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Research Note

First X-ray spectrum of the most luminous quasar PKS 2126–158

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Abstract. For the first time the detailed results of the spectral analysis of the X-ray (0.1–10 keV) spectrum of the luminous ($z=3.27$), radio-loud quasar, PKS 2126–158, are presented. The spectrum of this quasar was obtained from the EXOSAT database. Power law and fixed absorption model fits well with the spectrum. The parameters of this model suggest that this quasar is a flat spectrum source ($\alpha=0.3\pm0.15$). Derived soft (0.1–2 keV) and hard (2–10 keV) X-ray luminosities of this quasar are $(0.7\pm0.1)\,10^{48}$ erg s^{-1} and $(2.3\pm0.3)\,10^{48}$ erg s^{-1}, respectively. No soft excess and low energy absorption have been detected in this source. Thermal bremsstrahlung model also fits well with the spectrum of PKS 2126–158 and the derived rest-frame temperature is 6.4^{+40}_{-4} keV. This is the most luminous quasar which has been detected in the hard X-rays ($\sim$30 keV at source).

Key words: active galactic nuclei – radio-loud quasar – PKS 2126 –158, X-ray spectrum

1. Introduction

PKS 2126–158 is one of the brightest quasars [visual magnitude 17.3 (Condon et al. 1977) and absolute magnitude –30.0 (Veron-Cetty & Veron 1987)] with an emission redshift $z_{em}=3.27$ (Jauncey et al. 1978). Low, medium and high resolution spectroscopic observations of this quasar were carried out by different observers (Young et al. 1979; Sargent & Boksenberg 1983; Norris et al. 1983; Meyer & York 1987; Sargent et al. 1988, 1989, 1990), and heavy element composition has been detected in the absorption spectra of this quasar (Sargent et al. 1990 and references therein). This quasar is a radio-loud quasar (Bolton et al. 1975). X-ray detection of this source was done with EINSTEIN satellite (Zamorani et al. 1981) and later it was observed with EXOSAT in the 0.1–10 keV range. However, to the best knowledge of the authors, no spectral information (in the X-ray region) is available in the literature. From the search of the EXOSAT database, we obtained both the low (LE$\sim$0.1–2 keV) and medium (ME$\sim$2–10 keV) energy spectra of this quasar. In this note we present the detailed spectral parameters of this source which will be the first spectral information of PKS 2126–158 in the 0.1–10 keV range.

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2. Observations

PKS 2126–158 was observed on 1984/134 with EXOSAT. LE data of this source were obtained with Lexan 3000 (LX3) and aluminium/parylene (Al/P) filters. de Korte et al. (1981) have described in detail about the LE detectors. Background subtracted count rates with errors were obtained from the EXOSAT database (filter scattering correction and dead time corrections are included in the EXOSAT database LE count rates) and were converted into pulse height (PHA) spectra using XANADU (X-ray Analysis and Data Utilisation) software package. The ME spectrum of this source was obtained from eight argon-filled proportional counter detectors (Turner et al. (1981) have described in detail about the ME detectors). 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) which can be either aligned to the pointing axis or offset by upto 2° to obtain background emissions. The ME observation mode for this source was with the two detector halves offset to obtain simultaneous background data. Background-subtracted ME spectrum of PKS 2126–158 was obtained from the EXOSAT database. Log of LE and ME observations and the count rates are given in Table 1.

3. Spectral analysis and results

3.1. Power law fits

The XSPEC (X-ray Spectral Fitting) software package has been used to analyse the combined LE and ME spectra of PKS 2126 –158. Power law + uniform absorption (using the effective photo-electric cross-section given by Morrison & McCammon 1983) model (model 1) was used to fit to the spectrum of this quasar. The best-fit parameters of model 1 are given in Table 2a with the 90% confidence error limits which were computed for a given parameter, keeping all the other parameters free. The 90% errors were computed following the procedure detailed by Lampton et al. (1976) ($\chi^2_{min}+4.61$ for two free parameters). Although the χ^2 statistics (using the χ^2 minimisation) show that this model fits well to the spectrum, the value of the hydrogen column density (N_h) is lower than the galactic N_h value. Since the value of N_h (obtained from model 1) is lower than the galactic N_h value, we fix the column density to the galactic N_h value ($4.85\,10^{20}$ cm^{-2}; Elvis et al. 1989). This value of N_h is also consistent with the fact that high-luminosity AGN-like PKS 2126–158, in general, suffers

Table 1. Log of observation of the LE and ME spectrum and count rates of PKS 2126−158

Start time (1984)			End time (1984)			LE count rate		ME count rate[a] (10^{-4} cm^{-2} s^{-1})
						LX3	Al/P	
d	h	m	d	h	m	(10^{-5} cm^{-2} s^{-1})		
134	14	58	135	02	30	4.62 ± 0.82	2.96 ± 0.65	4.54 ± 0.53

[a] The count rate is for PHA channels 6 to 35 corresponding to the energy range 2–10 keV with the best signal-to-noise ratio. Detectors 1 to 4 were off during ME observations.

