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# Deep Blazar Surveys

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**Abstract.** I address the need for deep blazar surveys by showing that our current understanding of blazars is based on a relatively small number of intrinsically luminous sources. I then review the on-going deeper surveys, addressing in particular their limits and limitations. Finally, I present some preliminary results on the evolutionary properties of faint blazars as derived from the Deep X-ray Radio Blazar Survey (DXRBS).

## 1. Introduction

Blazars are the most extreme variety of Active Galactic Nuclei (AGN) known. Their signal properties, discussed in detail in this volume, include irregular, rapid variability; high optical polarization; core-dominant radio morphology; apparent superluminal motion; flat ($\alpha_{\rm r} \lesssim 0.5$) 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 (as originally proposed by Blandford & Rees in 1978), which gives rise to strong amplification and collimation in the observer's frame. It then follows that an object's appearance depends strongly on orientation. Hence the need for "Unified Schemes", which look at intrinsic, isotropic properties, to unify fundamentally identical (but apparently different) classes of AGN.

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. The current view is that there is actually a continuity of at least some properties between the two classes, so the distinction between a BL Lac and an FSRQ can be somewhat blurred (Landt et al., these proceedings).

Due to their peculiar orientation with respect to our line of sight, blazars represent a very rare class of objects, making up considerably less than 5% of all AGN (Padovani 1997). As a consequence, all existing blazar samples were, until very recently, relatively small and, due also to the difficulty in identifying them, at high fluxes. It then follows that *our understanding of the blazar phenomenon is mostly based on a relatively small number of intrinsically luminous sources, which means we have only sampled the tip of the iceberg of the blazar population.* For example, the radio luminosity function (LF) of FSRQ derived by Urry & Padovani (1995), although based on 52 sources (the best that could be done at the time), included only one source at $L_\mathrm{r} < 10^{26.5}$ W Hz$^{-1}$, the power which coincides roughly with the predicted flattening of the LF based on unified schemes (see § 7). Moreover, only in the limited range $10^{26.9} < L_\mathrm{r} < 10^{27.7}$ W Hz$^{-1}$ was the statistics good enough to have more than one source per bin! The need for deeper, larger blazar samples is obvious.

## 2. The "Classical" Blazar Samples

Before I discuss the on-going, deeper blazar surveys, I summarize here the basic facts about the "classical" blazar samples, the ones we all know and love and on which our knowledge of blazars is based.

*BL Lacs*

- 1 Jy, radio flux-limited, $f_{5\mathrm{GHz}} > 1$ Jy, with radio spectral index cut $\alpha_\mathrm{r} \leq 0.5$, $V < 20$; complete sample includes 34 objects (Stickel et al. 1991);
- EMSS, X-ray flux-limited, $f_{0.3-3.5\mathrm{keV}} \gtrsim 2 \times 10^{-13}$ erg/cm$^2$/s; complete sample includes 41 objects (Stocke et al. 1991; Rector et al. 2000);
- IPC Slew, X-ray flux-limited, $f_{0.3-3.5\mathrm{keV}} \gtrsim 2 \times 10^{-12}$ erg/cm$^2$/s; complete sample includes 51 objects (Perlman et al. 1996).

*Flat-spectrum Radio Quasars*

- 2 Jy, radio flux-limited, $f_{2.7\mathrm{GHz}} > 2$ Jy; complete sample includes 52 objects (Wall & Peacock 1985; di Serego Alighieri et al. 1994).

## 3. New Blazar Samples

Many groups are tackling the problem of assembling deeper, sizable blazar samples, for the reasons discussed above: number statistics and limiting fluxes. Most of these samples take advantage of the fact that blazars are relatively strong radio and X-ray sources and use a double radio/X-ray selection method (unlike the "classical" samples). Another difference lies in the identification process. When dealing with catalogs of up to $\sim 1,000$ sources, one can obtain an optical spectrum of all of them and identify the blazars. With the deeper, larger catalogs available today, with numbers $\gtrsim 100,000$ and reaching the millions, this becomes impossible without access to dedicated facilities or unlimited resources. Hence the need to increase the efficiency (e.g., via cross-correlation methods) to restrict the number of blazar candidates down to a manageable number.

Since not all groups could present their results at this conference, I summarize here the main on-going surveys, in chronological order. I make no claim of completeness, but I have tried my best to include the largest, deepest samples.

