BeppoSAX Observations of 1 Jy BL Lacertae Objects

Paolo Padovani[a,b,c], Paolo Giommi[d], Andrea Comastri[e], Gabriele Ghisellini[f], Tommaso Maccacaro[f], Franco Mantovani[g], Laura Maraschi[f], Carlo Stanghellini[g], Gianpiero Tagliaferri[f], C. Megan Urry[a], Anna Wolter[f]

[a]Space Telescope Science Institute, Baltimore, USA

[b]Affiliated to the Astrophysics Division, Space Science Department, European Space Agency

[c]On leave from Dipartimento di Fisica, II Università di Roma "Tor Vergata", Italy

[d]SAX/SDC, ASI, Roma, Italy

[e]Osservatorio Astronomico di Bologna, Italy

[f]Osservatorio Astronomico di Brera/Merate, Italy

[g]Istituto di Radioastronomia, Bologna, Italy

Preliminary results on *BeppoSAX* LECS and MECS observations of BL Lacertae objects selected from the 1 Jy sample are presented. All sources of the LBL type, that is, characterized by a peak in their multifrequency spectra at infrared/optical energies, seem to show a relatively flat ($\alpha_x \sim 0.7 - 0.8$) X-ray spectrum. This is in agreement with the supposed dominance of inverse Compton emission in the X-ray band of these sources.

1. Introduction

BL Lacertae objects represent an extreme class of active galactic nuclei (AGN), distinguished by their high luminosity, rapid variability, high polarization, radio core-dominance, apparent superluminal speeds, and very weak emission lines (e.g., Kollgaard 1994; Urry & Padovani 1995). Their broad-band emission, which extends from the radio up to the gamma-ray band, is dominated by non-thermal processes from the heart of the AGN, undiluted by the thermal emission present in other AGN. Therefore, BL Lacs represent the ideal class to study to further our understanding of the nuclear engine in AGN.

We are currently conducting an X-ray study of a well selected fraction of the 1 Jy BL Lac sample, which is presently the only sizeable, complete sample of radio selected such objects. This includes all sources with estimated $0.1 - 10$ keV flux larger than 2×10^{-12} erg cm^{-2} s^{-1} for which we have been granted *BeppoSAX* observing time.

Our main scientific objectives are: 1. study inverse Compton emission, thought to be the dominant X-ray component in this BL Lac subclass, which is characterized by a peak in their multifrequency spectra in the IR/Optical band; 2. compare the *BeppoSAX* spectra with the far- to near-infrared ($1 - 200\mu$) spectra for the objects observed by ISO as part of a GO program (P.I. P. Padovani); 3. check for any differences between the X-ray spectra of radio- and X-ray selected BL Lacs or, following a more physical division, BL Lacs with the peak of the emission in the IR/Optical band (LBL) and in the UV/X-ray band (HBL). Differences exist in the *ROSAT* band (e.g., Padovani & Giommi 1996). A parallel Core Program, in fact, deals with X-ray selected BL Lacs (HBL; Wolter et al. 1998); 4. compare the X-ray spectra of radio-selected BL Lacs with those of other classes of radio sources included in various Core Programs, i.e., radio-loud quasars and radio-galaxies (see e.g., Trussoni et al. 1998).

Table 1 gives the list of the seven 1 Jy BL Lacs approved as part of a *BeppoSAX* Core Program in AO1. One object has not been observed yet, while three of them have been observed only recently (and therefore their data have not been reduced at the time of writing). In this paper we will then restrict discussion to the remaining three sources. Some of the X-ray bright 1 Jy BL Lacs are included in other *BeppoSAX* programs (e.g., MKN 501: Pian et al. 1998; S5 0716+714: Chiappetti et al. 1998).

2. Observations and Data Analysis

Details of the *BeppoSAX* observations are given in Table 2. Note that PKS 0048–097 has been observed only for about 20% of the requested time (however, this source has been recently reobserved). Data analysis was based on the linearized, cleaned event files obtained from the *BeppoSAX* SDC on-line archive and on the XIMAGE package. Spectra were accumulated for each observations using the SAXSELECT tool and the recommended extraction radii.

Spectral analysis was performed with the XSPEC 9.00 package, using the response matrices released by SDC in early 1997. The spectra were rebinned such that each new bin contains at least 20 counts.

Spectral fits for PKS 1144−379, the only source for which LECS data were available, show that the fitted N_H value is consistent with the Galactic one. We then assumed Galactic N_H in all fits. For the objects without LECS data this assumption is also justified by the fact that the fit to the MECS data is not strongly dependent on N_H.