Table 2. Spectral fits to the LE+ME spectrum of PKS 2126−158

a. Model 1: power-law + absorption

α^b	N^c	N_H^d	χ_r^2 (d.o.f.)
$0.32^{+0.48}_{-0.37}$	$0.97^{+0.87}_{-0.40}$	$0<19.0$	0.88 (24)

b. Model 2: power-law + fixed absorption[a]

α^b	N^c	Flux[e]		L_X^f		χ_r^2 (d.o.f.)
		0.1–2 (keV)	2–10 (keV)	0.1–2 (keV)	2–10 (keV)	
0.31 ± 0.15	0.96 ± 0.16	2.20 ± 0.39	7.27 ± 0.84	0.7 ± 0.10	2.3 ± 0.3	0.90(25)

c. Model 3: bremsstrahlung + fixed absorption[a]

kT^g	N^c	χ_r^2 (d.o.f.)
$6.4^{+40.0}_{-4.0}$	$0.33^{+0.16}_{-0.33}$	0.82 (25)

[a] Fixed with the galactic N_H value (4.85 10^{20} cm^{-2}); [b] Photon index; [c] Normalization in 10^{-3} photons cm^{-2} s^{-1} keV^{-1} at 1 keV; [d] Column density in 10^{20} cm^{-2}; [e] Flux in 10^{-12} erg cm^{-2} s^{-1}; [f] Luminosity in 10^{48} erg s^{-1}; [g] Rest frame plasma temperature in keV

little internal absorption (Mushotzky 1984). We have therefore used the power law + fixed absorption model (model 2) to fit to the data. Results of the best-fit parameters of model 2 are presented in Table 2b. It is clearly evident from the reduced χ^2 values, given in Table 2b, that this model also fits well to the spectrum of PKS 2126−158. Spectral index value ($\alpha = 0.31 \pm 0.15$) of this quasar suggests that it is a flat spectrum source. Observed spectrum of PKS 2126−158 and the best-fit power law + fixed absorption model convolved through the detector response are shown in Fig. 1. Lower panel of this figure displays the residuals between the spectrum and the model. This figure shows that no soft excess is present in this quasar. Presence of an emission feature around ~3 keV can be seen from the residuals of Fig. 1. This emission feature may be due to the fluorescence of the redshifted 6.4 keV iron line. However, the rest-frame energy of the emission feature is ~13 keV which is unreal. Thus this emission feature will not be considered as intrinsic to the source.

3.2. Thermal fits

Next we fitted the spectrum using the thermal bremsstrahlung + fixed absorption model and the parameters of this model are given in Table 2c. Observed spectrum of this quasar along with the thermal bremsstrahlung model convolved through the detector response is shown in Fig. 2 and the residuals are shown in the lower panel of the figure. From the χ_r^2 value it can be seen that the thermal bremsstrahlung model also fits well with the data. The derived plasma temperature, reduced to the rest frame of the source is 6.4^{+40}_{-4} keV which is usually found in low redshift quasars (Ghosh & Soundararajaperumal 1991a).

4. Discussion

Soft (0.1–2 keV) and hard (2–10 keV) X-ray fluxes from PKS 2126 −158 as measured with EXOSAT are $(2.2 \pm 0.4)\,10^{-12}$

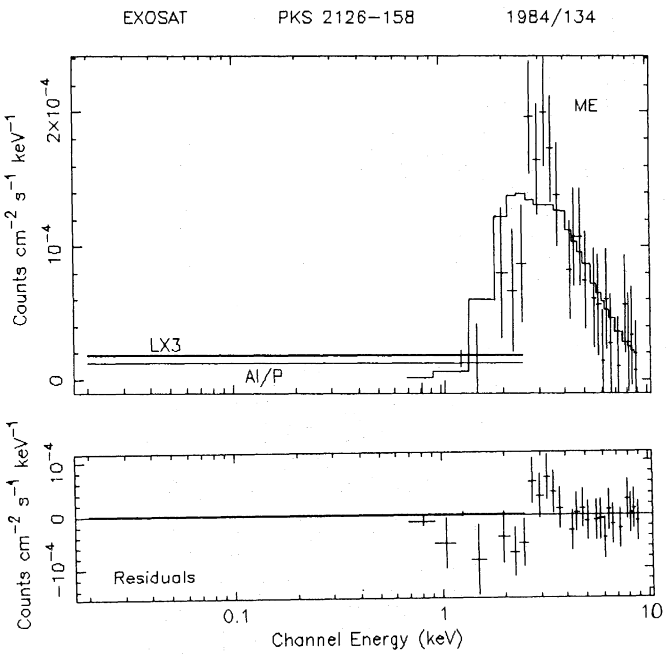

Fig. 1. Observed LE and ME spectrum of PKS 2126 − 158 for 1984/134 fitted with a simple power law and absorption model (fixed with the galactic N_h value). Lower panel of the figure shows the residuals in units of counts $cm^{-2} s^{-1} keV^{-1}$