*BL Lacs*

- DXRBS (Deep X-ray Radio Blazar Survey); uses radio (GB6, PMN)/X-ray (WGA [ROSAT PSPC]) selection; survey limits are $f_{5\mathrm{GHz}} \gtrsim 50$ mJy, $f_{0.1-2.4\mathrm{keV}} \gtrsim 2 \times 10^{-14}$ erg/cm$^2$/s, with a cut in radio spectral index $\alpha_{\mathrm{r}} \leq 0.7$; complete sample includes 37 objects (43 in whole sample) and is $\sim 90\%$ identified as of October 2000 (Perlman et al. 1998; Landt et al. 2001; and papers in preparation);

- RGB (ROSAT All Sky Survey [RASS]-Green Bank) sample; uses radio (GB6)/X-ray (RASS) selection, with an optical limit; survey limits are $f_{5\mathrm{GHz}} \gtrsim 20$ mJy, $f_{0.1-2.4\mathrm{keV}} \gtrsim 3 \times 10^{-13}$ erg/cm$^2$/s, $B < 18$; complete sample includes 33 objects (127 in whole sample) and is $\sim 94\%$ identified (Laurent-Muehleisen et al. 1998; 1999);

- REX (Radio-Emitting X-ray) sample; uses radio (NVSS)/X-ray (ROSAT PSPC) selection; survey limits are $f_{1.4\mathrm{GHz}} > 5$ mJy, $f_{0.1-2.4\mathrm{keV}} \gtrsim 3 \times 10^{-14}$ erg/cm$^2$/s; sample includes 72 objects, $\sim 30\%$ identified; subsample of $\sim 40$ objects with $f_{0.1-2.4\mathrm{keV}} \gtrsim 4 \times 10^{-13}$ erg/cm$^2$/s is $\sim 90\%$ identified (Caccianiga et al. 1999; 2000; Caccianiga et al., these proceedings);

- "Sedentary" Survey; uses radio (NVSS)/X-ray (RASS)/optical (APM, COSMOS) selection; survey limits are $f_{1.4\mathrm{GHz}} > 3.5$ mJy, $f_{0.1-2.4\mathrm{keV}} \gtrsim 10^{-12}$ erg/cm$^2$/s; two-point spectral index selection as well, $\alpha_{\mathrm{rx}} \lesssim 0.56$, $\alpha_{\mathrm{ro}} > 0.2$, to select a region populated by high-energy peaked BL Lacs (HBL) at $\sim 85\%$ level. Sample includes 155 candidates, $\sim 70\%$ identified, but high efficiency expected (Giommi, Menna & Padovani 1999; Giommi et al., these proceedings);

- FIRST Flat Spectrum sample; uses radio (FIRST, GB6) selection, with an optical limit; survey limits are $f_{1.4\mathrm{GHz}} > 35$ mJy, $f_{5\mathrm{GHz}} > 20$ mJy, $B < 19$, with a cut in radio spectral index $\alpha_{\mathrm{r}} < 0.5$. Sample includes 87 sources and is $\sim 84\%$ identified (Laurent-Muehleisen et al., in preparation).

*Flat-spectrum Radio Quasars*

- Parkes 0.25 Jy sample; uses radio selection (PKS); survey limit is $f_{2.7\mathrm{GHz}} > 250$ mJy, with a cut in radio spectral index $\alpha_{\mathrm{r}} \leq 0.4$; 444 sources, sample is 100% identified, in the process of being published (Shaver et al. 1996; Hook et al. 1999; Jackson & Wall, these proceedings);

- DXRBS (Deep X-ray Radio Blazar Survey); uses radio (GB6, PMN)/X-ray (WGA [ROSAT]) selection; survey limits are $f_{5\mathrm{GHz}} \gtrsim 50$ mJy, $f_{0.1-2.4\mathrm{keV}} \gtrsim 2 \times 10^{-14}$ erg/cm$^2$/s, with a cut in radio spectral index $\alpha_{\mathrm{r}} \leq 0.7$; complete sample includes 187 objects (193 in whole sample) and is $\sim 90\%$ identified as of October 2000 (Perlman et al. 1998; Landt et al. 2001; and papers in preparation);

- FIRST Flat Spectrum sample; uses radio (FIRST, GB6) selection, with an optical limit; survey limits are $f_{1.4\mathrm{GHz}} > 35$ mJy, $f_{5\mathrm{GHz}} > 20$ mJy, $B < 19$, with a cut in radio spectral index $\alpha_{\mathrm{r}} < 0.5$; 332 sources, sample is $\sim 84\%$ identified (Laurent-Muehleisen et al., in preparation).

