The Blazar Sequence: Validity and Predictions

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Abstract The "blazar sequence" posits that the most powerful BL Lacertae objects and flat-spectrum radio quasars should have relatively small synchrotron peak frequencies, $\nu_{\text{peak}}$, and that the least powerful such objects should have the highest $\nu_{\text{peak}}$ values. This would have strong implications for our understanding of jet formation and physics and the possible detection of powerful, moderately high-redshift TeV blazars. I review the validity of the blazar sequence by using the results of very recent surveys and compare its detailed predictions against observational data. I find that the blazar sequence in its simplest form is ruled out. However, powerful flat-spectrum radio quasars appear not to reach the $\nu_{\text{peak}}$ typical of BL Lacs. This could indeed be related to some sort of sequence, although it cannot be excluded that it is instead due to a selection effect.

Keywords Blazars · Jets · Emission Processes

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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 ($\alpha_r \lesssim 0.5$; $f_\nu \propto \nu^{-\alpha_r}$) radio spectra; and a broad continuum extending from the radio through the gamma-rays \cite{25}. 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. The blazar class includes flat-spectrum radio quasars (FSRQ) and BL Lacertae objects, which are thought to be the “beamed” counterparts of high- and low-luminosity radio galaxies, respectively. That is, according to unified schemes blazars are simply radio galaxies with their radio jets forming a small angle with respect to the line of sight \cite{25}. This also explains the intrinsic rarity of the blazar class.

Two blazar properties are most interesting for this paper and this conference: 1. their spectral energy distributions (SEDs), which are usually explained in terms of synchrotron and inverse Compton emission, the former dominating at lower energies, the latter being relevant at higher energies; 2. the fact that blazars are sites of very high energy phenomena, with bulk Lorentz factors up to \~{} 40 (corresponding to velocities \~{} 0.9997c) and photon energies reaching the TeV range. As a consequence, and despite their small numbers, blazars dominate the high energy sky. Indeed, the large majority of extragalactic sources detected by EGRET are blazars (see various papers at this conference), while 12/13 of the extragalactic TeV sources detected so far are BL Lacs \cite{17}.

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. Another difference between the two classes, which has been a puzzle for quite some time, relates to their SED. BL Lacs have a large range in synchrotron peak frequency, $\nu_{\text{peak}}$, 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 $\nu_{\text{peak}}$ distribution appears now to be continuous, it is still useful to divide BL Lacs into low-energy peaked (LBL), with $\nu_{\text{peak}}$ in the IR/optical bands, and high-energy peaked (HBL) sources, with $\nu_{\text{peak}}$ in the UV/X-ray bands \cite{22}. The location of the synchrotron peaks suggests in fact 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 ($\alpha_x \sim 1.5$) X-ray spectra, and inverse Compton emission in LBL, which have harder ($\alpha_x \sim 1$) spectra \cite{10,21,50}. Given their
The Blazar Sequence

The so-called "Blazar Sequence" was proposed in 1998 by two papers [3][6]. One of the main results of [6] is given in their Fig. 7, which plots various powers vs. \( \nu_{\text{peak}} \) for three blazar samples: the 2 Jy FSRQ (radio-selected), the 1 Jy BL Lacs (radio-selected), and the Einstein Slew Survey BL Lacs (X-ray selected). An anti-correlation was apparent, with the most powerful sources having relatively small synchrotron peak frequencies and the least powerful ones having the highest \( \nu_{\text{peak}} \) values.

The theoretical interpretation to this anti-correlation was given by [6]. The frequency of the peak of the synchrotron emission is related to the electron energy, as \( \nu_{\text{peak}} \propto B\delta^{2}\gamma_{\text{peak}}^{2} \), where \( B \) is the magnetic field, \( \delta \) is the Doppler factor, and \( \gamma_{\text{peak}} \) is a characteristic electron energy which is determined by a competition between accelerating and cooling processes. Since in more powerful sources the energy density (\( U \propto L/R^{2} \), where \( R \) is the characteristic size of the jet) is higher, the emitting particles have a larger probability of losing energy and therefore are subjected to more cooling. This translates into a lower value of \( \gamma_{\text{peak}} \) and therefore of \( \nu_{\text{peak}} \). Fig. 7 of [6] summarizes the blazar sequence by plotting \( \gamma_{\text{peak}} \) vs. energy density, \( U \), for HBL (high \( \gamma_{\text{peak}} \) - low \( U \)), LBL (lower \( \gamma_{\text{peak}} \) - higher \( U \)), and FSRQ (HPQ and LPQ in their notation; low \( \gamma_{\text{peak}} \) - high \( U \)).

