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The last gift of *BeppoSAX*: PDS observations of the two blazars 1ES 0507-040 and PKS 1229-021

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Towards the end of the *BeppoSAX* mission, the only operated Narrow Field Instrument was the PDS, which covers the energy range 13-300 keV. Two blazars, 1ES 0507-040 ($z = 0.304$) and PKS 1229-021 ($z = 1.045$), suitably located in the sky for *BeppoSAX* pointing, were observed for about 2 days each in Spring 2002 with the PDS and detected up to 50 keV. 1ES0507-040 had already been observed by the *BeppoSAX* NFIs at an earlier epoch for a much shorter time. We have re-analysed those data as well, and identified a possible contamination problem in the PDS spectrum. We present our recent PDS data on both sources, combined with the previous *BeppoSAX* data and with non-simultaneous observations at other frequencies. The derived Spectral Energy Distributions allow us to discuss the origin of the high energy component.

1. INTRODUCTION

The class of blazars contains the most extreme AGNs, characterized by fast variability, high degree of polarization, bright non-thermal continuum extending from radio up to γ -ray energies (e.g. cite1995PASP..107..803U). The study of these sources allows us to address several important issues related to the physics of relativistic jets. For these reasons it is of particular importance to obtain information on the high-energy emission of blazars. In this respect an excellent instrument has been the Italian-Dutch satellite *BeppoSAX* [2]. In fact the unprecedentedly wide band of *BeppoSAX* (from 0.1 to above 100 keV) is optimal to study the connection between the X-ray and the γ -ray continuum and to disentangle the different emission components. One can therefore constrain more effectively the physical properties of the emission regions.

In Spring 2002, the performance of *BeppoSAX* started to fail. In particular, the acquisition of fields too far from the celestial Equator became problematic. Therefore, our planned cam-

paign on the BL Lac Mkn 501 had to be canceled. Furthermore, the only NFI routinely operated (because of battery problems) was the high-energy instrument PDS (13-300 keV). We thus were solicited to investigate the opportunity of observing, in replacement of Mkn 501, blazar sources with celestial locations satisfying the limited pointing capabilities of *BeppoSAX*. The only 2 sources that could be pointed by the satellite at that epoch, and that appeared at the same time promising in view of a PDS detection, were: the BL Lac 1ES0507-040 and the luminous Flat Spectrum Radio Quasar (FSRQ) PKS 1229-021.

In the following we present the analysis of the data and the results of the observations (Sect 2) and the discussion (Sect 3).

2. DATA ANALYSIS AND RESULTS

2.1. PDS Data Analysis

We have performed the reduction of PDS data with XAS using standard prescriptions [3] inclusive of spike rejection, PSA correction, unit-by-unit subtraction of the background spectra taken

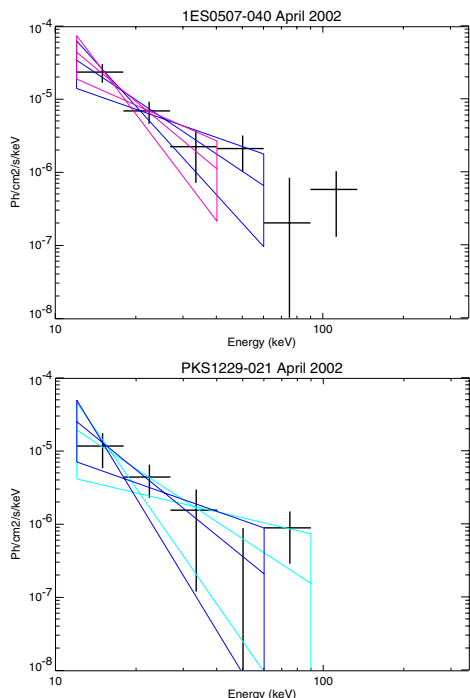


Figure 1. The PDS spectra of (*Top*) 1ES 0507-040 April 2002 and (*Bottom*) PKS1229-021 April 2002. The bow-ties indicate the 90% confidence correlated ranges of the slope and normalization of power law fits using a few different bin ranges.

with the collimator in offset position, and then summing the net spectra of the 4 units with gain equalization and contextual rebinning. In order to derive points for a spectral energy distribution (SED) we rebinned the data in some combinations of logarithmic bins and fitted the PDS data alone (see Figure 1) with a power law, computing the 90% confidence intervals on the spectral index, and using the correlated value of the normalization.