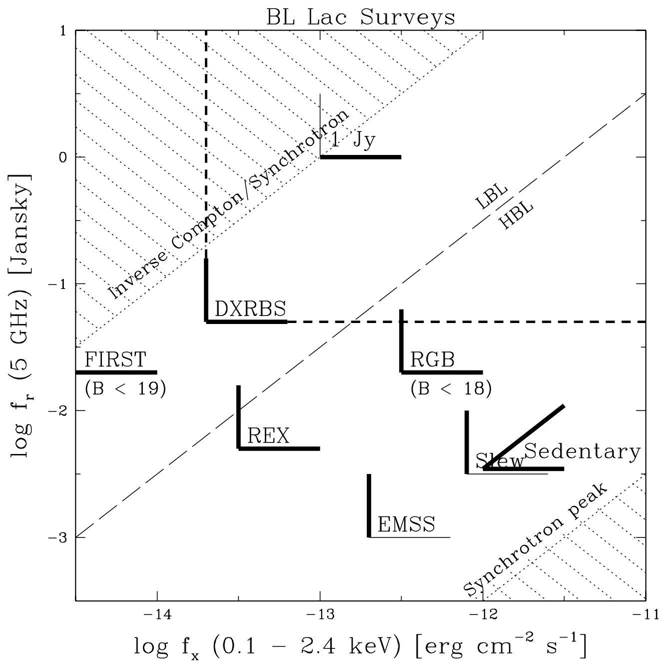


Figure 1. The sampling of the radio flux – X-ray flux plane by different BL Lac surveys. Thick lines represent "hard" survey limits, while thin lines are the fluxes reached in a band other than the one of selection. Sources belonging to a given survey occupy a region of the plane whose bottom-left corner is indicated by the thick/thin lines, as exemplified for DXRBS (short-dashed lines). The long-dashed line divides HBL from LBL, while the hatched regions represent the "forbidden" zones, where no known BL Lacs have been found so far. See text for more details.

## 4. Parameter Space Coverage

It is important to assess what regions of parameter space these various surveys are sensitive to, in order to understand what constraints they can or cannot put on blazar demographics. Given the double (radio/X-ray) selection criteria of most of the new surveys and the fact that the "classical" blazar samples were either radio or X-ray selected, I analyze how these samples cover the radio–X-ray flux plane.

This is shown in Figure 1 for BL Lacs. Every survey is characterized by one (or two) flux limits (thick lines), while the smallest flux reached by a sample in a band other than the one of selection is given by a thin line. For example, the EMSS BL Lacs reach $f_{\rm x} \sim 2 \times 10^{-13}$ erg/cm$^2$/s (thick line), by default the X-ray selection limit (actually, the faintest of various limits, due to the nature of the survey). A limit in one band translates into a limit in the other and in this case the radio faintest EMSS BL Lac has a flux $f_{\rm r} \sim 1$ mJy (thin line). The sources of a given survey occupy a region of the flux-flux plane whose bottom-left corner is shown in the figure.

The long-dashed line in the figure (X-ray-to-radio flux ratio $f_x/f_r = 10^{-11.5}$ erg/cm$^2$/s/Jy or $\alpha_{rx} \sim 0.78$) divides HBL from low-energy peaked BL Lacs (LBL). Although this distinction might sound arbitrary, there is convincing evidence that HBL are synchrotron-dominated in the X-ray band, unlike LBL where two components (or only one, inverse Compton emission) might coexist (Padovani & Giommi 1996). The parallel dotted lines (lines of constant $f_x/f_r$) represent the known range in $f_x/f_r$ for BL Lacs, which I derived from available X-ray and radio data. This is $10^{-13} \lesssim f_x/f_r \lesssim 10^{-8.5}$ erg/cm$^2$/s/Jy (or $0.4 \lesssim \alpha_{rx} \lesssim 1$). No known BL Lacs occupy the hatched regions. I believe that this is not mainly a selection effect, but that there are physical reasons for this. The limit at the low end of the $f_x/f_r$ range (marked "Inverse Compton/Synchrotron" in the figure) is likely due to the fact that in extreme LBL sources the X-ray band is dominated by inverse (synchrotron self-) Compton emission, the radio emission is synchrotron, and the ratio of the two is proportional to the ratio of photon density, $W$, to $B^2$, where $B$ is the magnetic field strength. There are probably physical reasons why $W/B^2$ cannot reach indefinitely low values in blazars (although I cannot exclude that sources with smaller $f_x/f_r$ exist). At the other end, the higher $f_x/f_r$, the larger the peak frequency of the synchrotron emission, $\nu_{\rm peak}$, in extreme HBL sources. And even in this case there are plausible physical reasons that limit $\nu_{\rm peak}$, which depends on the maximum electron energy (Ghisellini 1999).

