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A New Population of Radio Quasars

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Abstract We present the discovery of a new population of radio quasars. Unlike previously known sources, whose X-ray emission is due to (flat) inverse Compton radiation, these objects are characterized by (steep) synchrotron emission in the X-ray band, with a broad-band spectral energy distribution similar to that of BL Lacs with high energy synchrotron peaks. We discuss how this new class was discovered, the class properties, and the implications of its existence for our understanding of jet physics and active galactic nuclei in general.

Key words: BL Lacertae objects: general — galaxies: active — quasars: general — radiation mechanisms: nonthermal — radio continuum: galaxies — X-rays: galaxies

1 INTRODUCTION

Blazars are the most extreme variety of Active Galactic Nuclei (AGN) known. Their signal properties include irregular, rapid variability; high optical polarization; core-dominant radio morphology; apparent superluminal motion; flat ($\alpha_{\rm r} \lesssim 0.5$; $f_\nu \propto \nu^{-\alpha}$) radio spectra; and a broad continuum extending from the radio through the gamma-rays (e.g., Urry & Padovani 1995). Blazar properties are consistent with relativistic beaming, that is bulk relativistic motion of the emitting plasma at small angles to the line of sight, which gives rise to strong amplification and collimation in the observer's frame. In short, blazars are sites of very high energy phenomena, with photon energies reaching the TeV range and Lorentz factors corresponding almost to the speed of light. The blazar class includes flat-spectrum radio quasars (FSRQ) and BL Lacertae objects. These are thought to be the "beamed" counterparts of high- and low-luminosity radio galaxies, respectively. The main difference between the two blazar classes lies in their emission lines, which are strong and quasar-like for FSRQ and weak or in some cases outright absent in BL Lacs.

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Another difference between the two classes, which has been a puzzle for quite some time, relates to their spectral energy distribution (SED). The broad-band emission in blazars is generally explained in terms of synchrotron and inverse Compton emission, the former dominating at lower energies, the latter being relevant at higher energies. BL Lacs are known to have a large range in synchrotron peak frequency, $\nu_{\rm peak}$, which is the frequency at which the synchrotron energy output is maximum (i.e., the frequency of the peak in a $\nu - \nu f_\nu$ plot). Although the $\nu_{\rm peak}$ distribution appears now to be continuous (see below), it is still useful to divide BL Lacs into low-energy peaked (LBL), with synchrotron $\nu_{\rm peak}$ in the IR/optical bands, and high-energy peaked (HBL) sources, with $\nu_{\rm peak}$ in the UV/X-ray bands (Padovani & Giommi 1995). The location of the synchrotron peaks suggests a different origin for the X-ray emission of the two classes. Namely, an extension of the synchrotron emission responsible for the lower energy continuum in HBL, which display steep ($\alpha_{\rm x} \sim 1.5$) X-ray spectra, and inverse Compton emission in LBL, which have harder ($\alpha_{\rm x} \sim 1$) spectra (e.g., Padovani et al. 2001; Wolter et al. 1998).

The puzzling thing was that no such distinction appeared for FSRQ. All known FSRQ were of the "L" type, i.e., with synchrotron peaks at relatively low (IR/optical) energies and, therefore, X-ray band dominated by inverse Compton emission. We stress that this lack of "HFSRQ", as these sources have been labeled, is not only a taxonomical issue but has important consequences on our understanding of jet physics. On average, FSRQ are more powerful than BL Lacs so one could infer that in more powerful sources electron cooling is more severe and that nature can only make powerful "L" jets (Ghisellini et al. 1998). Based on this, a so-called "blazar sequence" has been proposed, with an anti-correlation between power and synchrotron peak frequency (see Sect. 4). Moreover, if HFSRQ existed one might expect a significant fraction of them to be 100 GeV to TeV emitters, based on the fact that known TeV blazars are HBL. As TeV gamma rays propagating in the intergalactic medium undergo absorption through electron pair production on infrared photons, this would be extremely important for probing the diffuse infrared background, which in turn is related to the star formation history in the Universe.

What if this lack of HFSRQ were only a selection effect? After all, while BL Lacs (mostly of the HBL-type, simply because their SEDs peaked in the UV/X-ray band) had been found in a fair number in X-ray surveys, FSRQ had not been looked for – at least until very recently.

