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MULTIFREQUENCY OBSERVATIONS OF THE BLAZAR PKS 0537–441 IN A MODERATELY ACTIVE STATE[1]

E. G. TANZI,[2] P. BARR,[3,4] P. BOUCHET,[5] L. CHIAPPETTI,[2] S. CRISTIANI,[5]
R. FALOMO,[6] P. GIOMMI,[3,4,7] L. MARASCHI,[8] AND A. TREVES[8]

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ABSTRACT

PKS 0537–441 was observed during an active state in 1985 February at infrared, optical, UV, and X-ray frequencies. Comparison with earlier measurements indicates that the source brightened by a factor of ~ 2 in all bands. This suggests that the same spatial region may be responsible for the emission in the whole spectral range observed.

Subject heading: BL Lacertae objects

I. INTRODUCTION

The optical counterpart of PKS 0537–441 (Peterson and Bolton 1972) has shown in the past strong variability with erratic fluctuations up to $\Delta m = 4$ (Eggen 1973; Liller 1974). Some variability was detected also in the radio band (Gilmore 1979; McAdam 1982; Kuhr *et al.* 1981; Komesaroff *et al.* 1984) and in the infrared (Glass 1981; Allen, Ward, and Hyland 1982). The object was classified as a BL Lac because the first optical spectra were featureless. However, Peterson *et al.* (1976), on one occasion, observed two broad emission lines at λ3617 and λ5300, which were identified with C III] λ1909 and Mg II λ2798 yielding a redshift $z = 0.894$ (see also Wilkes *et al.* 1983). No other detection of the two lines has been reported.

In 1985 January PKS 0537–441 was found in an active phase (Cristiani 1985). Here we report on a series of multifrequency observations from 1984 November to 1985 March. The optical and IR data were obtained at the European Southern Observatory, La Silla, Chile. *EXOSAT* and the *International Ultraviolet Explorer* were used for observations at X-ray and UV frequencies.

II. OBSERVATIONS

In 1984 November optical spectrophotometry and photometry of PKS 0537–441 was obtained referring to a relatively normal (low) state of the object (see § III and Fig. 2). A sudden brightening observed between 1985 January 10 and 12 motivated the request of observing the object as a target of opportunity with *EXOSAT* and *IUE* in 1985 February. Near-infrared magnitudes were also obtained on February 11, while optical photometry was not obtained until February 26 when the brightness was apparently declining. A detailed journal of observations is reported in Table 1.

The Image Dissector Scanner (IDS) spectra of 1984 November 9–13 (one per night) and that of 1985 March 11 covered the range 4000–8000 Å with dispersion of 230 Å mm^{-1} and a FWHM resolution of 15 Å. Data were reduced to absolute flux by repeated observations of standard stars (Stone 1977). A standard atmospheric correction for La Silla was applied. The resulting photometric accuracy is estimated to be better than 10% for both epochs.

No significant variability appears within the 1984 November spectra. The average spectrum dereddened with $A_v = 0.2$ (Maraschi *et al.* 1985) is represented by a steplike line on Figure 2. The average fluxes, integrated over 100 Å intervals, were fitted with a power law ($F_\nu \propto \nu^{-\alpha}$) yielding $\alpha = 1.7 \pm 0.1$ ($\chi^2_{\mathrm{red}} = 4.5$) for $A_v = 0.2$. The power-law fit is chosen to allow comparison with the spectral shape in other bands and with earlier data despite the high χ^2 value, which may be due to underestimated systematic errors in the response at low intensity. This applies also to the UV spectra discussed below. In the 1984 November spectra no indication of Mg II emission at λ5300 is present and a 1 σ upper limit of 5 Å to the equivalent width can be derived assuming a line width at half-maximum of 100 Å (Peterson *et al.* 1976). The signal-to-noise ratio of the 1985 March spectrum is poor and prevents a significative estimate of the spectral slope and of an upper limit to Mg II emission.

CCD photometry in the *V* band was obtained at La Silla on 1984 December 24, and 1985 January 10 and 12, with the 1.5 m Danish Telescope and on 1985 February 26, with the 2.2 m ESO Telescope.

Infrared magnitudes, in the ESO photometric system, were obtained with the InSb photometer attached to the 3.6 m ESO Telescope.

