Astron. Astrophys. 243, 67–70 (1991)

ASTRONOMY AND ASTROPHYSICS

EXOSAT observations of the quasar PKS 2135-147

K.P. Singh, A.R. Rao, and M.N. Vahia

Tata Institute of Fundamental Research, Homi Bhabha Road, Bombay-400005, India

Received April 18, accepted August 31, 1990

Abstract. A study of X-ray emission from the low polarization quasar, PKS 2135-147 (PHL 1657), is presented based on the EXOSAT observations carried out on two occasions separated by a week in 1984. There is little evidence for any variations in the X-ray intensity on hourly time scales during either of the two observations. About 30% change in the soft X-ray (0.1–2 keV) intensity is, however, observed over a week. The observed X-ray spectral data is best fitted by a power law with a photon index Γ of 1.6 ± 0.4 (error bars are with 90% confidence), and a line of sight column density consistent with the 21 cm observations. There is neither a detection of any significant low energy absorption within the quasar nor is there any evidence for soft X-ray excess.

Key words: quasars: individual – PKS 2135-147 – PHL 1657 – galaxies: nuclei of – radiation mechanisms: general – X-rays: spectroscopy

1. Introduction

The radio source PKS 2135-147 (PHL 1657) from the *Parkes Catalog* of radio sources was first optically identified as a quasar by Bolton & Ekers (1966) with a redshift of 0.2 measured from its emission line spectrum (Kinman & Burbidge 1967). The visual magnitude of the quasar as listed in the catalog of Hewitt & Burbidge (1987) is 15.91. The quasar is variable on time scales of months to years with $\Delta m = 1.3$ (Angione 1971, 1973; Lu 1972; Pica et al. 1980). The optical emission from this quasar shows 0.34% polarization (Stockman et al. 1984) and it is also referred to as a low polarization quasar (LPQ). Deep optical images of the quasar PKS 2135-147 show two faint companions with a common envelope for the three objects (Stockton 1982; Hutchings et al. 1984a, b; Smith et al. 1986).

The infrared flux from PKS 2135-147 has been measured by Neugebauer et al. (1979), Glass (1981), and Hyland & Allen (1982). The millimeter flux measurements have been reported by Owen & Puschel (1982) and Steppe et al. (1988). The quasar is an extremely strong source at the centimeter wavelengths. The first radio map at 0.6 GHz by Miley & Hartsuijker (1978) showed it to be a double-lobed source. Subsequent observations with the VLA by Gower & Hutchings (1984) show two widely separated radio lobes and an unresolved core. The radio emission from the quasar is polarized (Simard-Normandin et al. 1981) to the extent of 5% at 2695 MHz.

The X-ray observations of PKS 2135-147 were first carried out with Einstein Observatory Imaging Proportional Counter (IPC) (Zamorani et al. 1981; Zamorani et al. 1984). Two observations separated by one year showed that the X-ray emission is variable with its flux declining by nearly 20% in one year (Zamorani et al. 1984). Its X-ray spectral measurements have been reported by Wilkes & Elvis (1987) from the IPC observations of May 10, 1980. According to them the energy index of the soft X-ray (0.3–3.5 keV) power law continuum emitted by PKS 2135-147 is in the range 0.3 to 0.9 (90% confidence).

We have obtained archival data from two extended X-ray observations of PKS 2135-147 carried out in 1984 using the EXOSAT Observatory. The results from the analysis of this data are presented here. These observations were in the broad-band energy range of 0.1 to 10 keV, thus affording an accurate measure of the X-ray spectrum. The long duration observations were also analyzed for variability. In this paper, we first present the details of observations (Sect. 2), followed by the analysis and results in Sect. 3. We end with a discussion of the results in Sect. 4.

