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Research Note

X-ray spectrum of the radio-loud quasar PKS 1217+023

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Abstract. A study of the X-ray (0.1–10 keV) spectrum from the radio-loud quasar, PKS 1217+023 is presented. This quasar was observed with EXOSAT on two epochs in 1984 January 29 and May 14. The data were obtained from the EXOSAT archives. The soft (0.1–2 keV) and hard (2–10 keV) X-ray fluxes have displayed significant changes between the two observations. There is neither a detection of any significant low energy absorption within the quasar nor is there any evidence for the presence of soft X-ray excess. The energy indices, α, of the power law fits to the LE+ME data of January 29 and May 14 are $0.98^{+0.18}_{-0.14}$ and $0.82^{+0.12}_{-0.11}$ (error bars are with 90% confidence) respectively. The values of α are consistent with the values obtained from Ginga observations but larger than that obtained from Einstein data. A thermal bremsstrahlung model also provides a good fit to the X-ray data of PKS 1217+023.

Key words: quasar: PKS 1217+023 – active galactic nuclei – X-ray spectra

1. Introduction

PKS 1217+023 is a bright quasar, with an apparent visual magnitude of 16.53 ($B-V=-0.02$; $U-B=-0.87$), an absolute magnitude of -24.3 and a redshift of 0.24 (Bolton et al. 1965; Lynds et al. 1966; Hewitt & Burbidge 1987). This quasar has displayed many emission lines in its optical (Baldwin 1975; Baldwin et al. 1989) and ultraviolet (Wampler et al. 1984) spectra and the equivalent widths of the major ultraviolet emission lines are luminosity dependent (Baldwin et al. 1989). Due to its strong radio emission (Shimmins & Bolton 1972; Kellermann et al. 1968; Neff & Browne 1984) it is known as a radio-loud quasar (Wilkes & Elvis 1987; Turner et al. 1989). X-ray observations of this source were carried out with the Imaging Proportional Counter (IPC) on the Einstein Observatory in the soft X-ray region (0.3–3.5 keV) (Wilkes & Elvis 1987) and recently it has been observed with the Ginga in the 2–10 keV range (Turner et al. 1989). Also this quasar was observed on two occasions in 1984 with EXOSAT in the 0.1–10 keV range. Detailed results of the spectral analysis of the EXOSAT data of PKS 1217+023 are presented in this note and compared with those obtained from EINSTEIN and GINGA observations. Also the implication of these results are discussed.

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2. Observations

The X-ray observations were carried out on 1984 January 29 and May 14, using both the Medium Energy (ME) detectors and the Low Energy (LE) telescope with a Channel Multiplier Array (CMA) as the detector. The LE+CMA detectors covered the energy range of 0.05–2 keV and the ME detectors are sensitive to X-rays in the energy range of 1–10 keV. De Korte et al. 1981 have described the LE detectors and the details of the ME detectors are given by Turner et al. 1981. The particulars of the observations are shown in Table 1. The LE data were obtained with the Lexan 3000 (LX3) and the aluminium/parylene (Al/P) filters during the 1984 January 29 observations and only LX3 filter was used on May 14. Detail of the filter efficiencies is given by White & Peacock 1988.

The ME data were obtained from the eight argon filled proportional counter detectors. The eight detectors were divided into two halves (detectors 1 to 4 and 5 to 8 are collectively known as half 1 and half 2 respectively). These two halves can be either aligned to the pointing axis or offset by 2° to monitor the background. However, during both the observations of PKS 1217+023 only one half (half 2 – detectors 5, 6, 7 and 8) was on. Background subtraction of these two ME spectra were carried out using background data from source free regions during slew maneouvres on to and off the source, in the same detector

Table 1. Log of EXOSAT observations of PKS 1217+023 during 1984 and count rates

Start time	End time	LE count rate (10^{-4} cm^{-2} s^{-1})		ME count rate[a] (10^{-4} cm^{-2} s^{-1})
		LX3	Al/P	
$029^d00^h44^m$	$029^d04^h39^m$	2.92 ± 0.32	1.35 ± 0.18	5.06 ± 1.07
$135^d05^h16^m$	$135^d10^h14^m$	1.29 ± 0.13		2.80 ± 0.87

[a] ME count rates are for PHA channels 6 to 32 corresponding to the energy range of 2 to 9 keV with the best signal-to-noise ratio

configuration. Background subtraction analysis of the two spectra of PKS 1217+023 were carried out at the EXOSAT Observatory Data Center, Noordwijk, The Netherlands.

Background subtracted LE count rates with errors were obtained from the EXOSAT database and they were converted into LE pulse-height (PH) spectra using the XANADU (X-ray Analysis and Data Utilization) software package.