An ultraviolet spectrum in the range 2000–3000 Å was obtained with the *International Ultraviolet Explorer* on 1985 February 21 with an exposure time of 167 minutes. The

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[1] Optical and infrared observations were obtained at the European Southern Observatory, La Silla, Chile. UV and X-ray data derive, respectively, from observations with the *International Ultraviolet Explorer* collected at VILSPA, Spain, and with the *EXOSAT* satellite of the European Space Agency.

[2] Istituto di Fisica Cosmica, CNR, Milano.

[3] *EXOSAT* Observatory, ESA, Damstadt.

[4] Affiliated to Astrophysics Division, Space Science Department, ESA.

[5] European Southern Observatory, La Silla, Chile.

[6] Osservatorio di Padova-Asiago, Asiago, Italy.

[7] On leave of absence from Istituto di Fisica Cosmica, CNR, Milano.

[8] Dipartimento di Fisica dell'Università, Milano.

TABLE 1

JOURNAL OF OBSERVATIONS

Date	Instrumentation	Intensity
1984 Nov 9–13	ESO1.52 + IDS	$V^a = 15.95 \pm 0.1$
Dec 24	1.5 Danish + CCD	$V = 15.85 \pm 0.05$
1985 Jan 10	1.5 Danish + CCD	$V = 15.60 \pm 0.05$
Jan 12	1.5 Danish + CCD	$V = 15.18 \pm 0.05$
Feb 4...........	*EXOSAT*	$F(1\ \text{keV})^b = 0.46 \pm 0.08\ \mu\text{Jy}$
Feb 11	ESO 3.6 + InSb	$J = 12.40 \pm 0.05$; $H = 11.69 \pm 0.05$; $K = 10.86 \pm 0.05$
Feb 21	*IUE*	$F(2500\ \text{Å}) = 1.3 \pm 0.1$ mJy $V(\text{FES}) = 15.2 \pm 0.2$
Feb 24	*EXOSAT*	$F(1\ \text{keV})^b = 0.31 \pm 0.07\ \mu\text{Jy}$
Feb 26	ESO 2.2 + CCD	$V = 15.64 \pm 0.05$
Mar 11	ESO 1.52 + IDS	$V = 16.3 \pm 0.2$

[a] Mean value of the four nights.

[b] Pure statistical errors are quoted. Conversion to flux assumed $\alpha = 0.5$, $N_H = 4 \times 10^{20}$ cm^{-2}.

fluxes, averaged over 100 Å intervals, dereddened with $A_V = 0.2$ were best fitted with a power law yielding $\alpha = 1.8 \pm 0.3$ ($\chi^2_{\text{red}} = 4.5$). The V magnitude of the object, as deduced from the counting rate of the Fine Error Sensor on board *IUE*, was $V = 15.2 \pm 0.2$.

The source was observed by *EXOSAT* on 1985 February 4 and 24. The standard weak source configuration was used. The instrumentation included a Low Energy (LE) telescope which was used in conjunction with the thin lexan filter sensitive in the 0.05–2.5 keV range and two arrays of proportional argon counters (1–10 KeV) (ME). A detailed description of the instrumentation can be found in Taylor *et al.* (1981).

The source intensity in the LE was $(3.96 \pm 0.74) \times 10^{-3}$ counts s^{-1} on February 4 (exposure time: 14243 s) and $(2.64 \pm 0.60) \times 10^{-3}$ counts s^{-1} on February 24 (exposure time: 12197 s). Though with low significance the data indicate a decrease in intensity between the two observations. Assuming a power-law spectrum with $\alpha = 0.5$ in the X-rays and a column density $N_H = 4 \times 10^{20}$ cm^{-2}, as deduced by Maraschi *et al.* (1985) on the basis of measurements with the *Einstein Observatory* in 1979–1980, the monochromatic fluxes at 1 keV can be derived. These are reported in Table 1. The 1 keV fluxes corresponding to the 90% confidence limits on α ($0.15 < \alpha < 0.95$) allowed by the *Einstein* observations, are, respectively, 0.56 μJy and 0.34 μJy for the first *EXOSAT* observation, and 0.37 μJy and 0.22 μJy for the second one.