2. Observations

The X-ray observations of PKS 2135-147 were performed twice by the EXOSAT Observatory – on May 12, 1984 and May 19, 1984, using both the medium-energy (ME) detectors and the low-energy (LE) telescope having a channel multiplier array (CMA) as the detector. The details of the instruments used are given by Turner et al. (1981) for the ME detectors and by de Korte et al. (1981) for the LE+CMA combination. The log of the observations is given in Table 1. In the first set of observations done over two days the LE data were obtained using three filters viz., Lexan 3000 (LX 3), Aluminum/Parylene (Al/P) and Boron (BOR – see White and Peacock 1988 for filter efficiencies). In the May 19 observations, however, only the LX3 and BOR filters were used. The ME data were acquired from the eight Argon filled proportional counters. The eight ME detectors are divided into two half arrays, the detectors numbered 1, 2, 3, and 4 are collectively known as the half 1 array and the detectors numbered 5, 6, 7, and 8 are together known as the half 2 array. The ME observations were carried out by pointing only the half 2 array at the source while the other array simultaneously monitored the background. The background data for the half 2 array were obtained while it was slewing-in and slewing-out on the quasar, on both the occasions.

Send offprint requests to: K.P. Singh

Table 1. Log of EXOSAT observations of PKS 2135-147 in 1984 and the count rates

Detector combination	Start time (UT)	End time (UT)	Effective Exposure time (s)	Count rate[a] (10^{-4} cm^{-2} s^{-1})
CMA+LX3	May, 12 $17^h45^m46^s$	May, 12 $19^h05^m46^s$	4689	2.22±0.29
CMA+Al/P	May, 12 19 11 05	May, 12 21 29 46	8039	1.11±0.17
CMA+Boron	May, 12 21 32 58	May, 13 01 16 11	13051	0.25±0.10
ME (Half 2)	May, 12 17 13 20	May, 12 23 36 40	20724	7.30±0.47
CMA+LX3	May, 19 20 56 26	May, 19 22 34 50	5794	1.46±0.22
CMA+Boron	May, 19 20 37 54	May, 20 03 38 26	17669	0.18±0.08
ME (Half 2)	May, 19 20 29 06	May, 20 03 41 30	17473	6.43±0.44

[a] The count rate for the ME are for PHA channels 7 to 24 corresponding to the energy range of 1.5 to 6 keV with the best signal-to-noise ratio.

3. Analysis and results

The data reduction and analysis were performed using the XANADU (X-ray Analysis and Data Utilization) software package. The two sets of data were analyzed separately to avoid systematic effects due to background variations and possible source variability.

3.1. LE and ME source counts

Soft X-ray emission from a point source coinciding with the position of the quasar was detected in the LE observations with both the LX 3 and Al/P filters, and on both the occasions. In the BOR filter, however, the source was barely detectable. No other sources were detected in the central 20′ of the field of view of the LE. The effective exposure times and the background subtracted count rates corrected for vignetting, dead time and the sum-signal distribution are shown in Table 1. The background was obtained from the regions surrounding and adjacent to the position of the source in the detector. The soft X-ray flux detected with the LX 3 filter showed a significant decrease from the May 12 observation to May 19 observation with the count rate dropping by nearly 30%. No variations were detected on a time scale of an hour.

The ME data were selected after rejecting the data with very high background. The effective exposure times of the selected data and the source counts observed in each half-array are given in Table 1. A weak X-ray emission was detected in all the individual detectors at the same strength. The ME data also seem to show about 12% drop in the count rate from May 12 to May 19 observation. This result is, however, not statistically significant. The data were examined for short-term (time scale of hours) variations. A casual inspection of the data shows a significant variation during the May 12 observation, which was traced to be entirely due to background as correlated variation was observed simultaneously in the half 1 array monitoring the background. We show this ME data from the two half arrays in Fig. 1. No variations were detected during the May 19 observations.

