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Catching blazars in their ordinary life with INTEGRAL observations

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We present the hard X-ray view of a sample of blazars detected above 20 keV by the *INTEGRAL* survey. Most of the sources are classified as FSRQ, i.e. high luminosity blazar with the peak of emission in the X-ray band, as expected in the framework of the blazar spectral sequence. We find that high power FSRQ and low power BL Lac sources exhibit a different spectral behaviour in 20–100 keV band, with the former characterized by a flatter photon index with respect to the latter. We also discuss the missing population in the hard X-ray energy range of blazar detected by Fermi above 100 MeV .

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Table 1: The sample: Blazars detected in the 4th *INTEGRAL*/IBIS survey

Name	**redshift**	†**F**$_X$	$^{\diamond}$**log L**$_X$	Γ	Class
0033+595	0.086	1.8e-11	44.54	$3.3^{+0.5}_{-0.4}$	BL Lac
RX J0137.7+5814	-	1.0e-11	-	$2.2^{+1.2}_{-1.0}$	BL Lac
0212+735	2.367	2.7e-11	47.75	$1.4^{+1.2}_{-0.9}$	FSRQ
IGRJ03532-6829	0.086	1.6e-11	44.5	$3.5^{+2.1}_{-1.7}$	BL Lac
QSO B0836+710	2.172	5.8e-11	47.9	$1.2^{+0.4}_{-0.6}$	FSRQ
MKN421	0.03	3.7e-10	44.87	$2.50^{+0.05}_{-0.05}$	BL Lac
4C 04.42	0.965	2.7e-11	46.75	$0.8^{+0.6}_{-1.1}$	FSRQ
3C 273	0.158	1.9e-10	46.09	$1.93^{+0.07}_{-0.07}$	FSRQ
3C 279	0.5362	2.5e-11	46.35	$1.5^{+0.5}_{-0.7}$	FSRQ
H 1426+428	0.1290	1.9e-11	44.92	$2.5^{+1.8}_{-1.5}$	BL Lac
MKN501	0.034	4.7e-11	44.08	$2.2^{+0.6}_{-0.6}$	BL Lac
Swift J1656-3302	2.4	2.7e-11	47.87	$1.6^{+0.3}_{-0.4}$	FSRQ
PKS 1830-211	2.507	4.2e-11	48.16	$1.7^{+0.3}_{-0.2}$	FSRQ
1RXS J192450-2914	0.352	1.4e-11	45.7	$1.6^{+1.1}_{-1.6}$	FSRQ
QSO B1933-400	0.9650	3.8e-12	46.684	$1.8^{\star}$	FSRQ
PKS 2149-306	2.345	4.1e-11	47.88	$1.3^{\star}$	FSRQ
BLLac	0.069	2.4e-11	44.42	$2.1^{+0.7}_{-0.6}$	BL Lac
IGR J22517+2218	3.668	3.4e-11	48.5	$1.8^{+1.9}_{-1.7}$	FSRQ
3C 454.3	0.8590	1.8e-10	47.77	$1.9^{+0.2}_{-0.2}$	FSRQ

†In erg cm^{-2}s^{-1} for IBIS/ISGRI in 20–100 keV. $^{\diamond}$In 20–100 keV. *Frozen in the fit.

1. Introduction

Blazars are the most powerful objects in the observable Universe, they emit from radio frequencies up to the extreme gamma-rays. In the X-ray energy range, harder spectra are associated with the highest luminosity objects [8], and Flat Spectrum Radio Quasars (FSRQ) are the most luminous class of blazars. A new window has been opened in the gamma-ray energy domain with Fermi and AGILE, allowing the detection of more than 700 AGN (most of them, 596, are blazars [1]), and raising several questions about the emission properties of such powerful sources in the multiwavelength range. Gamma and X-ray observations are crucial to constraint the Synchrotron and Compton peaks of the Spectral Energy Distributions (SED), and, of a consequence, to investigate in some detail the radiative mechanisms at work in blazars and their jets. Here we characterize a sample of hard X-ray selected blazar as observed by *INTEGRAL* above 20 keV. The sample includes all blazars (both FSRQ and BL Lac) belonging to the 4th IBIS/ISGRI catalogue [6]. The general properties of the sample and the spectral behaviours of the single source are presented. Throughout this paper we adopt a ΛCDM cosmology [11] with Ω_m = 0.27, Ω_Λ= 0.73 and H$_0$ = 71 km s^{-1} Mpc^{-1}.