A few interesting points can be made about the position of the various surveys on the $f_r - f_x$ plane. First, it is clear why we came to think of radio-selected (RBL) and X-ray selected (XBL) BL Lacs as different types of sources: the 1 Jy and EMSS surveys sample vastly different regions of parameter space. Based on these two "classical" surveys it was hard to see that there was a distribution of synchrotron peak frequencies of which the 1 Jy and EMSS samples represented the two extremes. With the Slew sample we started to bridge the gap, as a few Slew BL Lacs are LBL and "intermediate", but it was not until the more recent surveys (DXRBS, REX, RGB), whose limits straddle the HBL/LBL division, that we realized that intermediate BL Lacs indeed existed in sizable numbers. Second, it is important to realize the limitations of surveys with double (radio/X-ray) flux limits. A survey whose limits fall quite far from the two dotted lines will not provide a complete picture of the BL Lac population. For example, the REX survey cannot provide BL Lac radio number counts to be compared with the predictions of a beaming model based on the 1 Jy sample, simply because it does not include all the BL Lacs above its radio limit (as it misses all those above the radio limit but below the X-ray limit). For the complementary reason, neither can REX provide X-ray number counts to be compared with the predictions from a beaming model based on the EMSS sample. REX will provide radio number counts for HBL, given its proximity to the HBL/LBL dividing line, and X-ray number counts for LBL (as it detects all LBL above its X-ray flux limit). The same arguments apply to the RGB survey, which has the further problem of an optical limit ($B < 18$). This implies that only BL Lacs with radio-optical spectral index $\alpha_{ro} < \alpha_{ro}(\rm lim)$, where $\alpha_{ro}(\rm lim)$ depends on radio flux (and is $\sim 0.4$ at the survey limit, for example) will be included. In the case of DXRBS, on the other hand, being relatively close to the leftmost

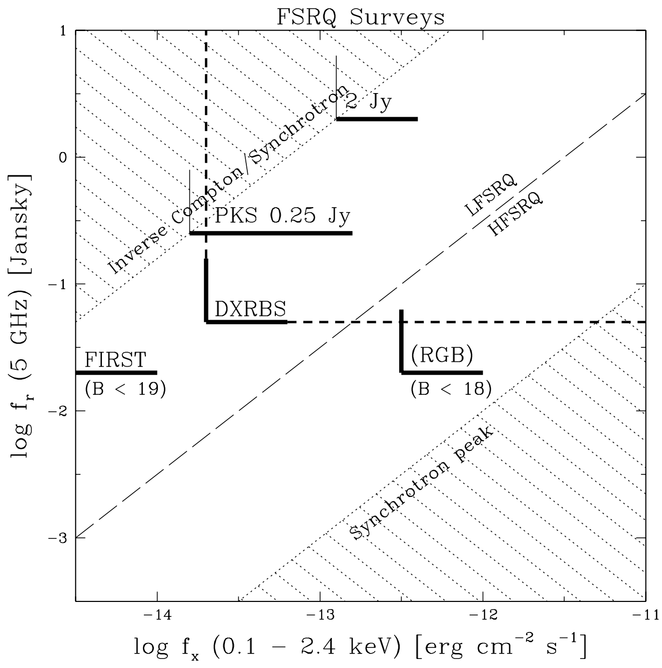


Figure 2. The sampling of the radio flux - X-ray flux plane by different FSRQ surveys. Thick lines represent "hard" survey limits, while thin lines are the fluxes reached in a band other than the one of selection. Sources belonging to a given survey occupy a region of the plane whose bottom-left corner is indicated by the thick/thin lines, as exemplified for DXRBS (short-dashed lines). The long-dashed line divides HFSRQ (high-energy peaked FSRQ) from LFSRQ (low-energy peaked FSRQ), while the hatched regions represent the "forbidden" zones, where no known FSRQ have been found so far. See text for more details.

boundary of the BL Lac region, the X-ray flux limit is not as important and can therefore be considered "almost" radio flux-limited only. The ideal sample, of course, has only one, faint, flux limit. FIRST does not have any X-ray cut but unfortunately the optical limit ($B < 19$) implies, as for RGB, that only BL Lacs with radio-optical spectral index $\alpha_{\rm ro}$ flatter than a given value (which depends on radio flux) will be included.