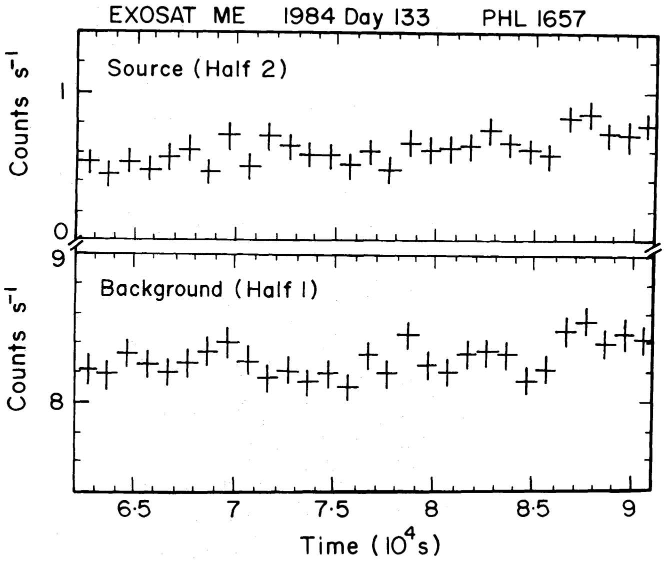

Fig. 1. The X-ray light curve of PKS 2135-147 as observed with the ME detectors in the 1.5–6.0 keV energy range. The lower panel shows the simultaneous measurement of the background in the other half-array of the ME detectors

3.2. X-ray spectrum

The pulse-height (PH) information obtained from the LE and the ME detectors was combined and analyzed together for determining the spectral parameters of the X-ray emission from PKS 2135-147. The spectral data obtained from the half 2 array of ME were used. The background spectral data were obtained from the same array of detectors during the slew. We have examined each detector data individually for any systematics arising from background subtraction. A simple power law was used and the resultant fit was examined visually and the results were also verified for an acceptable χ^2. It was found that detector number 6 gave discrepant results on both the occasions with respect to the other detectors and had unacceptably large χ^2. It was, therefore, not used for any spectral fitting. To avoid systematics of combining the data, we have treated data from each detector separately and fitted them simultaneously and grouped them together only for the plotting purposes.

We have used simple power law models along with absorption in the line of sight to the source to fit the data. The absorption cross-sections given by Morrison & McCammon (1983) were used. Using the χ^2 statistics we find that the simple model gives acceptable fits to both the sets of data. The best fit spectral

Table 2. Results of the spectral analysis of PKS 2135-147 using the EXOSAT LE + ME Data

Parameter	Date of Observation	
	1984 May 12	1984 May 19
A. Model: power law + absorption		
Photon index (Γ)	$1.59^{+0.37}_{-0.33}$	$1.35^{+0.42}_{-0.47}$
A (10^{-3} cm^{-2} s^{-1} keV^{-1})	$1.90^{+1.03}_{-0.66}$	$1.49^{+1.02}_{-0.72}$
N_H (10^{20} cm^{-2})	$1.50^{+3.78}_{-1.20}$	$1.39^{+4.88}_{-1.39}$
χ^2/dof	111.4/103	117.4/102
Flux (in the units of 10^{-12} erg cm^{-2} s^{-1})		
Energy band (keV)		
0.1– 2.0	5.34	4.07
2.0–10.0	9.27	10.66
B. Model: power law + fixed absorption ($N_H = 4.45\ 10^{20}$ cm^{-2})		
Photon Index (Γ)	$1.86^{+0.14}_{-0.14}$	$1.62^{+0.16}_{-0.18}$
A (10^{-3} cm^{-2} s^{-1} keV^{-1})	$2.69^{+0.33}_{-0.33}$	$2.12^{+0.38}_{-0.40}$
χ^2/dof	114.8/104	120.9/103

Note: Quoted errors are at 90% confidence level computed while keeping the rest of the variables as free parameters.