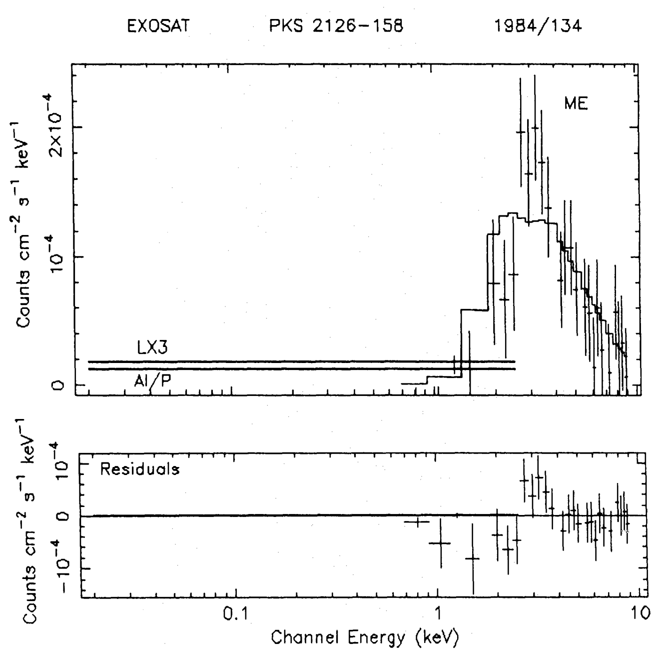

Fig. 2. Same as Fig. 1, but fitted with thermal bremsstrahlung model

$erg\,cm^{-2}\,s^{-1}$ and $(7.3\pm0.8)\,10^{-12}\,erg\,cm^{-2}\,s^{-1}$, respectively and the corresponding luminosities are $(0.7\pm0.1)\,10^{48}\,erg\,s^{-1}$ and $(2.3\pm0.3)\,10^{48}\,erg\,s^{-1}$, respectively. X-ray fluxes of this quasar in the 0.5–4.5 keV range as measured with EINSTEIN and EXOSAT are $2.6\,10^{-12}\,erg\,cm^{-2}\,s^{-1}$ (Zamorani et al. 1981) and $(4.7\pm0.5)\,10^{-12}\,erg\,cm^{-2}\,s^{-1}$, respectively. These results show that the variability of the soft (0.5–4.5 keV) X-ray flux of PKS 2126 − 158 between EINSTEIN and EXOSAT observations is only about 4σ and this does not include the systematic differences due to different instruments and different spectral assumptions. Thus it is suggested that there were no significant variations of this quasar between 1980 and 1984.

PKS 2126 − 158 is a radio-loud quasar whose X-ray (0.1–10 keV) spectral index, α, is flatter ($\alpha = 0.31 \pm 0.15$) than the "canonical" value (Turner & Pounds 1989) of AGNs. Also this result is in agreement with the conclusion of Wilkes & Elvis (1987), who suggested, based on EINSTEIN data, that the radio-loud quasars display flat X-ray spectrum. However, the X-ray spectra of two radio-loud quasars, PKS 1217 + 023 (Ghosh & Soundararajaperumal 1991b) and 1928 + 73 (Ghosh & Soundararajaperumal 1992), have displayed steeper spectral indices. Thus we suggest that the X-ray spectral index may not be a good parameter to differentiate between the radio-loud and radio-quiet quasars.

Observed X-rays may arise from cluster of galaxies around PKS 2126 − 158. However, no such cluster has been detected in the X-ray around this quasar. Recent deep CCD optical images have revealed two faint galaxies ($\sim$21 mag) located at 5″ and 10″ west of PKS 2126 − 158. Probably these two galaxies are the brightest members of a cluster which will be at a redshift of $z \sim 0.6$ (Sargent et al. 1990). Considering the relative magnitudes of the quasar and the galaxies of the cluster and its redshift, it can be shown that the contribution of X-ray emissions from the cluster will be negligible with respect to the contribution from the quasar. Also, recently Edge & Stewart (1991) have found a correlation between the X-ray luminosity and the temperature for clusters. A $(2.3\pm0.3)\,10^{48}\,erg\,s^{-1}$ (observed luminosity of PKS 2126 − 158) cluster would be expected to have a temperature much higher than the derived thermal temperature ($\sim$6.4 keV). This rules out the possibility of cluster origin of the detected X-rays towards this quasar. Thus we conclude that PKS 2126 − 158 is the most luminous quasar in which hard X-rays ($\sim$30 keV at source) have been detected.

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Note added in proof: The quasar S5 0014+81 ($z=3.41$) was known as the most luminous (luminosity in the 0.9–2.5 μm band is $2.2\,10^{14}\,L_{\odot}$) object in the universe (Kuhr H., et al., 1983, ApJ 275, L33; Kuhr H., et al., 1984, ApJ 284, L5; Steidel C.C., Sargent W.L.W., 1987, ApJ 313, 171) and recently it has been found that IRAS 10214+4724 is more luminous (luminosity in the 6–36 μm band is $3.0\,10^{14}\,L_{\odot}$) than S5 0014+81 (Rowan-Robinson M., et al., 1991, Nature 351, 719). However, with the present results we find that PKS 2126-158 is the most luminous (luminosity in the 0.1–10 keV band is $7.8\,10^{14}\,L_{\odot}$) object in the universe.