The coverage of the radio–X-ray flux plane for FSRQ surveys is shown in Fig. 2. As in Fig. 1, the parallel dotted lines represent the known range in $f_{\rm x}/f_{\rm r}$. For FSRQ I find $10^{-13.2} \lesssim f_{\rm x}/f_{\rm r} \lesssim 10^{-10}$ erg/cm$^2$/s/Jy (or $0.6 \lesssim \alpha_{\rm rx} \lesssim 1.05$). The long-dashed line divides high-energy peaked and low-energy peaked FSRQ (HFSRQ and LFSRQ respectively) at $f_{\rm x}/f_{\rm r} = 10^{-11.5}$ erg/cm$^2$/s/Jy (or $\alpha_{\rm rx} \sim 0.78$). The existence of HFSRQ, flat-spectrum quasars with synchrotron peak in the UV/X-ray band, was not suspected until the first results of DXRBS (Perlman et al. 1998; Landt et al. 2001; Perlman et al., these proceedings; Padovani et al., in preparation). As shown in Fig. 2, in fact, only by reaching relatively faint radio fluxes and by having X-ray information one can sample the HFSRQ region of the plane. The 2 Jy sample had too high of a radio flux limit to include a sizable number of FSRQ above the LFSRQ/HFSRQ line (only two sources in the sample, in fact, have $\alpha_{\rm rx} < 0.78$, both of them with $f_{\rm x} \sim 10^{-11}$ erg/cm$^2$/s). Note, however, that the region of the plane occupied by HFSRQ is *smaller* than that occupied by HBL (compare the position of the rightmost dotted line labeled "Synchrotron peak" in Fig. 1 and 2). For reasons we still do not understand, there seem to be no FSRQ with synchrotron peak at energies as high as those reached by HBL (Padovani et al., in preparation).

Turning to the surveys themselves, I first note that RGB does not include information on the radio spectral index, which is why it is in parentheses in the figure. Padovani et al. (in preparation) have cross-correlated the RGB sample with the NVSS to obtain radio spectral indices and extract the FSRQ. The limitations of the RGB sample described above (due to its position in the plane) still apply but given its radio/X-ray flux limits this is the survey which is most suited to find HFSRQ. As discussed above DXRBS, by being close to the leftmost dotted line, can be considered "almost" radio flux-limited only and therefore provides a sample of FSRQ which can be used to test the predictions of unified schemes at low radio fluxes. FIRST reaches even deeper fluxes but the optical limit ($B < 19$) implies that it will not give a complete picture of the FSRQ population.

In summary, it is vital to understand what the various surveys can and cannot provide and have their limits and limitations clear. In particular, *surveys with more than one flux limit can provide a complete picture of the blazar population only if the additional limits are relatively close to one edge of the region of parameter space occupied by blazars.* I now turn to analyze the preliminary results of DXRBS, the survey which I am directly involved with and for which I have direct access to the data, in terms of blazar demographics.

## 5. The Evolutionary Properties of DXRBS Blazars

The basic idea behind the Deep X-ray Radio Blazar Survey (DXRBS) is quite simple: blazars are relatively strong X-ray and radio emitters so selecting X-ray and radio sources with flat radio spectrum (one of their defining properties) should be a very efficient way to find these rare sources. By adopting a spectral index cut $\alpha_{\rm r} \leq 0.7$ DXRBS: 1. selects all FSRQ (defined by $\alpha_{\rm r} \leq 0.5$); 2. selects basically 100% of BL Lacs; 3. excludes the large majority of radio galaxies.

The survey limits are given in § 3, while details on the selection technique and identification procedures can be found in Perlman et al. (1998) and Landt et al. (2001). Here I will just note that DXRBS is currently the faintest and largest flat-spectrum radio sample with nearly complete ($\sim 90\%$ as of October 2000) identification. Redshift information is available for $\sim 95\%$ of the identified sources.

The simplest way to study the evolutionary properties of a sample is through the $V/V_{\rm max}$ test or, since the X-ray flux limit is a function of the area, the $V_{\rm e}/V_{\rm a}$ test (Avni & Bahcall 1980). Values of $V_{\rm e}/V_{\rm a}$ significantly different from 0.5 indicate evolution, which will be positive (i.e., sources were more luminous and/or more numerous in the past) for values $> 0.5$, or negative (i.e., sources were less luminous and/or less numerous in the past) for values $< 0.5$. Moreover, one can fit an evolutionary model to the sample by finding the evolutionary parameter which makes $V_e/V_a = 0.5$.