3. Spectral analysis and results

Analysis of the LE and ME spectra of PKS 1217+023 were carried out using the XSPEC (X-ray Spectral Fitting) software package. First we used a simple power law model with uniform absorption (using the absorption cross-sections given by Morrison & McCammon 1983) in the line of sight to the source, to fit the data. From the χ^2 statistics (using the χ^2 minimization) we find that this model provides acceptable fit to both the data sets. The parameters of this model, fitting to the combined LE+ME spectra, are presented in Table 2A. Also the 90% confidence error limits which were computed for a given parameter, keeping all the other parameters free, are given in this table along with the best fit parameters. The 90% confidence limits on each parameter were computed by the procedure detailed by Avni 1976 and Lampton et al. 1976 ($\chi^2_{\rm min}+4.61$ for two free parameters).

The energy index, α, of January 29 is $0.38^{+0.13}_{-0.10}$ and that of May 14 is $0.73^{+0.52}_{-0.50}$ which shows a negligible change in the slope of the power law, considering the error bars. The column density values of the equivalent hydrogen ($N_{\rm H}$) along the line of sight to the quasar are smaller than the galactic $N_{\rm H}$ value (1.97 $10^{20}\,{\rm cm}^{-2}$) (Elvis et al. 1989) or it is consistent, considering the large error bars of $N_{\rm H}$, with the galactic $N_{\rm H}$ value. This indicates that there is no absorption intrinsic to the source. Next a power law model with a fixed absorption (fixed with the galactic $N_{\rm H}$ value), were fitted

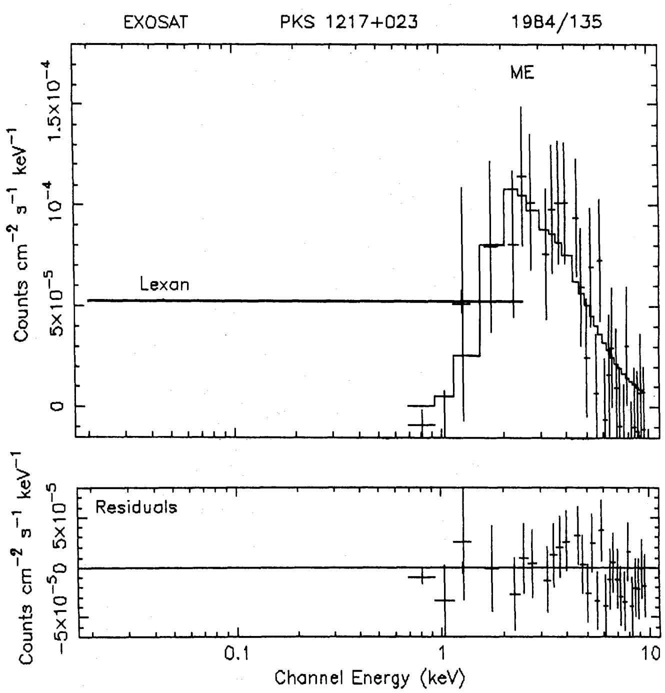

Fig. 1. Observed LE + ME spectrum of PKS 1217+023 for 1984/135 fitted with a simple power law and uniform absorption model. Lower panel of the figure shows the residuals between the spectra and the model in units of counts

with both the LE + ME data sets. Best fit parameters with the error bars are listed in Table 2B. The fit to the January 29 data gave significant change in the $\chi^2_{\rm min}$ value and also the slope of the power law became steeper ($\Delta\alpha \sim \leqq 0.6$). But no significant change in the $\chi^2_{\rm min}$ value was noticed for the data set of May 14. In Fig. 1 we show the observed LE + ME spectrum of PKS 1217+023 which was observed on 1984 May 14, with the best fit model (power law + fixed absorption) convolved through the detector response. Also the residuals between the spectrum and the model are shown in the lower panel of this figure. No soft excess is present at low energies in the LE.

The LE + ME spectra were also fitted with the thermal bremsstrahlung model with fixed absorption (fixed with the galactic $N_{\rm H}$ value). From the χ^2 statistics it can be seen that this model also provides good fits to both the data sets. The best fit parameters along with the 90% confidence error bars are presented in Table 2C. Derived temperatures for this model are $1.93^{+0.67}_{-0.56}$ and $3.14^{+1.11}_{-0.70}$ keV for the 1984 January 29 and May 14 data sets, respectively. PKS 1217+023 is a very weak source and the PHA spectra are of poor signal to noise (Fig. 1). Since the power law and fixed absorption model already provided acceptable fits ($\chi^2_{\rm red}=0.8$) to the LE + ME data sets, thus it is not justified to add a gaussian line component to the above model to search for an iron line in such poor signal-to-noise spectra, which may lead to a false result.