2 THE DEEP X-RAY RADIO BLAZAR SURVEY

DXRBS is the result of correlating the ROSAT WGACAT database (White, Giommi, & Angelini 1995) with several publicly available radio catalogs (GB6 and PMN at 5 GHz, NORTH20CM at 1.4 GHz), restricting the candidate list to serendipitous flat-spectrum radio sources ($\alpha_{\rm r} \leq 0.70$). Additionally, a snapshot survey with the Australia Telescope Compact Array (ATCA) was conducted for $\delta \lesssim 0°$ to get radio spectral indices unaffected by variability (and arc-second positions for the sources south of $\delta = -40°$, the limit of the NRAO-VLA Sky Survey [NVSS]; Condon et al. 1998). The DXRBS X-ray flux limits depend on the exposure time and the distance from the center of the ROSAT Position Sensitive Proportional Counter (PSPC) but vary between $\sim 10^{-14}$ and $\sim 10^{-11}$ erg cm^{-2} s^{-1}. 5 GHz fluxes reach down to ~ 50 mJy.

DXRBS is currently the faintest and largest flat-spectrum radio sample with nearly complete ($\sim 95\%$) identifications. Given its dual X-ray and radio flux limits, DXRBS is well suited for looking for HFSRQ. We include in this work only sources belonging to the complete sample, which fulfills all our selection criteria (see Landt et al. 2001). This is necessary because we want to compare in detail the properties (mainly the SED) of DXRBS FSRQ and BL Lacs and that requires well-defined samples, not to introduce any bias. Since we need the WGACAT sky coverage to de-convolve the observed distributions, otherwise faint sources would be artificially underrepresented, we have excluded sources with PSPC center offsets in the range $13' - 24'$, where the sky coverage is difficult to determine because of the effects of the spacecraft wobble and the rib structure. We are then left with 134 FSRQ and 31 BL Lacs, for a total of 165 blazars. Only about 10 more sources ($\sim 5\%$ of the total) with $\alpha_r \leq 0.50$ remain to be identified. The current blazar sample is therefore highly representative. We have also extracted a blazar sample from the ROSAT All Sky Survey (RASS)-Green Bank (RGB) catalog of radio and X-ray emitting sources (Laurent-Muehleisen et al. 1997, 1998). This was done by including the sources classified as BL Lacs and by deriving radio spectral indices (not included in the RGB) via a cross-correlation with the NVSS. We then isolated a sample of FSRQ ($\alpha_r \leq 0.5$). The RGB blazar sample thus includes 362 blazars: 233 FSRQ and 129 BL Lacs. To our knowledge the RGB sample is $\sim 44\%$ identified. This fraction goes up to $\sim 76\%$ for the part of the sample with $O \leq 18.5$. Considering only the sources with $\alpha_r \leq 0.5$, these fractions do not change much, being 49% and 73% respectively.

Overall, the two samples used include 497 distinct blazars, 342 FSRQ and 155 BL Lacs (30 objects are in common). In terms of its range of properties, size, depth, and selection criteria this ensemble of objects represents a unique sample with which to address some of the open questions of blazar research.

3 LOOKING FOR HFSRQ

As an initial step towards studying the broad-band properties of our sources, we first derived their α_{ox}, α_{ro}, and α_{rx} values. These are the usual rest-frame effective spectral indices defined between 5 GHz, 5,000 Å, and 1 keV. Figure 1 shows the distribution of our sources in the α_{ox}, α_{ro} plane. The figure shows also the 1 Jy FSRQ, a radio-selected sample, which occupy a region of α_{ox}, α_{ro} parameter space with α_{rx} similar to that typical of LBL (marked in the figure). FSRQ with low α_{rx} ($\lesssim 0.78$, roughly equivalent to the HBL/LBL division, or $L_x/L_r \gtrsim 10^{-6}$) constitute only $\sim 5\%$ of the 1 Jy sources with X-ray data. Importantly, none of the 1 Jy FSRQ fall in the region of the plane within 2σ from the mean α_{ro}, α_{ox}, and α_{rx} values of HBL, the "HBL box", derived by using all HBL in the multi-frequency AGN catalog of Padovani, Giommi, & Fiore (1997). The fainter radio/X-ray selected DXRBS and RGB FSRQ, on the other hand, reach much lower values of α_{rx} (higher f_x/f_r) and many sources "invade" the HBL region. Indeed, as can be seen by comparing the two panels of Figure 1, there is a progression of α_{ox}, α_{ro} from 1 Jy to DXRBS to RGB.