parameters obtained from this analysis along with their 90% confidence error bars estimated by keeping all the other interesting parameters free ($\chi^2_{min} + 4.61$ for two free parameters) are listed in Table 2) (Hereafter, all the quoted errors are with 90% confidence estimated in this fashion). The photon index (Γ) obtained from the May 12 observation is $1.59^{+0.37}_{-0.33}$. The May 19 data give the value of Γ as $1.35^{+0.42}_{-0.47}$, showing a negligible change. The slope of the power law is consistent with that of the canonical Seyfert spectra (Mushotzky 1984; Turner & Pounds 1989). The column density of the equivalent hydrogen along the line of sight is determined to be $1.5^{+3.8}_{-1.2}\ 10^{20}$ cm^{-2}. Considering the large error bars, it is consistent with that estimated from the accurate 21 cm observations by Elvis et al. (1989) who find $N_H = 4.45\ 10^{20}$ cm^{-2}. There is, therefore, no evidence for absorption intrinsic to the source from these observations. The PH data from the two observation are shown separately in Figs. 2(a) and 2(b). In the same figure the best fit power law model convolved with the detector response is shown as a histogram. The residuals between the data and the model are shown in the lower panel of the figures. No spectral excess is seen at low energies in the LE. Fixing the N_H to the 21 cm value gave no significant change in the χ^2_{min} value. Assuming a fixed N_H, however, gives smaller error bars for Γ (see Table 2) and gives a better agreement with the canonical Seyfert spectra. We do not find any improvement in the fit by including a line feature between 4 and 7 keV. The X-ray flux observed in various energy bands are also given in Table 2.

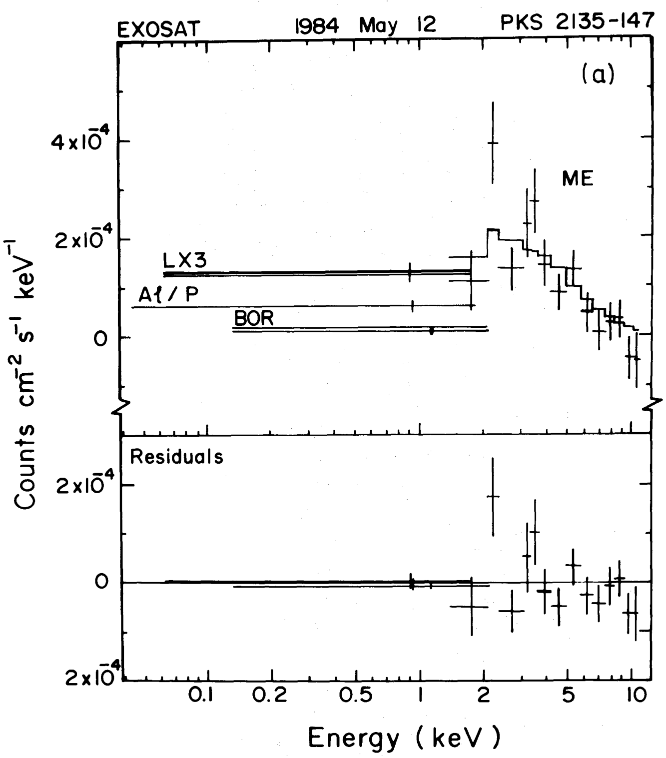

Fig. 2a. The pulse height (PH) data observed with the LE and ME detectors of EXOSAT on 1984 May 12 are shown. The three filters used for the LE observations are indicated. The histogram shows the predicted count distribution from the best fit single power law model including the line of sight absorption. The lower panel shows the residuals between the data and the best fit spectral model