The DXRBS sky coverage (the area of sky surveyed as a function of X-ray flux) has been derived by Paolo Giommi and Matteo Perri and will be used to derive the evolutionary properties of the sample. I present here some preliminary results based on the sample as of July 2000 ($\sim 30$ more sources have been identified in August 2000 but are not included in this analysis). The sky coverage is difficult to determine in the regions of the ROSAT PSPC field of view affected by the rib structure ($13' <$ offset $< 24'$) That area, and the sources within, have therefore been excluded from this analysis. Moreover, only sources with $f_r > 51$ mJy have been included since we still have not computed the sky coverage of the PMN survey below this flux (this excludes however only a handful of objects). Table 1 gives the sub-sample, the mean $V_e/V_a$ value, $\langle V_e/V_a \rangle$, the number of objects, and the best fit parameter $\tau$ assuming a pure luminosity evolution of the type $P(z) = P(0)exp[T(z)/\tau]$ (where $T(z)$ is the look-back time). The values $H_0 = 50$ km/s/Mpc and $q_0 = 0$ have been adopted.

Table 1. DXRBS Evolutionary Properties

| Sample | $\langle V_e/V_a \rangle$ | N | $\tau$ |
|---|---|---|---|
| All FSRQ | $0.58 \pm 0.03$ | 119 | $0.35^{+0.14}_{-0.08}$ |
| HFSRQ | $0.71 \pm 0.05$ | 32 | $0.17^{+0.03}_{-0.02}$ |
| BL Lacs | $0.57 \pm 0.05$ | 30 | |
| HBL | $0.65 \pm 0.09$ | 11 | |
| LBL | $0.52 \pm 0.07$ | 19 | |
| Unclassified ($z = 1.5$) | $0.80 \pm 0.05$ | 39 | |

The main results are the following:

1. DXRBS FSRQ evolve; however, their $\langle V_e/V_a \rangle$ value and evolutionary parameter $\tau$ reflect the fact that the sample is not completely identified (incompleteness decreases $\langle V_e/V_a \rangle$). By restricting the analysis to the HFSRQ (defined here by $\alpha_{rx} \leq 0.78$), a basically complete sub-sample as most unidentified sources have $\alpha_{rx} > 0.78$ (pending the effect of the k-correction on their $\alpha_{rx}$ values) $\langle V_e/V_a \rangle$ increases and the value of $\tau$ becomes consistent (within $\sim 2\sigma$) with that of 2 Jy FSRQ (Urry & Padovani 1995).

2. DXRBS BL Lacs do not evolve, i.e., their $\langle V_e/V_a \rangle$ value is not significantly different from 0.5 (and consequently $\tau \gtrsim 1$). (The results for BL Lacs are however more uncertain because of the smaller number statistics and the fact that $\sim 30\%$ of them have no redshift; $z = 0.4$ was assumed in this case).

3. the $\langle V_e/V_a \rangle$ values for HBL and LBL are not significantly different. This is a new result, which contradicts the commonly accepted fact that HBL and LBL have different evolutionary properties. Notice that *for the first time* we can study the evolution of HBL and LBL *within the same sample*. Previous comparisons had been made between the 1 Jy (radio-selected) and the EMSS samples (X-ray-selected). Admittedly, the errors on the $\langle V_e/V_a \rangle$ values are rather large but since, as noticed above, the still unidentified sources are mostly of