The fraction of sources which fall in the HBL box is $\sim 15\%$ and $\sim 9\%$ for DXRBS BL Lac objects and FSRQ respectively. This already shows that $\sim 10\%$ of DXRBS FSRQ have broad-band colors typical of high-energy peaked BL Lacs. This fraction is even larger ($\sim 30\%$) for RGB.

The spectral indices are easy to derive and provide useful information but to study in more detail the synchrotron peak frequencies of our sources we have used the multifrequency information at our disposal to extract nonsimultaneous SEDs for our blazars. These are based on our own radio, optical, and X-ray fluxes, infrared (2MASS) data (if available), and any other NASA/IPAC Extragalactic Database (NED) data. Since the SED coverage is quite sparse for most sources, we determined ν_{peak} for all 165 DXRBS blazars by applying an homogeneous synchrotron – inverse self-Compton (SSC) model in the log ν – log νf_ν plane to the available data. Previous works have derived ν_{peak} by fitting analytical functions, such as a parabola or a third-degree polynomial to the SEDs of blazars. We believe that our approach, which is more complex and time consuming, is more robust especially when dealing with sparsely sampled SEDs because we are guided by physics rather than just analytical fitting. FSRQ can have a disk (thermal) component in the optical/UV band but this, on average, makes up only $\sim 15\%$ of the continuum emission in DXRBS FSRQ (D'Elia, Padovani, & Landt 2003), and therefore should not strongly affect our derivation of ν_{peak}, at least in a statistical sense, although there are individual exceptions.

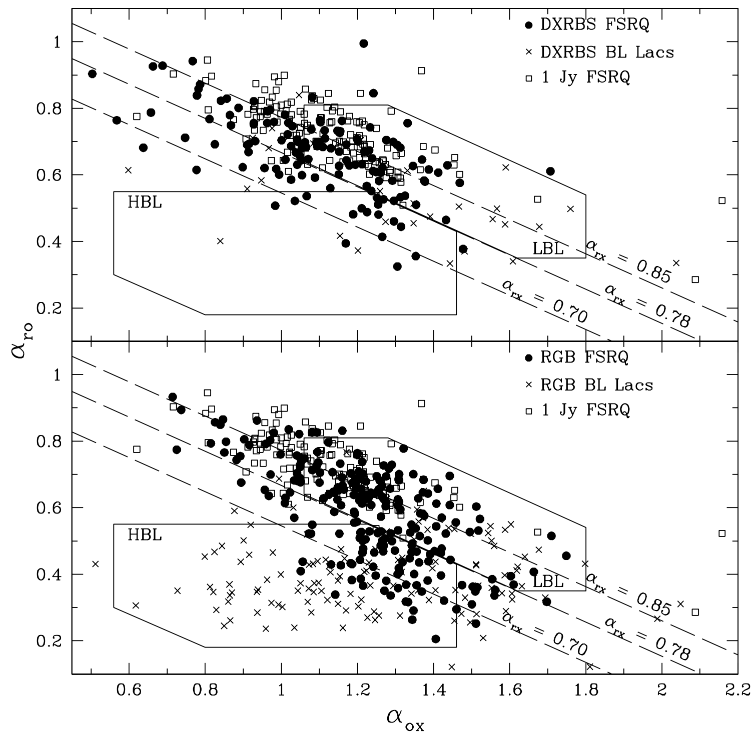

Fig. 1 The α_{ro}, α_{ox} plane for the DXRBS (top) and RGB (bottom) samples. Effective spectral indices are defined in the usual way and calculated between the rest-frame frequencies of 5 GHz, 5000 Å, and 1 keV. Filled circles represent the DXRBS and RGB FSRQ, open squares represent the 1 Jy FSRQ, while crosses are the DXRBS and RGB BL Lacs. The dashed lines represent, from top to bottom, the loci of $\alpha_{rx} = 0.85$, typical of 1 Jy FSRQ and LBL, $\alpha_{rx} = 0.78$, the dividing line between HBL and LBL, and $\alpha_{rx} = 0.70$, typical of RGB BL Lacs. The regions in the plane within 2σ from the mean α_{ro}, α_{ox}, and α_{rx} values of LBL and HBL are indicated by the solid lines and marked accordingly.