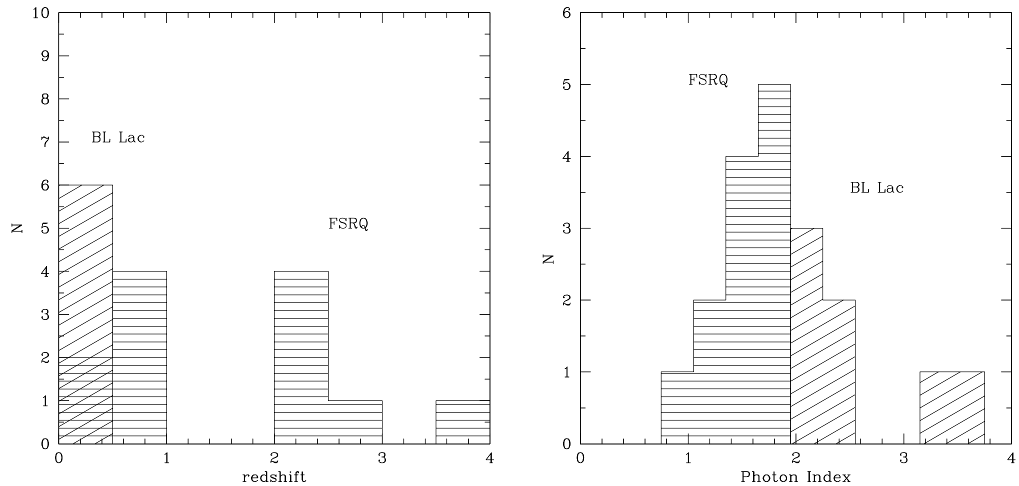

Figure 1: Blazar detected in the 4th *INTEGRAL*/IBIS survey. Left panel: Redshift distribution (apart from RX J0137.7+5814). Right panel: Photon index distribution

2. INTEGRAL blazars: the sample

In Table 1 we list the blazars included in the 4th *INTEGRAL*/IBIS survey [6]. The sample includes 7 BL Lac (1 with unknown redshift) and 12 FSRQ. The marginal evidence of a higher fraction of FSRQ with respect to BL Lac is not unexpected in view of the fact that, following the blazars spectral sequence, most of the external Compton emission in FSRQ is peaked in the X-ray energy range. The blazar population detected in gamma-ray energy domain by Fermi is instead showing the same number of high powerful FSRQ and low powerful BL Lac [1]. Even if selection biases for source identification and redshift determination make complicated the study of the relationship between the X-ray spectral properties and the spectral luminosity [3], the Fermi results seem compatible with the blazar sequence. In Figure 1 (left panel) we show the redshift distribution for our sample. High luminosity FSRQ are detected by *INTEGRAL* up to z=3.7, and 6 out of 12 FSRQ are at z>2, while low power BL Lac are all detected at z<1. As pointed out by [9] hard X-ray observations represent the best way to pinpoint high powerful blazars at high redshift. It is worth noting that our sample is extracted from the *INTEGRAL*/IBIS survey and therefore does not select sources in a bright or flaring state. In fact the spectra are extracted including all datasets from pointings available at the end of April 2008 [6]. Flaring and quiescent states are considered in the same spectrum, which can then be taken as the "average" state of the source. The procedure to extract *INTEGRAL*/IBIS spectra is discussed in detail in [6].