2.1 Predictions and Physical Implications

The blazar sequence makes very specific predictions. Namely:

1. since FSRQ are more powerful than BL Lacs (which is explained by the fact that FSRQ are thought to be the beamed version of high power radio-galaxies, the so-called Fanaroff-Riley type II), an anti-correlation between power and \( \nu_{\text{peak}} \) implies that FSRQ with high \( \nu_{\text{peak}} \) should not exist. This would then explain the puzzle of the missing HFSRQ. The immediate implication is that, since all known BL Lacs with TeV detections (twelve as of this meeting) are of the HBL type, TeV detectors should not expect to observe any FSRQ. A complication is that TeV photons interact with background infrared photons to produce electron-positron pairs and get therefore depleted, the more so the larger the distance of the emitter. Nevertheless these sources, if they existed, would increase the statistics and, being at higher redshifts than BL Lacs, would better constrain the IR background and, therefore, the star formation history in the Universe [4].

2. since low-luminosity sources are more numerous than high-luminosity ones (as all observed luminosity functions are of the type \( \phi(L) \propto L^{-\alpha} \), with \( \alpha > 0 \)), an anti-correlation between power and \( \nu_{\text{peak}} \) implies that HBL should be more numerous than LBL. The physical implications are two-fold: a) a simple demographical one relevant, for example, for deep surveys; b) strong constraints on jet physics. In fact, as \( \nu_{\text{peak}} \propto B\delta^{2}\gamma_{ \text{peak}}^{2} \), if high \( \nu_{\text{peak}} \) values were indeed more common, this would mean that Nature prefers certain types of jets and therefore some special combination of these parameters, a fact certainly worth of a thorough investigation.

2.2 Tests

These very specific predictions lend themselves to be tested, at least in theory, relatively simply. Namely, one can prove or disprove the sequence by:

1. checking the power - \( \nu_{\text{peak}} \) anti-correlation;
2. finding any "forbidden" objects, that is outliers from the correlation (high \( \nu_{\text{peak}} \) - high power and/or low \( \nu_{\text{peak}} \) - low power blazars);
3. counting sources; that is, are HBL really more numerous than LBL? (and is this consistent with the X-ray background?)

I will discuss these tests in detail in the following.

3 The power - \( \nu_{\text{peak}} \) anti-correlation

Before discussing any test of the anti-correlation, it is important to see in detail how the original plot was derived. Two BL Lac samples had been used by [6], one radio- and one X-ray-selected, and one FSRQ sample. These samples had been assembled in an independent
and somewhat different way, especially so as regards the selection band. Two caveats need then to be kept in mind: 1. it is always dangerous to infer parameter dependencies by plotting samples selected in an inhomogeneous way, particularly if one of the parameters depends on the selection method as in this case (most HBL are X-ray selected while most LBL are radio-selected). Indeed, none of the individual samples shown in Fig. 7 of [6] showed the claimed anti-correlation between power and \( \nu_{\text{peak}} \), which was only apparent by combining the three samples; 2. the only FSRQ sample was radio-selected. As the objects with the largest \( \nu_{\text{peak}} \) in the plot were X-ray selected BL Lacs, one might argue that the lack of high \( \nu_{\text{peak}} \) - high power sources was due to the lack of X-ray selected FSRQ.

In any case, it is clear that an independent check for the existence of this anti-correlation needed to be carried out. This has been done by various groups, whose results I am going to review next in chronological order.

