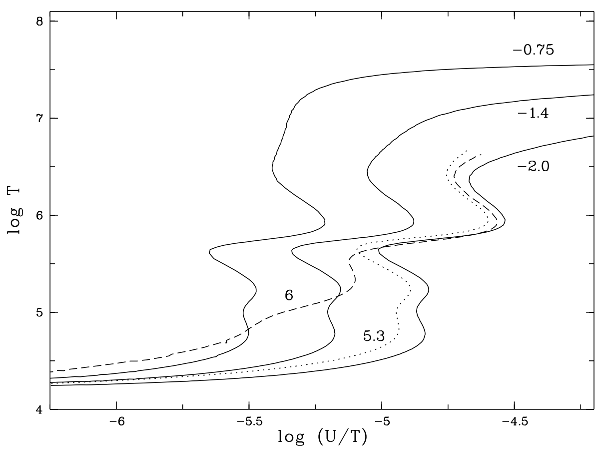

Fig. 8. Equilibrium curves for various EUV shapes of the ionizing spectrum illuminating the gas clouds. Solid lines: Continua with photon index $\Gamma_{\rm x}$ =–1.9 and varying $\alpha_{\rm uv-x} = -0.75, -1.4, -2.0$ as given in the figure. Broken lines: Black-body added to a mean Seyfert continuum with a 50% contribution to the total luminosity and a temperature of 10^6K (dashed line) and 2 10^5K (dotted line). Solar abundances were assumed. As can be seen, steep X-ray spectra remove the multi-valued behavior of the curves, and thus the possibility of multiple phases in pressure balance.

The thermal stability of broad line clouds can be examined by studying the behavior of temperature T in dependence of pressure, i.e., U/T (e.g. Guilbert et al. 1983, their Fig. 1; for a general discussion see also Krolik et al. 1981, Netzer 1990, Reynolds & Fabian 1995, Komossa & Fink 1997a,d). In case T is multi-valued for constant U/T, and the gradient of the equilibrium curve is positive, several phases may exist in pressure balance.

To test this idea, we have calculated equilibrium curves for the BLR gas for intrinsically steep X-ray spectra or spectra with a black-body-like soft excess. Additionally, the metal abundances were varied, which affect the cooling of the gas. Results are shown in Figs. 7, 8. The parts of the equilibrium curve with negative gradient correspond to thermally unstable equilibria. It is well known that the original Krolik-McKee-Tarter models face problems when a more realistic continuum shape is used, in the sense that a pressure balance between a cold, photoionization heated, and a hot, Compton heated phase no longer exists (see Fig. 7, e.g. $\Gamma_{\rm x}$ =–1.9 compared to $\Gamma_{\rm x}$ =–1.5). Reynolds & Fabian (1995) point to the existence of an intermediate-temperature stable region where U/T is multi-valued. We find that this intermediate region disappears for steep X-ray spectra.[6] Due to the relatively weaker X-ray flux and the fact, that the value of U is dominated by the EUV flux near the Lyman limit, the gas remains longer in the 'photoionization-heating, collisional-deexcitation-cooling' phase. The same holds for a continuum with a hot soft X-ray excess (Fig. 8).

These studies reveal that several spectral shapes and gas metal abundances lead to similar results, but show that the mechanism suggested by Brandt et al. (1994) works in general. More detailed models should then await better knowledge of the 0.1-10 keV X-ray spectral shape.

6. Summary and conclusions

We have presented a study of the X-ray spectral and temporal properties of four NLSy1-like galaxies and a radio-loud quasar. The results can be summarized as follows:

QSO 0117-2837. This NLSy1 galaxy shows a very steep X-ray spectrum with $\Gamma_{\rm x} \simeq -4.3$ when fit with a simple powerlaw, among the steepest spectra reported for NLSy1s. Alternatively, the spectrum can be described by a flat powerlaw with soft excess of $kT_{\rm bb} \simeq 0.1$ keV, or a warm-absorbed flat powerlaw. The extreme X-ray spectral steepness of QSO 0117-2837 is unexpected in the light of its fairly large FWHM of Hβ. With these properties QSO 0117-2837 fills the 'zone of avoidance' in the FWHM$_{H\beta}$–$\Gamma_{\rm x}$ diagram. The X-ray lightcurve of QSO 0117-2837 reveals constant source flux.