Figure 2, which shows the ν_{peak} distribution of our sources, illustrates the fact that indeed, the SEDs of some DXRBS FSRQ peak in the UV/X-ray band. The FSRQ distribution ranges between 10^{12} and 10^{16} Hz, with $\langle \nu_{peak} \rangle = 10^{13.70 \pm 0.06}$ Hz, while the BL Lac distribution ranges between 6×10^{12} and 8×10^{16} Hz, with $\langle \nu_{peak} \rangle = 10^{14.1 \pm 0.1}$ Hz. On average, then, BL Lacs have a synchrotron peak frequency a factor ~ 2.5 larger than that of FSRQ. The two distributions are also different at the 99.97% level according to a KS test. The BL Lac distribution is broader than the FSRQ one, with a tail reaching higher values. For example, while $\sim 64\%$ and $\sim 8\%$ of BL Lacs have $\nu_{peak} > 10^{14}$ and 10^{15} Hz, these fractions go down to $\sim 31\%$ and $\sim 4\%$ for FSRQ.

The study of the X-ray emission of the FSRQ with synchrotron peak frequencies in the UV/X-ray band is vital. The X-ray emission of HFSRQ, in fact, should be synchrotron in nature, in contrast to that of most FSRQ, where it is dominated by inverse-Compton emission (e.g., Sambruna et al. 1996); a dichotomy similar to that exhibited by LBL and HBL. In BL Lacs,

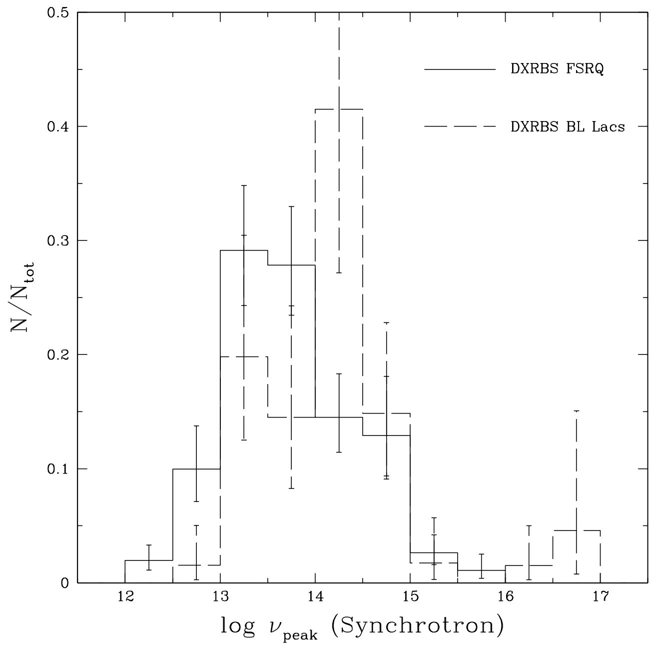

Fig. 2 The distribution of the synchrotron peak frequency for FSRQ (solid line) and BL Lacs (dashed line) for the DXRBS sample. The distributions have been de-convolved with the appropriate sky coverage. Error bars represent the 1σ range based on Poisson statistics. See text for details.

in fact, observational evidence points to a different origin for the X-ray emission of HBL and LBL (e.g., Padovani & Giommi 1996). In HBL, the X-ray continuum appears to be an extension of the synchrotron emission seen at lower energies, consistent with their steep ($\alpha_{\rm x} \sim 1.5$) X-ray spectra in the ROSAT band. In LBL, the X-ray continuum is more likely due to inverse Compton emission, consistent with their harder ($\alpha_{\rm x} \sim 1$) spectra. *BeppoSAX* observations of BL Lacs are confirming this picture (Wolter et al. 1998; Padovani et al. 2001).

We have derived X-ray spectral indices in the $0.4 - 2.0$ keV range for the DXRBS FSRQ using ROSAT hardness ratios following Padovani & Giommi (1996). To take into account the background contamination for fainter sources we have conservatively chosen a SNR cut of 10, which reduces our sample to 54 sources, 39 FSRQ and 15 BL Lacs. We stress that these effective spectral indices should be regarded as an estimate of the "average" X-ray spectral shape and are therefore most suitable for statistical studies. Errors on these spectral indices (1σ) were derived as described in Padovani & Giommi (1996) and are typically ~ 0.2.

Figure 3 shows the ROSAT X-ray spectral index vs. $\nu_{\rm peak}$ for DXRBS FSRQ (filled points) and BL Lacs (crosses). We note that $\alpha_{\rm x}$ is relatively flat ($\sim 1 - 1.5$) and constant for $\nu_{\rm peak} \lesssim 10^{14}$ Hz. For $10^{14} \lesssim \nu_{\rm peak} \lesssim 10^{15}$ Hz, $\alpha_{\rm x}$ steepens to reach values up to ~ 2.5. Above $\nu_{\rm peak} \sim 10^{15}$ Hz $\alpha_{\rm x}$ flattens again to reach values $\sim 1 - 1.5$. Fig. 3 shows a trend similar to that displayed by the BL Lacs included in Fig. 6 of Padovani & Giommi (1996), despite the fact that $\sim 70\%$ of the sources are FSRQ. We then infer that the interpretation put forward for BL Lacs applies to our FSRQ as well. Namely, at low $\nu_{\rm peak}$ values flat inverse Compton emission dominates.