The Deep X-ray Radio Blazar Survey (DXRBS) uses a double X-ray/radio selection and contains mostly FSRQ [25,23]. DXRBS is at present the faintest and largest flat-spectrum radio sample with nearly complete (\( \sim 95\% \)) identifications down to fluxes 10 – 20 times fainter than previous radio and X-ray surveys [26,14]. Therefore, it obviates to the selection effects present in the samples used by [6]. The DXRBS radio power - \( \nu_{\text{peak}} \) plot is shown in Fig. 1 which shows no correlation between the two parameters, a huge scatter, reaching 4 orders of magnitude in power, and outliers, that is sources occupying regions of this plot which were empty in the original one by [6]. In particular, of the 21 BL Lacs with \( \nu_{\text{peak}} < 10^{15.5} \) Hz and redshift information, \( \sim 1/3 \) "invade" the low-power part (\( L_r < 10^{25.3} \) W/Hz) of the plot.

The CLASS blazar survey has been used by [2] to study the radio power - \( \alpha_{\text{rx}} \) correlation. As mentioned in Sect. 1, this latter parameter is a proxy for \( \nu_{\text{peak}} \). Their Fig. 7 shows that, contrary to the predictions of
the blazar sequence, many sources at relatively low power and with \( \alpha_{\text{rx}} > 0.75 \) (that is, relatively large \( f_{\text{s}}/f_{\text{r}} \)) were found. In other words, even the CLASS sample shows the presence of low-power–low-\( \nu_{\text{peak}} \) BL Lacs. One complication with this result, however, is the fact that the relationship between \( \alpha_{\text{rx}} \) and \( \nu_{\text{peak}} \) is not very tight (see, e.g., Fig. 11 of [24]).

The 200 mJy sample was used by [1] to study the radio power - \( \nu_{\text{peak}} \) correlation. Their Fig. 4 shows a large number of sources with \( \nu_{\text{peak}} < 10^{15.5} \) Hz and \( \nu L_{5\text{GHz}} < 10^{42} \) erg/s, whereas none were found in [6]. Moreover, there is no correlation between the two parameters and a large scatter, reaching almost 5 orders of magnitude in power at a given \( \nu_{\text{peak}} \), is present.

The SEDs for a large, heterogeneous sample of BL Lacs taken from the Veron-Cetty & Veron BL Lac catalogue [29] and visible from the Metóshávi radio observatory were assembled by [18]. Their Fig. 3 shows an anti-correlation between radio power and \( \nu_{\text{peak}} \), a huge scatter, reaching 5 orders of magnitude in power, and many outliers as compared to Fig. 7 of [6], especially in the low-power–low-\( \nu_{\text{peak}} \) region.

The situation of the radio power - \( \nu_{\text{peak}} \) anti-correlation, as inferred by these studies, can then be thus summarised:

1. No radio power - \( \nu_{\text{peak}} \) anti-correlation is present when homogeneous, well-defined samples are used. Only when putting together objects from various surveys is such an anti-correlation observed. This points to selection effects being at the origin of the original anti-correlation;
2. For all studies, the scatter is huge, reaching 4-5 orders of magnitude in power at a given \( \nu_{\text{peak}} \). Therefore, even if there were an anti-correlation, it could not be very tight;
3. Outliers, that is sources which occupy regions of the plot which were empty in the original version, have been found by all studies. It is fair to say, though, that these are mostly in the low-power–low-\( \nu_{\text{peak}} \) region.

This last point is quite relevant. When using samples at lower fluxes than those used by [6], one is sampling sources which, by being fainter, could also be less beamed and therefore less powerful. Hence, one could expect some of the sources above the horizontal dotted line in Fig. 7 of [6] (see also Fig. 1) to move below the line in deeper surveys [7]. It is then especially important to look for the other type of outliers, the HFSRQ, that is high-power–high-\( \nu_{\text{peak}} \) blazars.

## 4 Looking for HFSRQ

How does one look for HFSRQ, that is high-power blazars with high \( \nu_{\text{peak}} \)? The steps are, at least in theory, simple enough. Namely:

1. start from X-ray selected samples, as HBL are mostly found in the X-ray band;
2. select suitable candidates by looking in regions of parameter space which are known to be occupied by HBL. For example, those defined by large \( f_{\text{s}}/f_{\text{r}} \);
3. after pre-selection, build the SED. One should check that, since we are dealing with quasars, which are known for their ultraviolet excess, any high-energy synchrotron peak is not due to the ultraviolet ”bump”;
4. as a final step, confirmation by X-ray observations is recommended. As discussed in Sect. 4 in fact, for a source to be an HFSRQ its X-ray spectrum should be synchrotron dominated and, therefore, relatively steep (\( \alpha_{\text{s}} > 1 \)) or, at least, concave (which would suggest that the X-ray band is sampling the synchrotron to inverse Compton transition).