3. General properties

For all sources of the sample we used a simple power-law model to fit the 20–100 keV *INTEGRAL*/IBIS spectrum. The result of this fit is shown in Table 1. For all source in the sample we calculated the X-ray luminosity according to $L_X = 4\pi d_L^2 F_X/(1+z)^{2-\Gamma}$ where F_X is the observed X–ray flux in the 20–100 keV energy range as listed in Table 1. The average values we obtained are $\langle\Gamma\rangle$=1.9±1.0 and Luminosity $\langle L_{20-100keV}\rangle = 2.4\times10^{46}$ erg s^{-1}. The quality of the data obtained

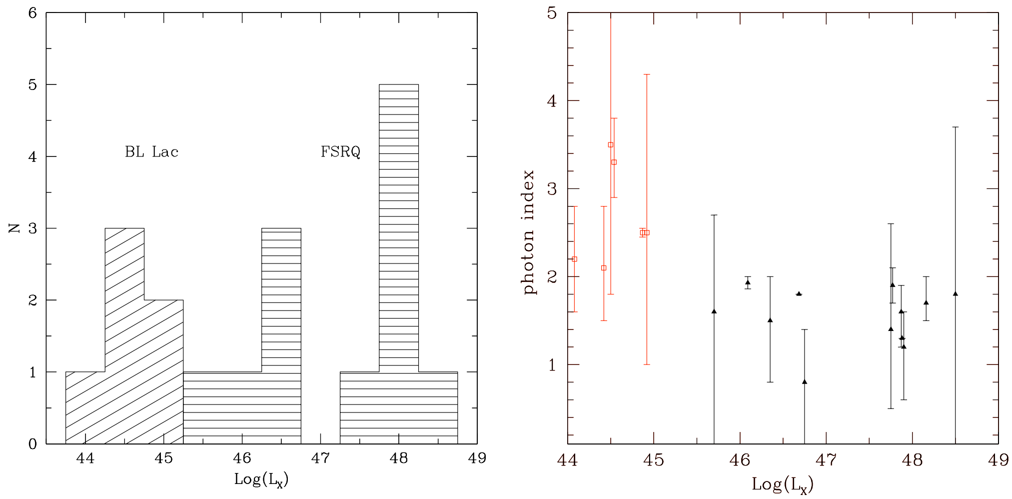

Figure 2: Blazar detected in the 4th *INTEGRAL*/IBIS survey. Left panel: Luminosity distribution. Right panel: Photon index as a function of the hard X-ray luminosity in 20–100 keV (apart from RX J0137.7+5814). BL Lac types are red open squares and FSRQ types are black filled triangles.

from the survey, from such weak sources, allowed us to determine only the average properties with large uncertainties. In the right panel of Figure 1 we show the photon index distribution for the whole sample, while the Luminosity distribution is shown in the left panel in Figure 2. BL Lac and FSRQ seem to be well separated in two different classes, with low power blazar characterized by a steeper Γ with respect to the high power blazar. All BL Lac have a photon index above 2, just one source 0033+595 is characterized by $\Gamma > 3$. In the right panel of Figure 2 we plot the photon index as a function of the hard X-ray luminosity (BL Lac are plotted in red and FSRQ in black). The errors in the determination of the photon indeces are too large to get any strong conclusion, however, in 20–100 keV band, there is marginal evidence that the high-luminosity blazars (FSRQ) are characterized by a flatter photon index with respect to low luminosity ones (BL Lac). Interestingly, we found the opposite behaviour in the Fermi energy domain as BL Lac tend to have $\Gamma < 2$ and FSRQ $\Gamma > 2$ [1]. This is probably due to the fact that *INTEGRAL* energy range probes the end part of the Synchrotron peak in BL Lac and the ascending part of the Compton peak in FSRQ, while the Fermi energy domain probes the ascending and decreasing part of the Compton component of BL Lac and FSRQ, respectively. This evidence supports the validity of the blazars spectral sequence. Recently [5] presented the analysis of a sample of 20 blazars detected above 20 keV in public *INTEGRAL* data. Among the 20 objects, 16 sources are in common with our sample. The spectral properties derived from this analysis are in fully agreement with the results we showed, with the photon index average value $\langle\Gamma\rangle$=2.1$\pm$0.1 and Luminosity $\langle L_{20-100keV}\rangle = 1.3 \times 10^{46}$ erg s^{-1}.