RX J0134-4258. This source underwent a drastic X-ray spectral transition from steep ($\Gamma_{\rm x} \simeq -4.4$) to flat ($\Gamma_{\rm x} \simeq -2.2$) between two ROSAT observations separated by 2 yr, while the mean countrate remained nearly constant. We examined several scenarios that might account for this peculiar behavior, with focus on the presence of a warm absorber. We find that a reaction of the ionized material to continuum changes requires non-equilibrium effects to be at work. Alternatively, and more likely, a cloud of warm gas may have passed our line of sight. This latter scenario shares some similarity with the one proposed by Rodriguez-Pascual et al. (1997) based on UV observations of a sample of NLSy1s. Variability of both components in the framework of a powerlaw-plus-soft-excess spectral description provides an alternative explanation.

[6] We only explore the rough trends here. The detailed shape of the equilibrium curve in the intermediate-temperature region also depends on the details of the heating-cooling processes and reflects to some extent the completeness with which these are implemented in the code used (see Ferland et al. 1998, Kingdon & Ferland 1999).

NGC 4051. We analyzed all ROSAT PSPC observations of this well-known Seyfert galaxy including previously unpublished ones. Variability by a factor of ∼30 in countrate is detected. The mean X-ray luminosity varies less but still by a factor of ∼7, whereas the properties of the warm absorber (U, $N_{\rm w}$; averaged over individual pointings) change by only a factor of ∼2, indicating that the bulk of the warm absorber is either of low density or out of photoionization equilibrium.

Mrk 1298. The ROSAT PSPC spectrum of this source shows clear signs of warm absorption, confirming Wang et al. (1996). Based on detailed warm-absorber modelling, we predict the contribution of the ionized absorber to opt-UV-EUV emission lines which is found to be quite weak. Repeated rapid variability by a factor ∼2 within time intervals of 800s is detected.

4C +74.26. We considered this quasar as a candidate for a *dusty* warm absorber. We show that such a model successfully fits the ROSAT X-ray spectrum of this source and resolves the discrepancy between the underlying powerlaw index derived from ROSAT and ASCA observations.

X-ray spectral complexity in NLSy1s and multi-phase BLR equilibrium. Given the increasing spectral complexity of NLSy1 galaxies, with often two or even three components contributing to the X-ray spectral shape, we examined the influence of different spectral shapes on BLR cloud multi-phase equilibrium, in an attempt to determine which spectral shapes dominates on average (within the limits of this scenario). We find that both, a steep powerlaw spectrum, and a strong EUV-X-ray excess component narrow down the range where a stable multi-phase equilibrium is possible.

Acknowledgements. I, St. K., gratefully remember Henner Fink for introducing me to the work with X-ray data, for many discussions and helpful advice. Henner Fink passed away in December 1996. We thank Hartmut Schulz and Dirk Grupe for a critical reading of the manuscript, Dirk Grupe for providing a preprint of his paper on RXJ0134 prior to publication, Gary Ferland for providing *Cloudy*, and Emmi Meyer-Hofmeister for her continuing kind interest. The ROSAT project has been supported by the German Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (BMBF/DLR) and the Max-Planck-Society. This research has made use of the NASA/IPAC extragalactic database (NED) which is operated by the Jet Propulsion Laboratory, Caltech, under contract with the National Aeronautics and Space Administration.
Preprints of this and related papers can be retrieved from our webpage at http://www.xray.mpe.mpg.de/∼skomossa/