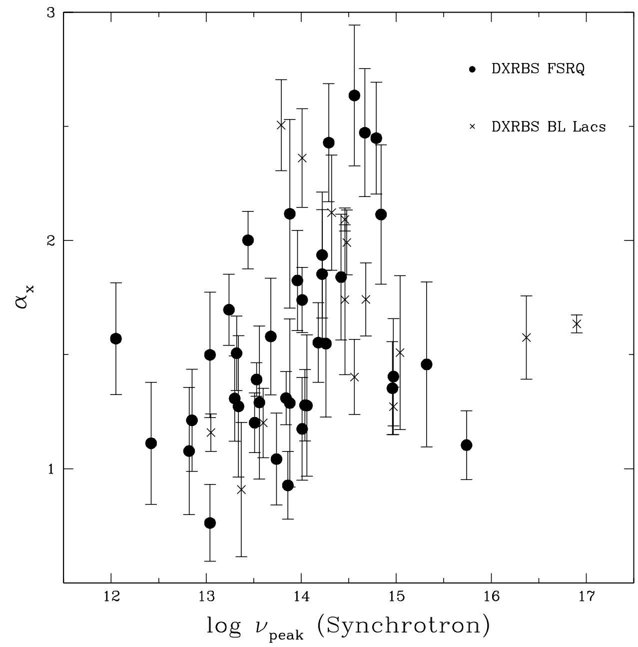

Fig. 3 ROSAT X-ray spectral index vs. the synchrotron peak frequency for DXRBS FSRQ (filled points) and BL Lacs (crosses). Error bars represent 1σ uncertainties.

For "intermediate" values the steep tail of the synchrotron component enters the ROSAT band. Finally, when $\nu_{\rm peak}$ gets even closer to the X-ray band, the X-ray spectrum will flatten out again, because the ROSAT band is now sampling the top of the synchrotron emission.

We do have X-ray spectra in hand for some HFSRQ candidates. Padovani et al. (2002) have presented *BeppoSAX* observations of four sources, with the following results: one source is clearly synchrotron dominated, with relatively high $\nu_{\rm peak} \sim 2 \times 10^{16}$ Hz and steep ($\alpha_{\rm x} \sim 1.5$) synchrotron X-ray spectrum. Two other sources have a flat X-ray spectrum but show evidence of steepening at low energies, similar to intermediate BL Lacs, with estimated $\nu_{\rm peak} \approx 10^{15}$ Hz. Finally, one is clearly inverse Compton dominated.

4 THE BLAZAR SEQUENCE

Fossati et al. (1998) and Ghisellini et al. (1998) have proposed that some blazar properties can be accounted for by an inverse correlation between intrinsic power and the synchrotron peak frequency, the so-called "blazar sequence". The peak of the emission is related to the electron energy, as $\nu_{\rm peak} \propto B\gamma^2_{\rm break,e}$, with $\gamma_{\rm break,e}$ a characteristic electron energy which is determined by a competition between acceleration and cooling processes. Therefore, less powerful sources (where the energy densities are relatively small) should reach a balance between cooling and acceleration at larger $\nu_{\rm peak}$, while in more powerful sources there is more cooling and the balance is reached at smaller $\nu_{\rm peak}$.

We now have the data to test this idea for FSRQ and BL Lacs *belonging to the same sample*. Figure 4 plots radio power at 5 GHz versus $\nu_{\rm peak}$ for the DXRBS sources. The dotted lines denote the two quadrants (top-left and bottom-right) occupied by the sources studied by