4. The missing hard X-ray blazars

The first catalogue of AGN detected with the Gamma-ray Large Area Space Telescope (LAT) onboard of Fermi (1LAC) [1] includes 709 AGN: 300 BL Lac, 296 FSRQ, 41 AGN of different type and 72 AGN of unknown type. If we consider all of the 1LAC sources with associated counterparts that fall within the error circles of the hard X-ray catalogs from *INTEGRAL*/IBIS and the 54-month

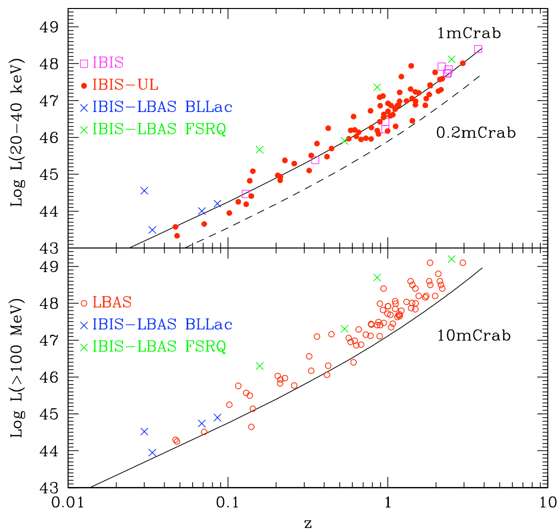

Figure 3: Luminosity vs z plot of the blazar in the 4th *INTEGRAL* survey (upper panel, filled points are upper limit) and Fermi LBAS (lower panel). See text for details.

Palermo BAT catalogue [7], we find that 50 of the 1LAC sources can be associated with known hard X-ray sources: 27 FSRQ, 16 BL Lac, and seven AGN of other types. However, the hard X-ray emission from most bright LAT blazars is, apparently, missed in spite of the sub-mCrab sensitivity reached with *INTEGRAL* and *Swift* in the deepest fields.

In Figure 3 we plot the hard X (20–40 keV) and gamma-ray (above 100 MeV) luminosity as a function of the redshift. Here we refer to the brightest Blazar included in the three months Fermi list (LAT Bright AGN Sample: LBAS sources [2]) and in the fourth *INTEGRAL*/IBIS catalogue. In the upper panel the filled red circles represent the *INTEGRAL* upper limits, while hard X-ray detections, FSRQ and BL Lac objects, are plotted as green and blue crosses respectively, the solid lines represent the flux of 1 mCrab and 0.2 mCrab in the 20–40 keV and 10mCrab limiting flux for E>100 MeV. Open squares in the plot show the blazars detected in hard X-ray by *INTEGRAL*/IBIS but not detected by Fermi neither in the LBAS sample [2] nor in the 1FGL catalogue [1]. From Figure 3 we can identify different behaviour for hard X-ray blazars.