However, all of the above is quite complex and time-consuming to put into practice. In fact, to the best of my knowledge, only our group has tackled this problem to this level of details. This is described partly in [20,25] to which the reader is referred for more details.

In brief, as an initial step towards studying the broadband properties of our sources, we first derived their \( \alpha_{\text{ox}}, \alpha_{\text{rx}}, \) and \( \nu_{\text{peak}} \) values. These are the usual rest-frame spectral indices defined between 5 GHz, 5,000 Å, and 1 keV. The fraction of sources which fall in the region of the plane within 2\( \sigma \) from the mean \( \alpha_{\text{ox}}, \alpha_{\text{rx}}, \) and \( \nu_{\text{peak}} \) values of HBL, the “HBL box”, derived by using all HBL in the multi-frequency AGN catalog of [24], is \( \sim 15\% \) and \( \sim 9\% \) for DXRBS BL Lac objects and FSRQ respectively (see Fig. 2). This already shows that \( \sim 10\% \) of DXRBS FSRQ have broadband colours typical of high-energy peaked BL Lacs. For comparison, the 1 Jy FSRQ, a radio-selected sample, occupy a region of \( \alpha_{\text{ox}}, \alpha_{\text{rx}} \) parameter space with \( \alpha_{\text{ox}} \) similar to that typical of LBL. FSRQ with low \( \alpha_{\text{ox}} \) \((\lesssim 0.78, \) roughly equivalent to the HBL/LBL division) constitute only \( \sim 5\% \) of the 1 Jy sources with X-ray data. However, none of the 1 Jy FSRQ fall in the HBL box.

BeppoSAX observations of four candidate HFSRQ were carried out by [20] with mixed results: one source had an X-ray spectrum dominated by inverse Compton emission, while two others had a flat X-ray spectrum with evidence of steepening at low energies. RGBJ1629+4008, however, was clearly synchrotron dominated in the X-ray band, with \( \alpha_{\text{rx}} \sim 1.5 \), which is typical of HBL. This source represents therefore the first example of confirmed HFSRQ, with \( \nu_{\text{peak}} \sim 2 \times 10^{16} \) Hz (\( \sim 0.1 \) keV).

It has to be pointed out, however, that, despite being an FSRQ, its relatively low radio power \((L_{5\text{GHz}} \sim 6 \times 10^{24} \) W/Hz\) places this source still in the bottom-right quadrant of Fig. 1 that is, where it should be according to the blazar sequence. Moreover, although clearly way above the values reached by LBL and well within the HBL range, its \( \nu_{\text{peak}} \) is towards the low end of the HBL distribution.
Fig. 2 \((\alpha_{\text{ro}}, \alpha_{\text{ox}})\) plane for the DXRBS sample. Effective spectral indices are defined in the usual way and calculated between the rest-frame frequencies of 5 GHz, 5,000 Å, and 1 keV. Filled circles represent FSRQ, while open squares represent BL Lacs. The region in the plane within 2\(\sigma\) from the mean \(\alpha_{\text{ro}}, \alpha_{\text{ox}},\) and \(\alpha_{\text{rx}}\) values of HBL is indicated by a solid polygon.

The latter result has been confirmed by more extensive searches, summarized in \cite{25,13,16}. In short, various X-ray selected samples have been searched thoroughly, and XMM and Chandra data have been taken \cite{16}. HF-SRQ, that is, broad-lined blazars with \(\nu_{\text{peak}}\) typical of HBL have been found, despite previous claims to the contrary (the issue of the effect of the UV bump on the estimated value of \(\nu_{\text{peak}}\) has been discussed by \cite{25,16}). However, their maximum \(\nu_{\text{peak}}\) is still \(\sim 0.1\) keV, while HBL reach typically \(\sim 1\) keV and exceptionally \(\sim 100\) keV (as in the case of MKN 501; \cite{27}).