References

Bade N., Fink H.H., Engels D., et al., 1995, A&AS 110, 469
Becker C.M., Remillard R., Rappaport S.A., 1996, In: Greiner J. (ed.) Supersoft X-ray Sources. Lect. Notes in Phys. 472, p. 289
Boller T., Brandt W.N., Fink H.H., 1996, A&A 305, 53 (BBF96)
Boroson T.A., Green R.F., 1992, ApJS 80, 109
Brandt W.N., Boller T., 1999, In: Gaskell C.M., Brandt W.N., Dietrich M., et al. (eds.) Structure and kinematics of quasar broad line regions. ASP Conf. Ser., in press
Brandt W.N., Fabian A.C., Nandra K., Reynolds C.S., Brinkmann W., 1994, MNRAS 271, 958
Brandt W.N., Fabian A.C., Pounds K.A., 1996, MNRAS 278, 326
Brandt W.N., Mathur S., Elvis M., 1997, MNRAS 285, 25
Briel U., Aschenbach B., Hasinger G., et al., 1994, ROSAT user's handbook. MPE, Garching
Brinkmann W., Yuan W., Siebert J., 1997, A&A 319, 413
Brinkmann W., Otani C., Wagner S., Siebert J., 1998, A&A 330, 67
Cappi M., Mihara T., Matsuoka M., et al., 1996, ApJ 458, 149
Ciliegi P., Maccacaro T., 1996, MNRAS 282, 477
Comastri A., Fiore F., Guainazzi M., et al., 1998, A&A 333, 31
Contini M., Viegas S.M., 1999, ApJ in press; astro-ph/9904226
Dickey J.M., Lockman F.J., 1990, ARA&A 28, 215
Done C., Pounds K.A., Nandra K., Fabian A.C., 1995, MNRAS 275, 41
Fabian A.C., 1996, In: Zimmermann H.U., Trümper J., Yorke H. (eds.) MPE Report 263, p. 403
Ferland G.J., 1993, University of Kentucky, Physics Department, Internal Report
Ferland G.J., Korista K.T., Verner D.A., et al., 1998, PASP 110, 761
Fink H.H., Walter R., Schartel N., Engels D., 1997, A&A 317, 25
Fiore F., Elvis M., Mathur S., Wilkes B.J., McDowell J.C., 1993, ApJ 415, 129
Gaskell M., 1985, ApJ 291, 112
George I.M., Mushotzky R., Turner T.J., et al., 1998, ApJ 509, 146
Goodrich R.W., 1989, ApJ 342, 224
Greiner J., 1996, In: Greiner J. (ed.) Supersoft X-ray Sources. Lect. Notes in Phys. 472, p. 285
Greiner J., Danner R., Bade N., et al., 1996, A&A 310, 384
Grevesse N., Anders E., 1989, In: Waddington C.J. (ed.) Cosmic Abundances of Matter. AIP 183, American Institute of Physics, New York, p. 1
Grupe D., 1996, Ph.D. Thesis, Universität Göttingen
Grupe D., Beuermann K., Thomas H.-C., Mannheim K., Fink H.H., 1998, A&A 330, 25
Grupe D., Beuermann K., Mannheim K., Thomas H.-C., 1999a, A&A, in press
Grupe D., Leighly K., Thomas, H.-C., 1999b, A&A, submitted
Guainazzi M., Mihara T., Otani C., Matsuoka M., 1996, PASJ 48, 781
Guainazzi M., Nicastro F., Fiore, et al., 1998a, MNRAS 301, L1
Guainazzi M., Comastri A., Stirpe G.M., 1998b, A&A 339, 327
Guilbert P.W., Fabian A.C., McCray R., 1983, ApJ 266, 466
Halpern J.P., 1984, ApJ 281, 90
Halpern J.P., Oke J.B., 1987, ApJ 312, 91
Hayashida K., 1997, In: Peterson B.M., Cheng F.-Z., Wilson A.S. (eds.) Emission Lines in Active Galaxies - New Methods and Techniques. ASP Conf. Ser. 113, p. 40
Iwasawa K., Brandt W.N., Fabian A.C., 1998, MNRAS 293, 251
Kingdon J.B., Ferland G.J., 1999, ApJ 516, in press
Komossa S., 1997, Ph.D. Thesis, Ludw.-Max.-Univ. München
Komossa S., Bade N., 1998, A&A 331, L49
Komossa S., Fink H., 1997a, A&A 322, 719
Komossa S., Fink H., 1997b, A&A 327, 483
Komossa S., Fink H., 1997c, A&A 327, 555
Komossa S., Fink H., 1997d, In: Meyer-Hofmeister E., Spruit H. (eds.) Accretion Disks – New Aspects. Lecture Notes in Physics 487, p. 250
Komossa S., Fink H., 1997e, In: Peterson B.M., Cheng F.-Z., Wilson A.S. (eds.) Emission Lines in Active Galaxies - New Methods and Techniques. ASP Conf. Ser. 113, p. 246
Komossa S., Greiner J., 1995, Astron Ges. Abstr. Ser. 11, 217
Komossa S., Greiner J., 1999, In: Poutanen J., Svensson R. (eds.) High Energy Processes in Accreting Black Holes. ASP Conf. Ser. 161, p. 228