3. Results

The results of the combined LECS (for one object) and MECS fits are given in Table 3. Note the very large errors on the spectral index of PKS 0048−097, due to the very short exposure.

The LECS and MECS data of PKS 1144−379, shown in Fig. 1, can be parametrized by a relatively flat energy index $\alpha_x \sim 0.8$. On closer inspection, however, it turns out that a broken power-law model improves the fit at the 98.8% level. Best-fit parameters are, assuming Galactic N_H based on LECS data: $\alpha_{\rm soft} = 1.8^{+0.6}_{-0.7}$, $\alpha_{\rm hard} = 0.6^{+0.3}_{-0.3}$, $E_{\rm break} = 2.1^{+0.6}_{-1.3}$ keV, $\chi^2_\nu = 1.22$ for 32 degrees of freedom (errors are 90% uncertainties for one interesting parameter, as the uncertainties for three interesting parameters are not very well constrained).

The MECS data of PKS 2005−489, shown in Fig. 2, can be fitted by a single power-law model modified at low energies by absorption due to neutral gas in the Galaxy (no LECS data are available for this source, due to technical problems). The energy index is determined to be $\alpha_x = 1.32 \pm 0.04$.

A comparison with ROSAT data (from Urry et al. 1996) for these objects show that both the soft X-ray spectral index and flux of PKS 1144−379 are similar, within the rather large errors, to the ROSAT ones. In the case of PKS 2005−489, on the other hand, the *BeppoSAX* spectral index is flatter than the ROSAT one, while the *extrapolated* 0.1 − 2.4 keV flux is a factor ~ 3 higher. Note that the overall spectral energy distribution of PKS 2005−489 is of the HBL type, that is, it peaks at UV/X-ray energies. This source, therefore, is more similar to the BL Lacs selected in X-ray surveys studied by Wolter et al. (1998).

A preliminary analysis of the other three 1 Jy BL Lacs recently observed by *BeppoSAX* shows that all of them, as PKS 1144−379, are characterized by a relatively flat ($\alpha_x \sim 0.7 - 0.8$) energy index. This agrees with the expected dominance of inverse Compton emission in BL Lacs of this kind (LBL). We will be able to reach more specific conclusions on the hard X-ray properties of 1 Jy BL Lacs after the completion of our observing program.

REFERENCES

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Table 1
The *BeppoSAX* 1 Jy BL Lac Sample

Name	z	V	F_{5GHz} Jy	F_x(0.1–10 keV) 10^{-12} c.g.s. (estimated)	Exposure time ks
PKS 2005–489	0.071	14.4	1.2	105.	10
OJ 287[a]	0.306	15.1	2.6	14.0	10
PKS 0048–097	>0.2	16.3	2.0	11.3	10
BL Lac[a]	0.069	14.9	4.8	9.8	10
4C 56.27[a]	0.664	18.4	1.7	8.3	10
PKS 1144–379	1.048	17.4	1.6	5.8	20
PKS 1519–273[b]	>0.2	18.1	2.4	4.3	20

[a] Observed October - November 1997: data not yet reduced.
[b] Still to be observed.

Table 2
Journal of Observations

Name	LECS exposure (s)	LECS count rate (10^{-2} s^{-1})	MECS exposure (s)	MECS count rate (10^{-2} s^{-1})	Observing date
PKS 0048−097	...	...	2,285	3.1 ± 0.5	02-DEC-1996
PKS 1144−379	10,834	1.0 ± 0.1	23,421	1.9 ± 0.1	10/11-JAN-1997
PKS 2005−489	...	...	9,910	141.0 ± 1.4	29/30-SEP-1996