2.2. Results

1ES0507-040: this BL Lac object was discovered by EINSTEIN and was the target of a previous *BeppoSAX* observation in a program aimed at studying the spectral properties of a sample of

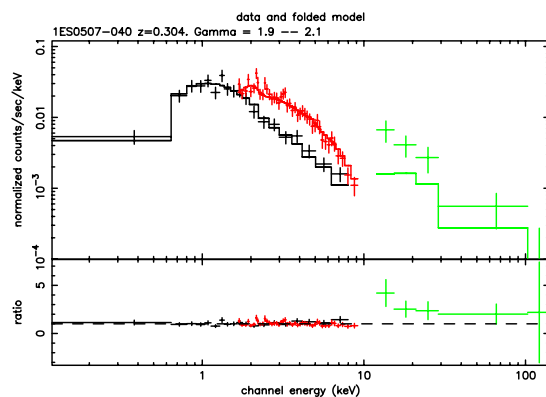


Figure 2. *BeppoSAX* spectrum of 1ES0507-040: LECS and MECS data (dark grey) are from the 11-12/02/1999 observation, (10 ks for LECS and PDS and 20 ks for MECS) in which the PDS detection was marginal. The longer 2002 observation with the PDS (37 ks) is shown in light grey.

X-ray selected BL Lacs [1]. It had been detected also in the ROSAT All-Sky Survey (RASS).

Since the PDS count rate of the 2002 observation is consistent with that measured in 1999 (0.047 ± 0.019 vs 0.044 ± 0.020 cts/s; see Figure 1(*Top*) for the April 2002 spectrum), it is appropriate to fit both observations together, exploiting the larger range observed in 1999 due to the LECS and MECS instruments. The best fit spectral index for a power law in the range 0.1-50 keV with $N_H = 9.15 \times 10^{20} \text{ cm}^{-2}$ (frozen at the Galactic value) is $\Gamma = 2.03$ (1.95-2.13). The PDS normalization has been fixed at the canonical value of $0.8 \times$ MECS normalization. The PDS spectral slope is consistent with that at lower energies at 90% confidence, while the flux is about a factor 3 higher. The global fit is formally acceptable ($\chi^2 = 1.06$ with 76 d.o.f.) due to the low statistical weight of the PDS points. However *the PDS flux is clearly in excess of the fit prediction* (see Figure 2).

A plausible reason for this excess is that PDS data of 1ES0507-040 are contaminated by the

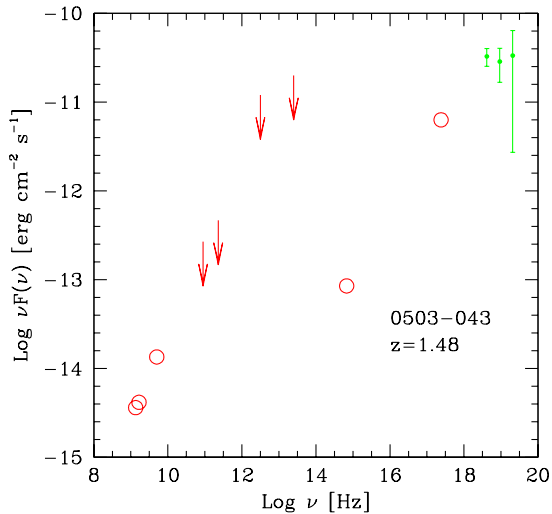


Figure 3. Spectral Energy Distribution of S3 0503-04. The PDS flux has been calculated with the appropriate off-axis correction (0.15), assuming that the totality of the emission is produced by S3 0503-04.

emission from another source present in the large PDS Field of View (about 1 deg). An inspection of catalogs shows that three possible contaminant sources are located within 1 deg from 1ES0507-040:

The radio source S3 0503-04, located at ~ 1 deg from 1ES0507-040, had been identified with a BL Lac of unknown redshift, and later shown to have strong emission lines at $z = 1.481$ [10]. The radio morphology is compact [8]. The radio spectrum is flat, thus implying a blazar nature. In the X-rays the situation is less clear: there is a 3σ detection with HEAO A-2 [4] at fluxes $\sim 10^{-11}$ erg cm $^{-2}$ s $^{-1}$, but this is not confirmed by the RASS data ($F_{0.2-2.4} < \text{few } 10^{-13}$ erg cm $^{-2}$ s $^{-1}$). A possibility to account for the large difference between the optical/soft X-ray luminosity and the hard X-ray luminosity is to admit that low frequency radiation is heavily absorbed. The possible SED