Komossa S., Janek M., 1999, In: Inoue H., Ohashi T., Takahashi T. (eds.) Heating and acceleration in the universe. Astron. Nachr. 320, in press; astro-ph/9907373
Komossa S., Schulz H., 1997, A&A 323, 31
Komossa S., Breitschwerdt D., Greiner J., Meerschweinchen J., 1999a, In: Berry D., Breitschwerdt D., da Costa A., Dyson J. (eds.) Astrophysical Dynamics. Ap&SS, in press; astro-ph/9906330
Komossa S., Breitschwerdt D., Meerschweinchen J., 1999b, In: Berry D., Breitschwerdt D., da Costa A., Dyson J. (eds.) Astrophysical Dynamics. Ap&SS, in press; astro-ph/9906377
Komossa S., Grupe D., Burwitz V., 2000, In: X-ray Astronomy 1999: Stellar Endpoints, AGN and the X-ray Background. Astrophys. Lett. and Comm., in press
Krolik J.H., McKee C.F., Tarter C.B., 1981, ApJ 249, 422
Laor A., Fiore F., Elvis M., Wilkes B., McDowell J.C., 1994, ApJ 435, 611
Laor A., Fiore F., Elvis M., Wilkes B., McDowell J.C., 1997, ApJ 477, 93
Lawrence A., 1997, In: Peterson B.M., Cheng F.-Z., Wilson A.S. (eds.) Emission Lines in Active Galaxies - New Methods and Techniques. ASP Conf. Ser. 113, p. 230
Lawrence A., Watson M.G., Pounds K.A., Elvis M., 1985, MNRAS 217, 685
Lawrence A., Elvis M., Wilkes B., McHardy I., Brandt N., 1997, MNRAS 285, 879
Leighly K.M., Mushotzky R.F., Yaqoob T., Kunieda K., Edelson R., 1996, ApJ 469, 14
Leighly K.M., Kay L.E., Wills B.J., Wills D., Grupe D., 1997, ApJ 489, L137
Madau P., 1988, ApJ 327, 116
Malkan M., 1986, ApJ 310, 679
Mannheim K., Grupe D., Beuermann K., Thomas H.C., Fink H.H., 1996, In: Zimmermann H.U., Trümper J., Yorke H. (eds.) MPE Report 263, 471
Marshall F.E., Holt S.S., Mushotzky R.F., Becker R.H., 1983, ApJ 269, L31
Mathis J.S., Rumpl W., Nordsieck K.H., 1977, ApJ 217, 425
Mathur S., 1994, ApJ 431, L75
Matsuoka M., Piro L., Yamauchi M., Murakami T., 1990, ApJ 361, 440
McHardy I.M., Green A.R., Done C., et al., 1995, MNRAS 273, 549
Mihara T., Matsuoka M., Mushotzky R., et al., 1994, PASJ 46, L137
Miller P., Rawlings S., Saunders R., Eales S., 1992, MNRAS 254, 93
Moran E.C., Halpern J.P., Helfand D.J., 1996, ApJS 106, 341
Nandra K., Pounds K.A., 1992, Nat 359, 215
Netzer H., 1990, In: Courvoisier T.J.-L., Mayor M. (eds.) Active Galactic Nuclei. Saas-Fee Lecture Notes 20, Springer Verlag
Nicastro F., Fiore F., Perola G., Elvis M., 1999, ApJ 512, 184