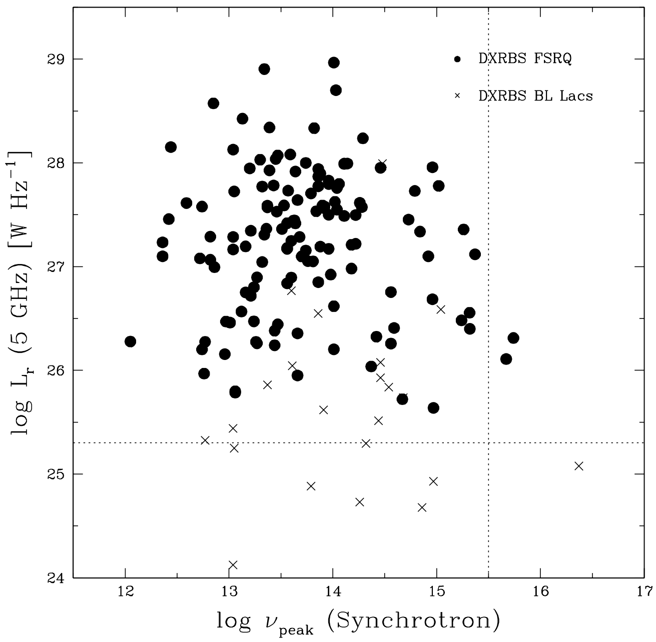

Fig. 4 Radio power at 5 GHz vs. the synchrotron peak frequency for FSRQ (filled points) and BL Lacs (crosses) for the DXRBS sample. The dotted lines denote the two quadrants (top-left and bottom-right) occupied by the sources studied by Fossati et al. (1998). See text for details.

Fossati et al. (1998), which belonged to the 1 Jy and Slew BL Lac samples and the 2 Jy FSRQ sample.

A few points can be made about this figure. First, as already shown in Fig. 2, DXRBS BL Lacs reach $\nu_{\rm peak}$ values slightly higher than DXRBS FSRQ. Second, DXRBS sources are starting to occupy regions of this plot (top-right and particularly bottom-left) which were "empty" in the original plot of Fossati et al. (1998). DXRBS reaches lower radio powers than the 1 Jy sample and therefore detects low-power LBL. In particular, out of the 21 BL Lacs with $\nu_{\rm peak} < 10^{15.5}$ Hz and redshift information, 7 (or 33%) "invade" the low-power part ($L_{\rm r} < 10^{25.3}$ W Hz^{-1}) of the plot. Third, no correlation ($P \sim 93\%$) is present between radio power and $\nu_{\rm peak}$ for the whole sample, or for the FSRQ and BL Lac samples separately. We also note that the scatter in the plot is very large, reaching four orders of magnitude in power for $10^{13} \lesssim \nu_{\rm peak} \lesssim 10^{15}$ Hz. Therefore, by using an homogeneous, well-defined sample which includes both FSRQ and BL Lacs over a relatively wide region of parameter space, the Fossati et al. correlation is not confirmed. Fourth, an upper envelope, however, seems to be present in the right part of the diagram. For example, all sources with $L_{\rm r} > 10^{27.5}$ W Hz^{-1} have $\nu_{\rm peak} \lesssim 10^{15}$ Hz while sources with $L_{\rm r} > 10^{28}$ W Hz^{-1} have $\nu_{\rm peak} \lesssim 10^{14}$ Hz.

We have checked the radio power and $\nu_{\rm peak}$ values and distributions for DXRBS blazars in and out of the HBL box. We find that the two classes have indistinguishable radio powers but significantly different synchrotron peak frequencies, with mean values $\langle\nu_{\rm peak}\rangle \sim 10^{15.2\pm0.1}$ and $\sim 10^{13.66\pm0.05}$ Hz respectively, again in contrast to the proposed correlation.

It is interesting to explore possible correlations between $\nu_{\rm peak}$ and other powers. The correlation suggested by Fossati et al. (1998) and Ghisellini et al. (1998) was between synchrotron peak frequency and *intrinsic* power. As our sources are all flat-spectrum their radio power is strongly affected by beaming and this could influence the interpretation of Fig. 4. We have then evaluated two intrinsic powers for our FSRQ, namely the Broad Line Region (BLR) luminosity, $L_{\rm BLR}$, following Celotti, Padovani, & Ghisellini (1997), and the kinetic jet power, $L_{\rm jet}$, following D'Elia, Padovani, & Landt (2003). $L_{\rm BLR}$ is an isotropic quantity, related to the ionizing, disk (thermal) emission via the covering factor $f_{\rm cov}$, i.e., $L_{\rm disk} = f_{\rm cov}^{-1} L_{\rm BLR}$, with $f_{\rm cov} \approx 10\%$ for FSRQ (D'Elia, Padovani, & Landt 2003). No hint of an inverse correlation between $L_{\rm BLR}$, proportional to disk power, and $\nu_{\rm peak}$ is present, the opposite is rather apparent. There is in fact a strong correlation ($P > 99.99\%$), with a large scatter, between the two quantities, with $L_{\rm BLR} \propto \nu_{\rm peak}^{0.51 \pm 0.11}$. It could be argued that the stronger the disk emission, the larger its contribution to the optical/UV flux, and the higher the estimated $\nu_{\rm peak}$. However, this is not a very likely explanation. First, as mentioned above, D'Elia, Padovani, & Landt (2003) have shown that the disk (thermal) component in DXRBS FSRQ is only $\sim 15\%$ on average. Second, we find no correlation between $L_{\rm BLR}$ or $\nu_{\rm peak}$ and the ratio of disk to total emission as defined in D'Elia, Padovani, & Landt (2003). This would be expected if larger BLR luminosities and/or larger peak frequencies were due to a stronger disk component.