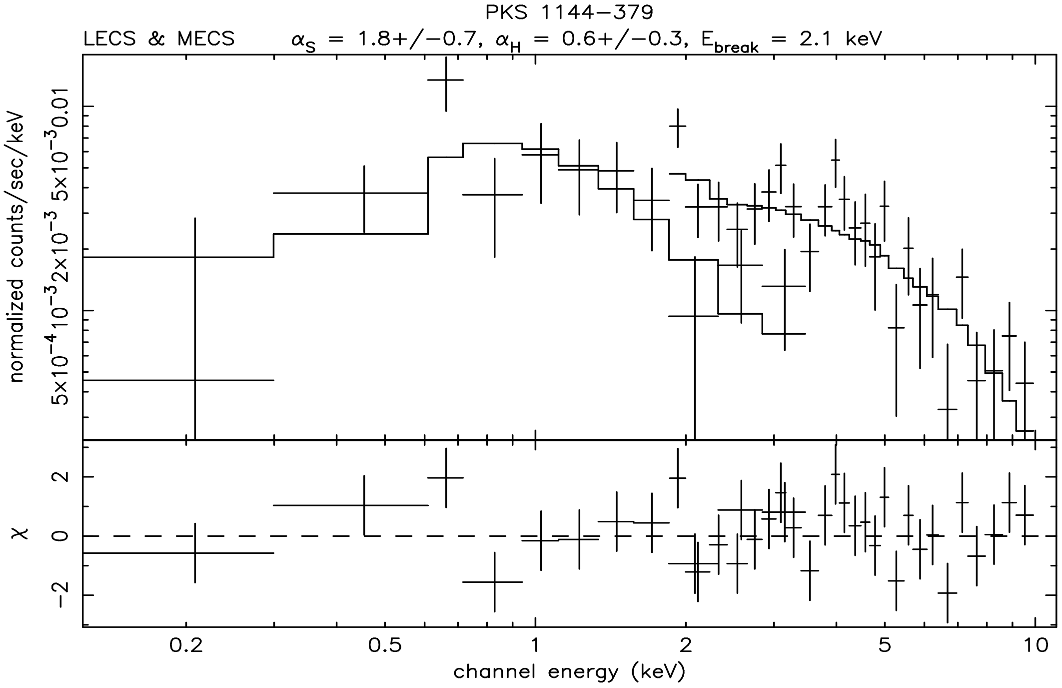

Figure 1. The LECS and MECS spectrum of PKS 1144−379.

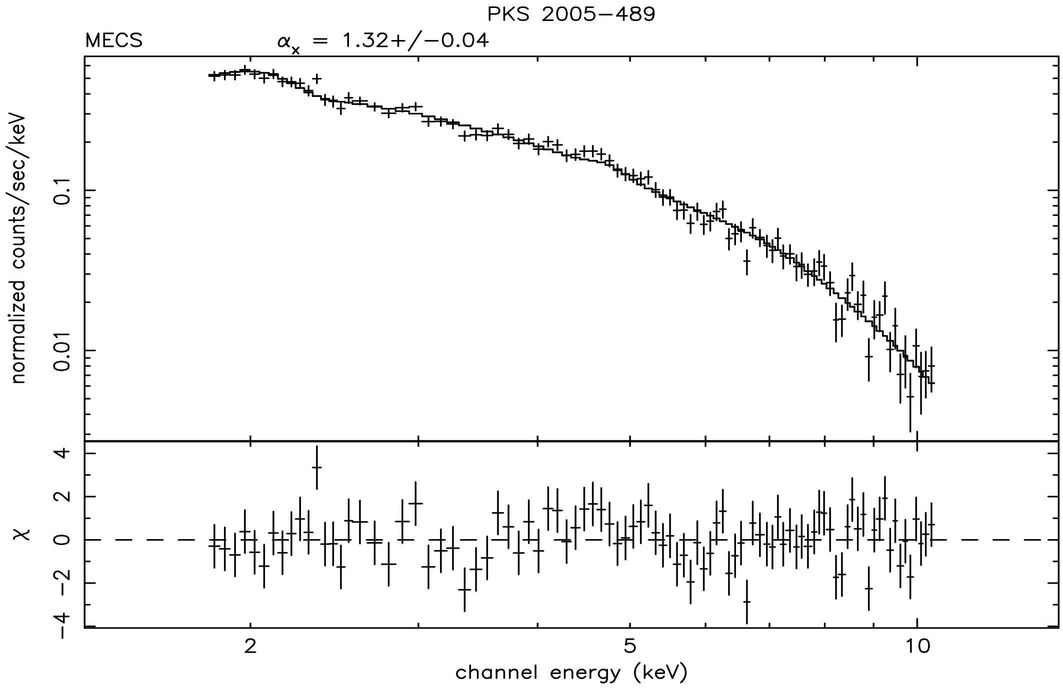

Figure 2. The MECS spectrum of PKS 2005−489.

Table 3
LECS and MECS Spectral Fits

Name	α_x^a	χ^2_ν(dof)	Flux $(2-10$ keV$)^b$ 10^{-12} erg cm^{-2} s^{-1}
PKS 0048−097[c]	$1.3^{+2.4}_{-1.2}$	0.63(1)	1.8 ± 0.3
PKS 1144−379[d]	$0.77^{+0.31}_{-0.27}$	1.32(34)	0.84 ± 0.04
PKS 2005−489[c]	$1.32^{+0.04}_{-0.04}$	1.18(91)	62.3 ± 0.6

[a] Assuming Galactic N_H; errors correspond to 90% uncertainties for one interesting parameter.
[b] Unabsorbed flux. 1 σ errors for best-fit model.
[c] Only MECS data available.
[d] Broken power-law better fit to the data: see text.