The brightest sources have been detected in the *INTEGRAL* survey (crosses points above 1mCrab limiting flux in the upper panel). Nevertheless, only a small fraction of Fermi blazar are detected in the hard-X ray band. This could be due to the poor exposure in the *INTEGRAL* survey around the sky region of the source. However, in the plot is also shown a group of sources well exposed (upper limits between 1 and 0.2 mCrab limiting flux) that have not been detected in the *INTEGRAL* survey, suggesting a different spectral behaviour in the gamma and hard X-ray energy domain. These sources are "really" missing hard X-ray blazar. We mentioned that *INTEGRAL*/IBIS survey is a description of the average state of the source. The data extracted with this procedure will loose the flaring activity of the source, this effect is shown in Figure 4 in which we report the SED of the two FSRQ 1030+61, 1454-3542 (upper panels from [10]) and the two BL Lacs PKS 2155-304 and 1ES 1959+650 (lower panels from [12]). Overimposed on these SED we show the *INTEGRAL* flux for each source as detected in the survey. In the case of two FSRQ, *INTEGRAL* missed (in the ”average” procedure of the survey) the flaring state. In the case of BL

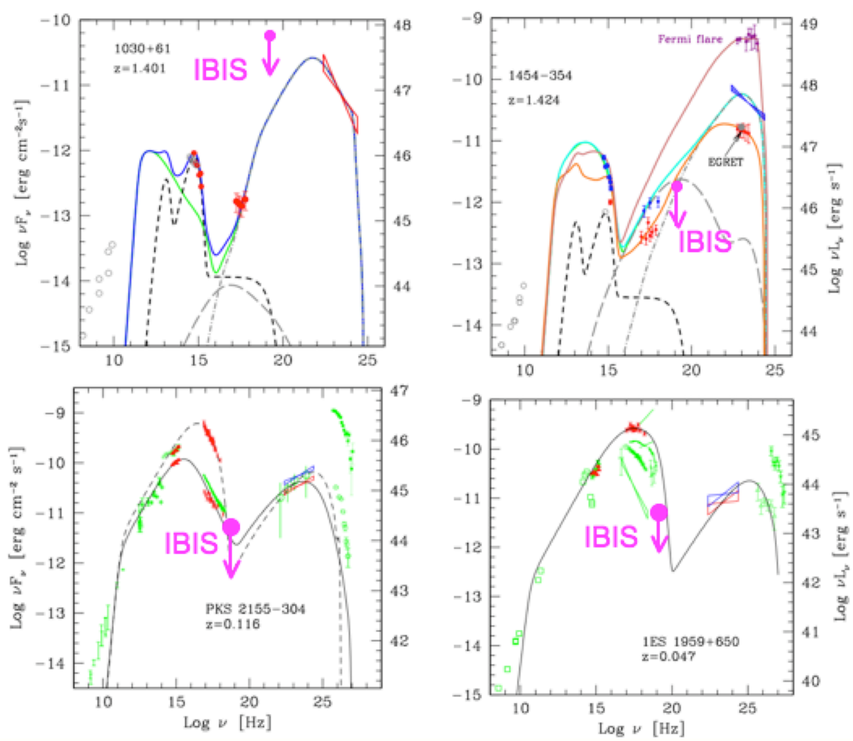

Figure 4: SED of two FSRQ (upper panels) and two BL Lac (lower panels) detected by Fermi and missing in the hard X-ray *INTEGRAL*/IBIS survey. Frequencies are given in the observer frame.

Lac the Figure 4 show that *INTEGRAL*/IBIS falls in the energy range that is monitoring just the gap between the Synchrotron component and the Compton one, making hard any detection.

5. Conclusions

We presented the spectral characterization of a sample of blazars detected in the 4th *INTEGRAL*/IBIS survey. FSRQ and BL Lac are characterized by a different photon index, when the 20–100 keV spectrum is reproduced with a simple power-law, the BL Lac having a steeper Γ with respect to FSRQ. The same result is achieved through Swift/BAT observations [4]. This evidence, together with the evidence of the opposite behaviour above 100 MeV (with Γ of BL Lac flatter with respect to Γ of FSRQ), may favour the blazars spectral sequence, even if alternative scenarios have been proposed. We also found that the missing population of Fermi blazars in hard X-ray band is probably due to the average procedure used to build the survey's spectra, that hide flaring states in the average procedure. In addition, in the case of BL Lac, *INTEGRAL* energy band just falls in the gap between the Synchrotron and Compton peak.

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