It is more difficult to estimate the total kinetic jet power $L_{\rm jet}$ as it depends on many uncertain astrophysical parameters. We have derived it according to the prescriptions of D'Elia, Padovani, & Landt (2003). No correlation is present between $L_{\rm jet}$ and $\nu_{\rm peak}$. As $L_{\rm jet}$ is an intrinsic power, again this is in contrast with the "blazar sequence" of Fossati et al. (1998) and Ghisellini et al. (1998). Similarly to Fig. 4, however, there might be also indications of an upper envelope. For example, sources with $L_{\rm jet} > 10^{39}$ W all have $\nu_{\rm peak} \lesssim 10^{15}$ Hz while sources with $L_{\rm r} > 10^{40}$ W have $\nu_{\rm peak} \lesssim 10^{14}$ Hz.

5 HOW EXTREME CAN HFSRQ BE?

We have seen that there are indications that, although we have indeed discovered a class of FSRQ with synchrotron peak frequency in the UV/X-ray band, these sources appear not to reach values as high as BL Lacs. We can test this further by using samples with values of X-ray-to-radio flux ratios, $f_{\rm x}/f_{\rm r}$, larger than those of DXRBS. $f_{\rm x}/f_{\rm r}$, in fact, is broadly related to $\nu_{\rm peak}$ in the sense that the higher the synchrotron peak frequency, the larger the X-ray-to-radio flux ratio (but see Padovani et al. 2003).

Table 1 reports the mean values of $\langle f_{\rm x}/f_{\rm r} \rangle$ for the DXRBS, RGB, and *Einstein* Medium Sensitivity Survey (EMSS) samples. Both RGB and EMSS are known to include BL Lacs with relatively high $\nu_{\rm peak}$. The $\langle f_{\rm x}/f_{\rm r} \rangle$ values are given in "HBL units", namely in terms of the (approximate) value dividing HBL and LBL. In other words, values < 1 imply LBL ratios, while values > 1 imply HBL ratios. The table reports also the fraction of sources in the HBL box. Table 1 shows that DXRBS, given its radio and flux limits, is not the optimal sample to find blazars of the "H" type. RGB and EMSS, on the other hand, are sensitive to sources with progressively larger $f_{\rm x}/f_{\rm r}$ ratios, with the fraction of BL Lacs in the HBL box and their mean X-ray-to-radio flux ratios increasing. It is also apparent, however, that although the fraction of HFSRQ does increase as well, FSRQ do not reach the same values as BL Lacs.

An even more extreme sample is the Sedentary survey (Giommi, Menna, & Padovani 1999), an X-ray/radio selected sample based on the RASS Bright Source Catalog (RASSBSC) and the NVSS, which is sensitive *only* to $f_{\rm x}/f_{\rm r} \gtrsim 50$. The current sample is $\sim 90\%$ identified so our conclusions should be relatively stable. The number of radio-loud broad-lined sources in the sample is currently around 20 (or $\sim 12\%$), but most of these sources are very close to the radio-loud/radio-quiet dividing line, both in terms of their $\alpha_{\rm ro}$ values and their radio powers. Some of these sources could therefore have their X-ray emission dominated by thermal processes and would not be the counterparts of HBL. We will discuss the presence of HFSRQ in the Sedentary survey in a future paper (Giommi et al., in preparation).