The source was not detected with the ME experiment at either epoch. A conservative upper limit, at 99% confidence level, is 0.29 μJy and 0.65 μJy at 3 keV for the first and second observations, respectively, assuming the same spectral slope adopted in the LE range, i.e., $\alpha = 0.5$. The derived upper limit for February 4 is only marginally consistent with an extrapolation from the LE range with the assumed spectral shape.

III. DISCUSSION

The light curve in the V band, as from our observations of 1984–1985, is reported in Figure 1. The maximum observed variation is $\Delta m = 1$, with an increase of 0.4 mag in 2 days. The recorded activity has amplitude smaller than, but time scale similar to that detected in 1971–1972 by Eggen (1973). Similar episodes of activity are not uncommon according to the secular light curve reported by Liller (1974). The active state discussed in this *Letter* started in early 1985 January and probably culminated at the beginning of 1985 February when no observation in the V band is available. In fact extrapolation to the visible of the IR observation of 1985 February 11 yields $m_V \approx 15$.

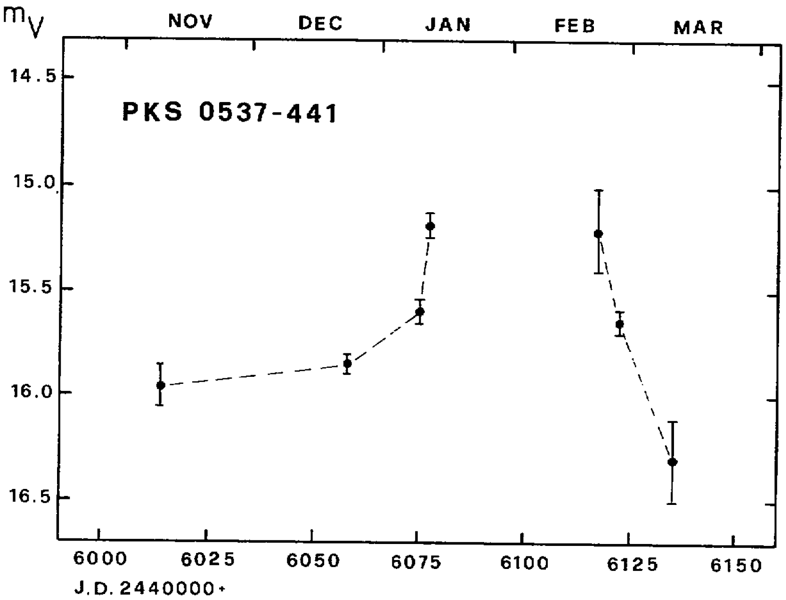

FIG. 1.—Light curve of PKS 0537−441 in the V band (broken lines are drawn as an eyeguide)