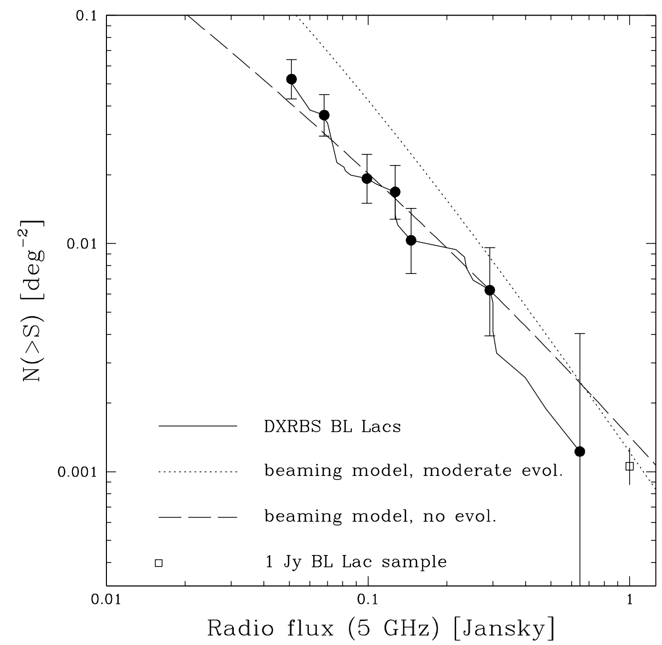


Figure 3. The (preliminary) radio integral number counts at 5 GHz of DXRBS BL Lacs (solid line and filled points) compared to the predictions of a beaming model with the moderate evolution of the 1 Jy BL Lacs (dotted line) and no evolution (dashed line). The empty square represents the surface density of the 1 Jy BL Lacs. Error bars correspond to $1\sigma$ Poisson errors and are shown only for a few selected points for clarity. The drop in the observed counts at high fluxes is due to the serendipitous nature of DXRBS. All the ROSAT targets, in fact, have been excluded and these were mostly well-known, high-flux sources.

the LBL type, completion of the identification process will likely *decrease* the difference between the HBL and LBL values.

4. $\langle V_{\rm e}/V_{\rm a}\rangle$ for the still unclassified sources which, based on our results so far, will be for the most part FSRQ, is quite high (assuming $z = 1.5$, the mean value for the FSRQ); this implies that when these sources will be identified and included in the whole FSRQ sample, the FSRQ $\langle V_{\rm e}/V_{\rm a}\rangle$ will likely reach that of the HFSRQ.

The $V_{\rm e}/V_{\rm a}$ test is a simple way to study the evolutionary properties of a sample. To move to the demographics one needs number counts or, if complete redshift information is available, the luminosity function. I will address these in turn for the DXRBS BL Lacs and FSRQ.

## 6. DXRBS BL Lac Number Counts

For the past 10 years or so the only sizable, complete, radio-selected sample of BL Lacs has been the 1 Jy sample (Stickel et al. 1991). The predictions of relativistic beaming have been tested and tuned to this sample and constraints on beaming parameters (Lorentz factor distribution, angles) have been derived. We can now test unified schemes on a sample which reaches $\sim 20$ times fainter radio fluxes. Given the fact that redshifts are still missing for $\sim 30\%$ of the DXRBS BL Lacs we start by deriving the radio number counts.

Figure 3 shows the (preliminary) integral number counts at 5 GHz for the DXRBS BL Lacs down to $\sim 50$ mJy, compared to the predictions of unified schemes based on a fit to the 1 Jy LF (Urry & Padovani 1995). The DXRBS counts have been corrected for incompleteness by scaling them up by 15%. The dotted line assumes the best-fit 1 Jy evolution ($\tau = 0.32^{+0.27}_{-0.08}$). Note that the $V/V_{\rm m}$ value for the 1 Jy BL Lacs is $0.60 \pm 0.05$, i.e., a departure from the non evolutionary case significant only at the $2\sigma$ level. For this reason, and because the $V_{\rm e}/V_{\rm a}$ results for DXRBS are at present consistent with no evolution, I also show the surface density of BL Lacs predicted assuming no evolution. Fig. 3 shows that the preliminary number counts agree with the no evolution case, in agreement with the $V_{\rm e}/V_{\rm a}$ results. There are a couple of caveats, however, which should be kept in mind. First, the identification process of the DXRBS sample is not complete yet. This has been taken into account by scaling the counts up appropriately but most of the unidentified sources are the faint end so the shape of the counts could change. Second, the definition of a BL Lac for the 1 Jy and DXRBS samples is different, the latter being less restrictive following Marchã et al. (1996). This implies that the comparison between predictions and observations should be restricted to the DXRBS BL Lacs which fulfill the 1 Jy definition. As these make up $\sim 70\%$ of the sample, however, this should not make much of a difference.