Table 1 HFSRQ Statistics

	$\langle f_x/f_r \rangle$ (HBL units)				% in HBL box	
Sample	FSRQ	N	BL Lacs	N	FSRQ	BL Lacs
DXRBS	0.4	134	0.3	31	9%	15%
RGB	0.7	233	5.9	129	27%($\lesssim$ 38%)	60%
EMSS	3.5	15	24.2	41	79%	100%

6 SUMMARY AND CONCLUSIONS

We have used the results of two recent surveys, DXRBS and RGB, to study the spectral energy distribution of about 500 blazars. Never before had this been done with a sample even remotely close to ours in terms of size, depth, and well-defined selection criteria. DXRBS, in particular, is $\sim$ 95% complete and reaches fluxes $\sim$ 20 times lower than previously available blazar radio surveys. We have first derived the effective spectral indices $\alpha_{\rm ox}$, $\alpha_{\rm ro}$, and $\alpha_{\rm rx}$. The synchrotron peak frequencies for DXRBS blazars have also been derived by using multi-frequency information and an homogeneous synchrotron - inverse self-Compton model. Broad line region and jet powers were also estimated. One of the main aims of this work was to look for the strong-lined counterparts of high-energy peaked (HBL) BL Lacs, the HFSRQ, that is FSRQ with high-energy synchrotron peaks. We have found them. Our main results can be summarized as follows:

1. About 10% of DXRBS FSRQ have effective spectral indices typical of HBL (to be compared with 15% for BL Lacs) and can therefore be called HFSRQ. The fractions of HFSRQ and HBL increase to $\sim$ 30% and $\sim$ 60% for RGB and to $\sim$ 80% and 100% for the EMSS, respectively. Although HFSRQ have X-ray-to-radio flux ratios larger than previously known FSRQ, in none of the samples they manage to reach values as high as those of HBL.
2. The synchrotron peak frequency distribution of DXRBS FSRQ and BL Lacs is continuous and peaks at $\approx 10^{14}$ Hz, with the former sources having an average $\nu_{\rm peak} \sim 2.5$ times smaller than the latter. We have verified that blazars with effective spectral indices typical of HBL indeed have larger $\nu_{\rm peak}$ values (by a factor $\sim$ 35) than other blazars. About 60% and > 8% of DXRBS BL Lacs have $\nu_{\rm peak} > 10^{14}$ and 10^{15} Hz respectively, to be compared with $\sim$ 30% and $\sim$ 5% for FSRQ.
3. These results, together with the dependence we find of the X-ray spectral index, estimated from the hardness ratios, on $\nu_{\rm peak}$, *confirm the existence of strong-lined counterparts of high-energy peaked BL Lacs.* As is the case for HBL, we would expect a significant fraction of these sources to emit at 100 GeV – TeV energies.
4. We find no anti-correlation between synchrotron peak frequency and radio, broad line region, and jet powers, contrary to the predictions of the so-called "blazar sequence" scenario, which calls for an inverse dependence of $\nu_{\rm peak}$ on intrinsic power due to the effects of the more severe electron cooling in more powerful sources. On the other hand, available data from DXRBS and other surveys suggest that high-$\nu_{\rm peak}$–high-power blazars have not been found yet, and that HFSRQ do not reach the extreme synchrotron peak frequencies of BL Lacs. This indicates that after all there might be an intrinsic, physical limit to the synchrotron peak frequencies and therefore electron energies which can be reached by powerful blazars.

The discovery of HFSRQ and the study of their properties have important implications for our understanding of jet formation and physics. Since $\nu_{\rm peak} \propto \gamma_{\rm peak}^2 \delta B$, where $\gamma_{\rm peak}$ is the Lorentz factor of the electrons emitting most of the radiation, we have shown that *powerful* jets with large magnetic fields *and* electron Lorentz factors can indeed exist – regardless of whether or not they have strong emission lines – albeit up to a point. This provides an important challenge for existing models that advocate that the spectral energy distribution of relativistic jets is strongly affected by the external radiation field. We have also shown that selection effects are very strong and that, in particular, the HBL/HFSRQ fraction is sample-dependent. Can we separate selection effects from physics? We think we can. By using DXRBS we have sampled a region of parameter space which should be largely unbiased in terms of $\nu_{\rm peak}$ (unlike that covered by the EMSS, for example). We have found that HBL/HFSRQ make up a minority of the blazar population, $\sim 10\% - 15\%$. We then believe that the available evidence suggests that nature preferentially makes jets which peak at IR/optical energies. We will address this issue in detail in a future paper.

It is also clear that, although a consistent picture comes out of our results, we need more information on these sources. We have recently obtained XMM time to observe four of our newly discovered HFSRQ to further constrain their X-ray emission processes. More details on the results presented in this paper can be found in Padovani et al. (2003).

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