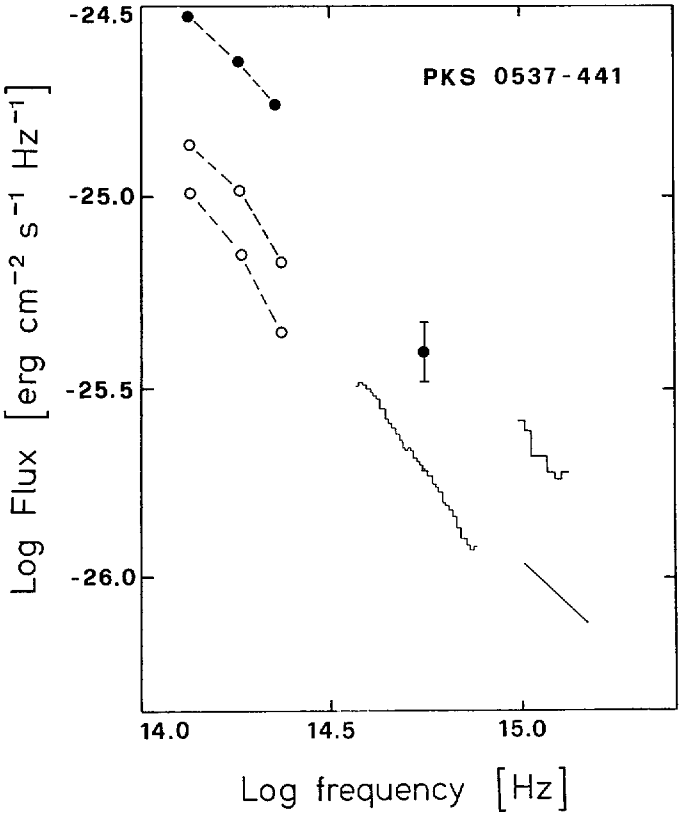

FIG. 2.—Energy distribution of PKS 0537 − 441 in two different brightness states. The filled circles and the steplike line in the UV range represent measurements obtained during the brightening of 1985 February. The other data represent a lower brightness state. Open circles in the infrared are from Allen *et al.* (1982). The steplike line in the optical represents our observations of 1984 November, and the continuous line in the UV is from the 1980 observation by Maraschi *et al.* (1985).

In Figure 2 the observations presented in this *Letter* are compared with data obtained in 1980. These consist of UV spectroscopy obtained with *IUE* in 1980 September 27 (Maraschi *et al.* 1985) and infrared photometric data by Allen, Ward, and Hyland (1982) of 1980 August (*upper open circles*) and 1980 November (*lower open circles*). The variation in the IR on this short time scale amounts to 0.3 m. The interpolation between the infrared and UV data of 1980 matches well the optical spectrum obtained in 1984 November when our monitoring started (see Fig. 2). This group of data therefore appears to depict a low-state spectrum with respect to which the observations of 1985 February show a brightening of a factor ~ 2 from infrared to ultraviolet frequencies. In the IR the brightening is actually larger (a factor of 3), but these observations were the nearest to the maximum presumed brightness as inferred from the light curve reported in Figure 1.

Comparison of the X-ray fluxes derived from the present observations with those obtained from *Einstein* IPC observations in 1980 simultaneous with *IUE* involves some hypotheses on the spectral shape. Assuming that the source spectrum does not vary and taking the best-fit value of the slope of the *Einstein* data for fixed $N_{\rm H}$ (4×10^{20} cm^{-2}), the *EXOSAT* flux of 1985 February 4 is higher than the *Einstein* one by 0.24 ± 0.09 μJy, which corresponds to a factor of 2 increase though with limited significance (~ 3 σ). The increase is larger if the assumed slope is flatter than 0.5 but reduces to 0.1 ± 0.06 μJy if the steepest slope ($\alpha = 1$) compatible with the *Einstein* data is assumed. We can therefore conclude that also the X-ray data indicate a brightening, with respect to those of 1980, the amplitude of which is consistent with that observed at lower frequencies. The decrease observed between 1985 February 4 and February 24 within the *EXOSAT* data suggests that the X-ray brightening is associated with the optical flare.

In conclusion, though several indirect arguments have to be invoked, the multifrequency data discussed above suggest that the broad-band energy distribution of PKS 0537 − 441 above 10^{14} Hz remains essentially unmodified in the active state, which is consistent with the absence of significant spectral variations within the IR and UV bands between the 1985 and 1980 data.

Multifrequency observations of variability of blazars are still rather scarce. Some objects like 3C 66A, PKS 2155 − 304, and MK 421 (Maccagni *et al.* 1983; Morini *et al.* 1985; Brodie, Bowyer, and Tennant 1986) appear to be more variable in X-rays than in the optical-UV band. On the other hand PKS 0735 + 178 appears steady in X-rays, while varying by a factor of 3 in the optical–UV range (Bregman *et al.* 1984). In the case of PKS 0537 − 441 the variability from infrared to X-ray frequencies may be similar in time scale and amplitude, which is at variance with the above examples, and makes the object worthy of continued monitoring.

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P. BARR and P. GIOMMI: *EXOSAT* Observatory, ESOC, 6100 Darmstadt, Federal Republic of Germany

P. BOUCHET and S. CRISTIANI: European Southern Observatory, La Silla, Chile

L. CHIAPPETTI and E. G. TANZI: Istituto di Fisica Cosmica, CNR, Via Bassini 15, 20133 Milano, Italy

L. MARASCHI and A. TREVES: Dipartimento di Fiscia dell'Università, Via Celoria 16, 20133 Milano, Italy