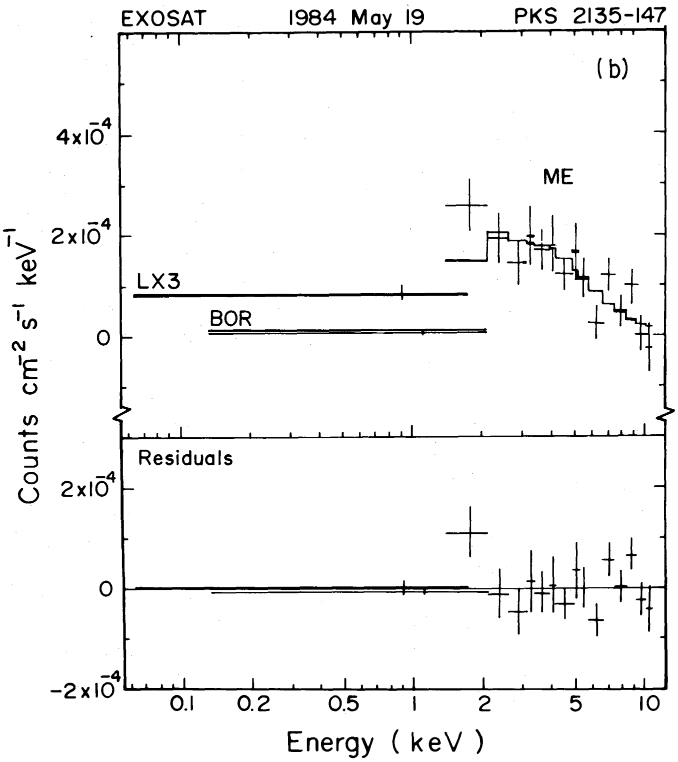

Fig. 2b. The pulse height (PH) data observed with the LE and ME detectors of EXOSAT on day 1984 May 19 are shown. The two filters used for the LE observations are indicated. The histogram shows the predicted count distribution from the best fit single power law model including the line of sight absorption. The lower panel shows the residuals between the data and the best fit spectral model

4. Discussion

The X-ray flux from PKS 2135-147 as measured with EXOSAT on May 12, 1984 in the 2–10 keV energy band is $9.3\ 10^{-12}\ \mathrm{erg\,cm^{-2}\,s^{-1}}$, whereas on May 19, 1984 it was $10.7\ 10^{-12}\ \mathrm{erg\,cm^{-2}\,s^{-1}}$. These fluxes correspond to X-ray luminosity values of $2.0\ 10^{45}\ \mathrm{erg\,s^{-1}}$ and $2.3\ 10^{45}\ \mathrm{erg\,s^{-1}}$ respectively, emitted by the source in its rest frame energy range of 2.4–12.0 keV. We assume a distance corresponding to the redshift of 0.2, $H_0 = 50\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$ and $q_0 = 0$ in the Friedman Cosmology. Thus the hard X-ray source seems to show negligible fluctuations on a time-scale of a week. The soft X-ray (0.1–2 keV) luminosity, however, shows a significant change ($\simeq 30\%$) in a week's time decreasing from $1.15\ 10^{45}$ to $0.9\ 10^{45}\ \mathrm{erg\,s^{-1}}$.

For comparison of these results with those obtained from the IPC observations, we have calculated the flux in the $(0.5–4.5)/(1+z)$ keV range. The source luminosity thus obtained in the rest frame of the quasar in this energy range is $1.7\ 10^{45}\ \mathrm{erg\,s^{-1}}$ on May 12, 1984 and $1.6\ 10^{45}\ \mathrm{erg\,s^{-1}}$ on May 19, 1984. The IPC observations on May 19, 1979 detected a luminosity of $1.44\ 10^{45}\ \mathrm{erg\,s^{-1}}$ and on May 10, 1980 the X-ray luminosity was observed to be lower at $1.18\ 10^{45}\ \mathrm{erg\,s^{-1}}$ (Zamorani et al. 1984). Our luminosity measurements appear to be consistent with the 1979 measurement using the IPC.

Three high redshift quasars –21342-149 ($z=2.2$; $V=18.3$), 21354-145 ($z=1.9$; $V=19.9$) and 21357-147 ($z=2.1$; $V=19.3$) lie very close to PKS 2135-147 (Anderson & Margon 1987). None of this objects were detected in the IPC observations and an upper limit of approximately $8\ 10^{-14}\ \mathrm{erg\,cm^{-2}\,s^{-1}}$ for the X-ray flux has been reported for them by Anderson & Margon (1987). These quasars were also in the field of view of the EXOSAT detectors. None were detected in the LE, however. The contribution of these quasars to the ME flux is expected to be negligible even if these quasars were to increase in their luminosity by a few times between the Einstein and the EXOSAT observations.

The present observations determine the X-ray spectrum of PKS 2135-147 over two epochs separated by a week. The slope of the power law spectrum is found to be similar (on both the occasions) to that of the of the well-studied brighter AGN's (Mushotzky 1984; Turner & Pounds 1989). The measured spectral index is consistent with that observed with the IPC in 1980. Although no significant variation in the spectral index is observed over a time scale of one week, the low energy flux did, however, show a significant drop unaccompanied by any hard X-ray variations. This could be due to a separate soft component which is spectrally unresolved with the present observations, or due to an overall hardening of the X-ray spectrum indicated by the data albeit with negligible significance. A recent analysis of the IPC+MPC data from the 1980 observations with the Einstein Observatory (Wilkes et al. 1989) also failed to resolve any low energy excess in the source.