Table 2. Results of the spectral analysis of LE+ME data during 1984

Parameter	January 29	May 14
(A) Model: power law + absorption		
Energy index (α)	$0.38^{+0.13}_{-0.10}$	$0.73^{+0.52}_{-0.50}$
$A\,(10^{-3}\,{\rm cm}^{-2}\,{\rm s}^{-1}\,{\rm keV}^{-1})$	$0.83^{+0.16}_{-0.17}$	$1.00^{+0.90}_{-0.50}$
$N_{\rm H}\,(10^{20}\,{\rm cm}^{-2})$	$0<0.03$	$1.45^{+4.40}_{-1.40}$
Flux (0.1 – 2.0 keV)[a]	5.60 ± 0.6	3.20 ± 0.3
Flux (2 – 10 keV)[a]	4.64 ± 0.9	3.88 ± 1.1
χ^2_r/d.o.f.	0.93/25	0.79/26
(B) Model: power law + fixed absorption[b]		
Energy Index (α)	$0.98^{+0.18}_{-0.14}$	$0.82^{+0.12}_{-0.11}$
$A\,(10^{-3}\,{\rm cm}^{-2}\,{\rm s}^{-1}\,{\rm keV}^{-1})$	$1.92^{+0.30}_{-0.30}$	$1.13^{+0.14}_{-0.14}$
χ^2_r/d.o.f.	0.84/26	0.76/27
(C) Model: thermal bremsstrahlung + fixed absorption[b]		
kT (keV)	$1.93^{+0.67}_{-0.56}$	$3.14^{+1.11}_{-0.70}$
$A\,(10^{-3}\,{\rm cm}^{-2}\,{\rm s}^{-1}\,{\rm keV}^{-1})$	$2.73^{+0.84}_{-0.63}$	$1.08^{+0.30}_{-0.22}$
χ^2_r/d.o.f.	0.84/26	0.84/27

[a] In units of $10^{-12}\,{\rm erg\,cm}^{-2}\,{\rm s}^{-1}$.
[b] Fixed with the galactic $N_{\rm H}$ value.

4. Discussion

X-ray fluxes from PKS 1217+023 in the soft band (0.1–2 keV) are (5.6 ± 0.6) and (3.2 ± 0.3) $10^{-12}\,{\rm erg\,cm}^{-2}\,{\rm s}^{-1}$ in January 29 and May 14, respectively and that in the hard band (2–10 keV) are (4.6 ± 0.9) and (3.9 ± 1.1) $10^{-12}\,{\rm erg\,cm}^{-2}\,{\rm s}^{-1}$, respectively. The X-ray luminosity of PKS 1217+023, as measured with EXOSAT on two epochs, between 1984 January 29 and May 14, in the soft band (0.1–2 keV) decreased from $(1.40 \pm 0.15)\ 10^{45}\ \mathrm{erg\,s^{-1}}$ to $(0.80 \pm 0.07)\ 10^{45}\ \mathrm{erg\,s^{-1}}$ and that in the hard band (2–10 keV) decreased from $(1.13 \pm 0.22)\ 10^{45}\ \mathrm{erg\,s^{-1}}$ to $(0.94 \pm 0.26)\ 10^{45}\ \mathrm{erg\,s^{-1}}$. These results show that the luminosity of PKS 1217+023 has decreased by 43% in the soft band and 17% in the hard band during the interval of the two observations in 1984. However, from the LE and ME count rates (Table 1) it can be seen that the decrease in the LE and ME bands were around 56% and 45% respectively. Though the decrease in luminosity of this quasar in the hard band is not significant, on the basis of the observed count rates it is noted that PKS 1217+023 has undergone significant changes in both the LE and ME bands. From the comparison of the X-ray luminosities of this source measured by EINSTEIN on 1979 June 20 in the soft band ($1.98^{+0.61}_{-0.21}\ 10^{45}\ \mathrm{erg\,s^{-1}}$ in the 0.3–3.5 keV range), by EXOSAT on 1984 January 29 in the soft [$(1.40 \pm 0.15)\ 10^{45}\ \mathrm{erg\,s^{-1}}$ in the 0.1–2 keV rang] and hard [$(1.13 \pm 0.22)\ 10^{45}\ \mathrm{erg\,s^{-1}}$ in the 2–10 keV range] bands and by GINGA on 1988 June 21 in the hard band ($0.88\ 10^{45}\ \mathrm{erg\,s^{-1}}$ in the 2–10 keV), it is seen that there were no large variations on the time scales of years.

The value of α in the soft X-ray range (0.3–3.5 keV) obtained from the results of EINSTEIN observations for this quasar (Wilkes & Elvis 1987) is some what flatter ($\alpha = 0.5^{+0.5}_{-0.2}$) than but consistent with the EXOSAT (see Table 2) and the GINGA values ($\alpha = 0.73 \pm 0.38$) (Turner et al. 1989). On the basis of the EXOSAT and the GINGA results, it can be suggested that this radio-loud quasar is not a flat spectrum X-ray source. Rather the spectral index is consistent with the "canonical" value ($\alpha = 0.7$) of AGNs (Turner & Pounds 1989). Based on Einstein data, Wilkes & Elvis 1987 have suggested the association between radio loudness and flat X-ray spectra of quasars. However, it is not supported by the higher energy EXOSAT and GINGA results for PKS 1217+023.

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