Osterbrock D.E., Dahari O., 1983, ApJ 273, 478
Osterbrock D.E., Pogge R.W., 1985, ApJ 297, 166
Otani C., Kii T., Miya K., 1996, In: Zimmermann H.U., Trümper J., Yorke H. (eds.) MPE Report 263, p. 491
Pan H.C., Stewart G.C., Pounds K.A., 1990, MNRAS 242, 177
Pfeffermann E., Briel U.G., Hippmann H., et al., 1987, SPIE 733, 519
Pounds K.A., Nandra K., Fink H.H., Makino F., 1994, MNRAS 267, 193
Pounds K.A., Done C., Osborne J.P., 1995, MNRAS 277, L5
Puchnarewicz E.M., Mason K.O., Cordova F.A., et al., 1992, MNRAS 256, 589
Rafanelli P., Bonoli C., 1984, A&A 131, 186
Reynolds C.S., Fabian, A.C., 1995, MNRAS 273, 1167
Reynolds C.S., Ward M.J., Fabian A.C., Celotti A., 1997, MNRAS 291, 493
Riley J.M., Warner P.J., Rawlings S., et al., 1988, MNRAS 236, 13p
Rodriguez-Pascual P.M., Mas-Hesse J.M., Santos-Lleo M., 1997, A&A 327, 72
Rosenblatt E.I., Malkan M.A., Sargent W.L.W., Readhead A.C.S., 1992, ApJS 81, 59
Schartel N., Walter R., Fink H., Trümper J., 1996a, A&A 307, 33
Schartel N., Green P.J., Anderson S.F., et al., 1996b, MNRAS 283, 1015
Schartel N., Komossa S., Brinkmann W., et al., 1997a, A&A 320, 421
Schartel N., Schmidt M., Fink H., Hasinger G., Trümper J., 1997b, A&A 320, 696
Schwartz D.A., Zhao P., Remillard R., 1993, BAAS 25, 811
Shakura N.I., Sunyaev R.A., 1973, A&A 24, 337
Shields J.C., Ferland G.J., Peterson B.M., 1995, ApJ 441, 507
Stephens S.A., 1989, AJ 97, 10
Stocke J.T., Morris S.L., Gioia I.M., et al., 1991, ApJS 76, 813
Tanaka Y., 1997, In: Meyer-Hofmeister E., Spruit H. (eds.) Accretion Disks – New Aspects. Lecture Notes in Physics 487, p. 1
Trümper J., 1983, Adv. Space Res. 2, 241
Turner T.J., Nandra K., George I.M., Fabian A.C., Pounds K.A., 1993, ApJ 419, 127
Ulrich-Demoulin M.-H., Molendi S., 1996, ApJ 457, 77
Vaughan S., Reeves J., Warwick R., Edelson R., 1999, MNRAS in press; Leicester Univ. preprint XRA 99/08
Walter R., Orr A., Courvoisier T.J.-L., Fink H.H., et al., 1994, A&A 285, 119
Wandel A., 1997, ApJ 490, L131
Wang T., Brinkmann W., Bergeron J., 1996, A&A 309, 81 (WBB96)
Wang T., Brinkmann W., Wamsteker W., Yuan W., Wang Y.X., 1999, MNRAS, in press
Wisotzki L., Bade N., 1997, A&A 320, 395
Xu D.W., Wei J.Y., Hu J.Y., 1999, ApJ 517, 622
Yuan W., 1998, Ph.D. Thesis, TU München
Zimmermann H.U., Becker W., Belloni T., et al., 1994, MPE Report 257