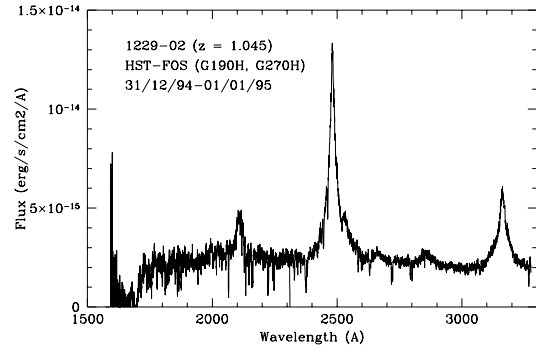


Figure 4. HST FOS spectrum of PKS 1229-021 obtained by combining 2 spectra taken with grism G190H on 31 Dec 1994 with a grism G270H spectrum taken on 01 Jan 1995. The fluxes are corrected for Galactic extinction ($E_{B-V} = 0.032$). Prominent broad Ly α , Ly β , CIV and weak SiIV emission are detected.

is reported in Fig. 3. Further X-ray observations are needed to investigate this interesting possibility.

The other two bright *RASS* sources in the vicinity of 1ES0507-040 are identified with G stars (HD 293857 at 25' and HD 32704 at 70'). They are unlikely to contribute to the PDS unless very peculiar (indeed HD 293857 is a lithium star, with $L_X \sim 10^{30}$ erg/s) or binaries.

PKS 1229-021: this is a bright quasar ($z=1.045$), detected by EGRET in the γ -ray and with a steep spectrum ($\Gamma = 2.85$) [6]. The optical spectrum shows luminous emission lines (eg Fig. 4).

We have retrieved from the HST FOS archive 2 spectra taken on Dec 31, 1994 with the G190H grating (1500-2300 Å) and one taken on 01 Jan, 1995 with the G270H grating (2200-3300 Å). The spectrum, reported in Fig. 4, has been corrected for the Galactic extinction ($E_{B-V} = 0.032$, [7]). Strong emission lines are detected, corresponding to Ly α , Ly β , Si IV, C IV. After removal of the emission lines, a power-law fit of the combined

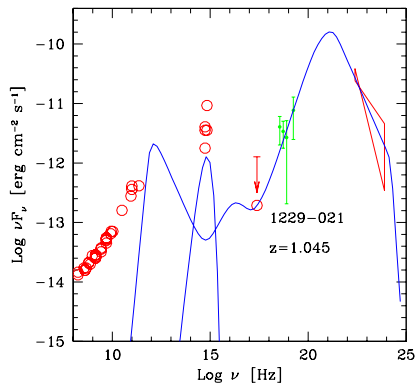


Figure 5. Spectral Energy Distribution of PKS1229-021. Multiwavelength data are taken from the literature, while PDS data are from this paper. The solid line reports the synchrotron - Inverse Compton emission (calculated according to the model described in Ghisellini, Celotti & Costamante [5]) assuming the following parameters: $\delta = 14.3$, $B = 2.5$ G, $L_{inj} = 9 \times 10^{43}$ erg/s. The emitting region is a cylinder with radius $R = 2 \times 10^{16}$ cm and thickness 1.5×10^{15} cm. The disk radiation (bump at 10^{15} Hz, $L_d = 1.2 \times 10^{46}$, 10 times the line luminosity) is reprocessed by the BLR clouds located at 2×10^{17} cm.

spectra over the 1500-3300 Å range yields an index $\alpha_\nu = 1.12 \pm 0.08$ ($f_\nu \propto \nu^{-\alpha_\nu}$).

In the X-rays the source has been studied with ROSAT (RASS). We have constructed the overall SED, shown in Figure 5, using data from the literature and our PDS data (see Figure 1 *Bottom*). We have reproduced the SEDs with the synchrotron-IC model of Ghisellini, Celotti & Costamante [5]. We refer to that paper for a full description of the model. The values of the basic physical parameters are reported in the figure caption.

3. DISCUSSION AND CONCLUSIONS

The last *BeppoSAX* observations of blazars confirm the importance of exploring the hard X-ray band in the study of blazars, as initiated by *BeppoSAX*.

In PKS1229-021 the PDS spectrum allows us to constrain the position of the high energy peak and to infer the basic physical parameters of the relativistic jet.

The case of 1ES 0507-040 is more complex, due to a possible contamination in the PDS spectrum by another source in the field of view. The identification of the contaminant is difficult: based on the soft X-ray emission the possible candidates are two active stars and a peculiar radio-loud AGN. Future study with *INTEGRAL* and/or new X-ray data are required to clarify the issue.

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