The most extreme case is that of the Sedentary survey \cite{11,13}, which was designed to find extreme HBL, as a selection was made on \(f_x/f_r\) (roughly equivalent to \(\nu_{\text{peak}} \gtrsim 10^{16}\) Hz). Nineteen broad-lined AGN were found, out of 169 candidates, as compared to 150 HBL, but none of them was a definite FSRQ. These sources, in fact, turned out to be mostly nearby, low radio luminosity AGN very close to the radio-loud/radio-quiet border.

Is this lack of HFSRQ with high \(\nu_{\text{peak}}\) values telling us something about jet physics and the blazar sequence or is it still a selection effect? Recall that RGBJ1629+4008, and also the other three HFSRQ candidates studied in \cite{20}, had all relatively low radio powers (\((L_{5\text{GHz}}) \sim 10^{25}\) W/Hz), more typical of BL Lacs than of FSRQ and in any case close to the low-luminosity end of the FSRQ radio luminosity function \cite{29}. Similarly, the HFSRQ studied by \cite{15} were also of low power, reaching powers more typical of low-luminosity (Fanaroff-Riley type I) radio galaxies.

One could argue that the fact that HFSRQ are found at relatively low radio power is not coincidental. Indeed, for a high radio power HBL-like source, the optical flux would be totally dominated by the non-thermal, featureless nuclear emission, which would make any redshift estimation a very difficult task (see details in \cite{20} and Fig.
7 of [13]). In other words, high-power HFSRQ sources would lack a redshift (which is indeed the case for many BL Lacs with featureless spectra) and therefore we would have no way of knowing that they are at high power.

The situation of the search for high-power–high-νpeak blazars, the so-called HFSRQ, can then be thus summarised:

1. HFSRQ have been found and they make up ∼ 10% of the FSRQ in DXRBS, which is both X-ray- and radio-selected. The previously noted absence of these sources was due to the fact that the majority of FSRQ samples had been radio-selected and that no X-ray survey had looked for FSRQ.

2. Despite the fact that these sources have νpeak values way above those reached by LBL and well within the HBL range, their maximum νpeak is ∼ 0.1 keV, below the typical (∼ 1 keV), and well below the largest (∼ 100 keV), values for HBL.

3. It is still not clear if the fact that HFSRQ do not reach the extreme νpeak values of HBL is indicative of the fact that, after all, there might be an intrinsic, physical limit to this parameter. An alternative scenario is one where really high-power–high-νpeak blazars have their thermal emission swamped by the non-thermal, featureless jet emission, which makes their redshift determination impossible. This explanation for the fact that presently known HFSRQ are of relatively low power cannot be ruled out.

In this respect, the discovery of a very powerful (Lx ∼ 10^{47} erg/s) z ∼ 4 FSRQ with a likely νpeak > 50 keV is extremely interesting and worth following up [3].

5 Counting Sources: are HBL more numerous than LBL?

The last test to be carried out regards the relative fraction of the BL Lac subclasses. Namely, are HBL more numerous than LBL, as predicted by the blazar sequence?

The problem here is that the selection band affects the selected objects, in the sense that X-ray selection finds mostly HBL, while radio selection finds mostly LBL. Since the large majority of BL Lac samples are either X-ray or radio selected (even optically selected ones, see [2], have their biases, as the optical band would preferentially select HBL), one would need an unbiased selection method, say a volume-limited sample. Since we are still very far from having such an unbiased BL Lac sample, one needs to make some assumptions and then predict the relative fraction of HBL and LBL in X-ray- and radio-selected samples.

Let us assume that the blazar sequence is indeed a valid representation of the truth and that, therefore, HBL are intrinsically the most numerous BL Lac subclass. Therefore, although initially radio selection favours LBL, the fraction of HBL in the radio band will have to increase at lower fluxes until HBL become the majority at the faintest fluxes. In the X-ray band, on the other hand, HBL are the dominant class and their fraction is expected to be basically constant. Indeed, detailed predictions under a scenario where νpeak has an an inverse dependence on bolometric power, as required by the blazar sequence, have been worked out [26] and conform to these simple arguments.