## 7. DXRBS FSRQ Luminosity Function

The situation for FSRQ is better, both because of the better statistics and the fact that redshifts are available for all objects. In this case we can then derive directly the luminosity function and compare it with what expected from unified schemes. I take into account the fact that the identification is not complete yet by applying the best-fit evolution derived from the complete subsample of HFSRQ to the whole sample. Keeping this in mind, Figure 4 presents the (preliminary) local radio luminosity function (de-evolved to zero redshift using the best-fit evolution) for the DXRBS FSRQ. The predictions of unified schemes based on a fit to the 2 Jy LF (Urry & Padovani 1995) are also shown (solid line). A few interesting points can be made: 1. the 2 Jy and DXRBS LFs are in good agreement in the region of overlap; 2. DXRBS has much better statistics: the two lowest bins of the 2 Jy LF contain only one object each, while the number of DXRBS sources in the same bins is $\sim 20-30$; 3. the DXRBS LF reaches powers more than one order of magnitude smaller than those reached by the 2 Jy LF, as expected given the much fainter ($\sim 30$) flux limit; 4. the DXRBS LF is in (amazingly!) good agreement with the predictions of unified schemes; 5. we are getting close to the limits of the FSRQ "Universe"; as FSRQ are thought to be the beamed counterparts of high-power radio galaxies, their luminosity function should end at relatively high powers. Assuming that the value inferred from the fit to the 2 Jy LF is correct (solid line in the figure, based on the 2 Jy LF of

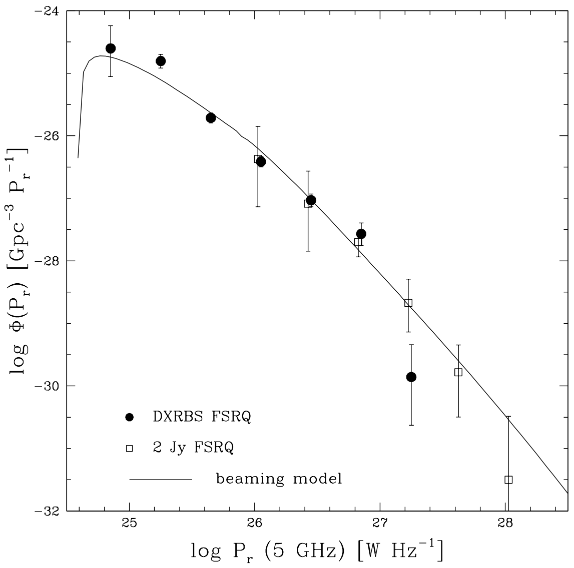


Figure 4. The (preliminary) radio luminosity function of DXRBS FSRQ (filled points) compared to the predictions of a beaming model based on the 2 Jy luminosity function and evolution (solid line). The open squares represent the 2 Jy luminosity function. Error bars correspond to $1\sigma$ Poisson errors.

Fanaroff-Riley type II radio galaxies; see Urry & Padovani 1995), then DXRBS is approaching that value.

## 8. Even Deeper Surveys?

What is in store for the future? Will we be able to go even deeper in our quest for blazars, to probe the even less powerful sources? It will not be easy. Consider in fact a radio survey reaching $\sim 1$ mJy. A typical radio-loud source (with a two-point radio-optical spectral index $\alpha_{\rm ro} \sim 0.6$) will have $V \sim 24$, beyond the reach for spectroscopy of 4m class telescopes even in the presence of strong, broad lines, let alone if one is dealing with a BL Lac! Similarly, at the Chandra/XMM fluxes $f_{\rm x} \sim 10^{-15}$ erg/cm$^2$/s a typical radio-loud source (with $\alpha_{\rm ox} \sim 1.2$) will reach $V \sim 26$. These magnitudes are starting to become problematic for spectral identification even for 8-10m class telescopes, especially in the absence of strong features. I stress that these problems will plague all radio-loud AGN and not only blazars!

This means that we will need to be very efficient in our pre-selection of candidates, as optical identification will require large resources. Statistical identification of sources based on their location in multi-parameter space, which will imply a smaller need for optical spectra (similar to the method employed for the "Sedentary" survey; § 3), will also have to become more common.

## 9. Summary

The main conclusions are as follows:

1. "Classical" blazar samples are small and at relatively high fluxes; it then follows that our understanding of the blazar phenomenon is based mostly on the intrinsically most powerful sources.

2. A number of on-going, deeper surveys are probing the more common, less luminous blazars, and will reveal the bulk of the blazar population. Before drawing conclusions about blazar demographics, however, care has to be taken to assess the limitations of these surveys and what regions of blazar parameter space they are sampling.

3. Preliminary results of the Deep X-ray Radio Blazar Survey (DXRBS) in terms of evolution, number counts, and luminosity functions agree with the predictions of unified schemes (based on samples having flux limits $\sim 20$ times larger).

4. Even deeper blazar surveys will face daunting identification problems, due to the faintness of the optical counterparts. The good news is, however, that due to the relatively high radio powers of flat-spectrum quasar, we might be approaching the limits of their Universe.

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