Future observations with instruments of higher sensitivity and broad band width would be extremely desirable to improve the precision of spectral measurements. It is also very important to extend the observations beyond 10 keV and to look for line emission near 6 keV (rest frame).

Acknowledgements. We wish to thank the EXOSAT Observatory staff at ESTEC for providing us with the data from the archives. We are grateful to the IoA, Cambridge, UK for giving us the XANADU package. We thank the referee for his critical comments.

References

Anderson S.F., Margon B., 1987, ApJ 314, 111
Angione R.J., 1971, AJ 76, 25
Angione R.J., 1973, AJ 78, 353
Bolton J.G., Ekers J., 1966, Aust. J. Phys. 19, 713
de Korte P.A.J., Blecker J.A.M., den Boggende A.J.F., Branduardi-Raymont G., Brinkman A.C., Culhane J.L., Gronenschild E.H.B.M., Mason I., Mckechnie S.P., 1981, Space. Sci. Rev. 30, 495
Elvis M., Lockman F.J., Wilkes B.J., 1989, AJ 97, 777
Glass I.S., 1981, MNRAS 194, 795
Gower A.C., Hutchings J.B., 1984, AJ 89, 1658
Hewitt A., Burbidge G., 1987, ApJS 63,1
Hyland A.R., Allen D.A., 1982, MNRAS 199, 943
Hutchings J.B., Crampton D., Campbell B., 1984a, ApJ 280, 41
Hutchings J.B., Crampton D., Campbell B., Duncan D., Glandening B., 1984b, ApJS 55, 319
Kinman T.D., Burbidge E.M., 1967, ApJ 148, L59
Lu P.K., 1972, AJ 77, 829
Miley G.K., Hartsuijker A.P., 1978, A & AS 34, 129
Morrison R., McCammon D., 1983, ApJ 270, 119
Mushotzky R.F., 1984, Adv. Space Res. 3, 157
Neugebauer G., Oke J.B., Becklin E.E., Mathews K.: 1979, ApJ 230, 79
Owen F.N., Puschell J.J., 1982, AJ 87, 595
Pica A.J., Pollock J.T., Smith A.G., Leacock, R.J., Edwards P.L., Scott R.L., 1980, AJ 85, 1442
Simard-Normandin M., Kronberg P.P., Button S., 1981, ApJS 46, 239
Smith E.P., Heckman T.M., Bothun G.D., Romanshin W., Ballick B., 1986, ApJ 306, 64
Steppe H., Salter C.J., Chini R., Kreysa A., Brunswig W., Lobata Perez J., 1988, A & AS 75, 317
Stockman H.S., Moore R.L., Angel J.R.P., 1984, ApJ 279, 485
Stockton A., 1982, ApJ 257, 33
Turner M.J.L., Smith A., Zimmermann H.U., 1981, Space Sci Rev. 30, 479
Turner T.J., Pounds K.A., 1989, MNRAS 240, 833
White N.E., Peacock A., Memoire della Societa Astronomica Italiana, 59, 7
Wilkes B.J., Elvis M., 1987, ApJ 323, 243
Wilkes B.J., Masnou J-L., Elvis M., Mc Dowell J., Arnaud K., 1989, in: Proc. 23rd ESLAB Symposium on Two Topics in X-ray Astronomy II. AGN and X-ray Background, ESA publication, SP-296, Vol. 2, p. 1081
Zamorani G., Henry J.P., Maccacaro T., Tananbaum H., Soltan A., Avni Y., Liebert J., Stocke J., Strittmatter P.A., Weymann R.J., Smith M.G., Condon J.J., 1981, ApJ 245, 357
Zamorani G., Giommi P., Maccacaro T., Tananbaum H., 1984, ApJ 278, 28