Fig. 3 shows the integral radio number counts for the HBL Sedentary sample at 1.4 GHz. For lack of deeper samples, these were compared by [11] to the counts for all BL Lacs predicted by unified schemes and based on the radio luminosity function fitted to the 1 Jy sample assuming no evolution (Fig. 1 of [24]). We can now compare the HBL counts also with the observed BL Lac counts from DXRBS [24]. Fig. 3 shows that the fraction of extreme HBL is constant, as the HBL counts are parallel to the total ones. This is at variance with the predictions of the blazar sequence, according to which this fraction should increase at lower fluxes (dashed line in Fig. 3 [5]).

The fraction of all (and not only extreme) HBL as a function of radio flux could not be studied until the completion of our own DXRBS sample. We show that the ratio LBL/HBL is basically constant and ∼ 6 [24], while at the radio fluxes reached by DXRBS a value ∼ 2 would be expected [5]. The HFSRQ fraction is also roughly constant with radio flux. Again, this goes against what predicted by the blazar sequence.

We note that a completely independent argument against the strong increase in the HBL fraction at low radio fluxes required by the blazar sequence can be made [10]. In fact, were that the case, the blazar contribution to the soft X-ray background, estimated around ∼ 12% and mostly due to the synchrotron component in HBL, would be much larger and inconsistent with observational data.

The dependence of the fraction of LBL in an X-ray selected sample could also not be studied to fluxes deep enough until DXRBS came into the scene. This is shown in Fig. 4 which shows the integral X-ray number counts for BL Lacs, adapted from [22], compared to our best estimate of the integral number counts of LBL in the X-ray band [23]. The solid line represents the X-ray number counts for LBL predicted by [12] and revised by [22] on the assumption that HBL represent ∼ 10% of the BL Lac population, while the dashed line shows the predictions of [3] normalized at high fluxes. The figure shows that the fraction of LBL in the X-ray band increases at lower fluxes, as expected if they were the dominant population. The blazar sequence, on the other hand, predicts LBL to make up a constant fraction of the total, as shown by the dashed line, in contrast with observations.
Fig. 3 The integral radio number counts for the extreme HBL Sedentary sample at 1.4 GHz (filled circles). The solid line represents the expected radio counts for all types of BL Lacs estimated from the radio luminosity function of [22], while the dashed line shows the predictions of the blazar sequence for all HBL [5]. The BL Lac surface densities from the 1 Jy (open square), S4 (cross), and S5 (open triangle) are also shown, together with the DXRBS number counts [23]. All data apart from the HBL have been converted from 5 GHz assuming $\alpha = -0.27$. Adapted and updated from [11].

6 Summary

I have investigated the validity of the blazar sequence and tested its predictions against recent observational data. My main conclusions are as follow:

1. There is no anti-correlation between radio power and synchrotron peak frequency in blazars, once selection effects are properly taken into account. Furthermore, outliers to the originally proposed sequence have been found, both in the low-power–low-$\nu_{\text{peak}}$ and high-power–high-$\nu_{\text{peak}}$ regions.

2. The "missing" class of flat-spectrum radio quasars with synchrotron peak frequency in the UV/X-ray band, whose existence is not expected within the blazar sequence, has been found.

3. Contrary to the predictions of the blazar sequence, all observational data are consistent with the idea that the HBL subclass makes up a small ($\approx 10\%$) minority of BL Lacs.

4. Based on all of the above, the blazar sequence in its simplest form cannot be valid.

5. The point remains, however, that the maximum synchrotron peak frequency of FSRQ appears to be $\sim 10 - 100$ times smaller than that reached by BL Lacs (but see [9] for a possible exception to this rule). Is this telling us something about jet physics or is it still a selection effect due to the fact that for really high-power–high-$\nu_{\text{peak}}$ blazars it might be hard to get a redshift estimate? This question could be answered by the detection of high-power, moderately high-redshift TeV blazars.

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Fig. 4 The integral X-ray number counts for BL Lacs ([23], adapted from [22]). Data for five X-ray selected samples are shown. Filled triangles represent the bivariate X-ray counts for the 1 Jy LBL with $f_x \sim 3 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$, while filled squares show the DXRBS LBL with $f_x \geq 1.6 \times 10^{-13}$ erg cm$^{-2}$ s$^{-1}$ [23]. In both cases these define complete, X-ray flux limited LBL samples. The solid line represents the X-ray number counts for LBL predicted by [12] and revised by [22], while the dashed line shows the predictions of the blazar sequence [5] normalized at high fluxes.

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