X-ray spectral curvature of High Frequency Peaked BL Lacs: a predictor for the TeV flux

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1 Abstract

We present the X-ray analysis of a sample of HBLs not detected at TeV energies (NBLs), to compare their spectral behavior with that of TBLs looking for TeV candidates.

2 Introduction

Most of the extragalactic sources detected at TeV energies are BL Lac objects. They belong to the subclass of "high frequency peaked BL Lacs" (HBLs) exhibiting spectral energy distributions with a lower energy peak in the X-ray band; this is widely interpreted as synchrotron emission from relativistic electrons.

The X-ray spectra are generally curved, and well described in terms of a log-parabolic shape. In a previous investigation of TeV HBLs (TBLs) we found two correlations between their spectral parameters: (1) The synchrotron peak luminosity L_p increases with its peak energy E_p; (2) the curvature parameter b decreases as E_p increases. The first is consistent with the synchrotron scenario, while the second is expected from statistical/stochastic acceleration mechanisms for the emitting electrons.

We present the results of the X-ray analysis of a sample of HBLs observed with *XMM-Newton* and *Swift* but not detected at TeV energies (NBLs), to compare their spectral behavior with that of TBLs. Investigating the distributions of their spectral parameters and comparing the TBL X-ray spectra with that of NBLs, we develop a criterion to select the best HBLs candidates for future TeV observations.

3 Sample selection

There are 118 NBLs in the four samples considered: the Einstein Slew Survey, the Sedentary survey of extreme HBLs, the ROSAT All-Sky Survey-Green Bank BL Lac catalog and the Hubble Space Telescope Survey of BL Lacertae Objects with known redshift. However, 71 NBLs are excluded on adopting the selection criteria reported below.

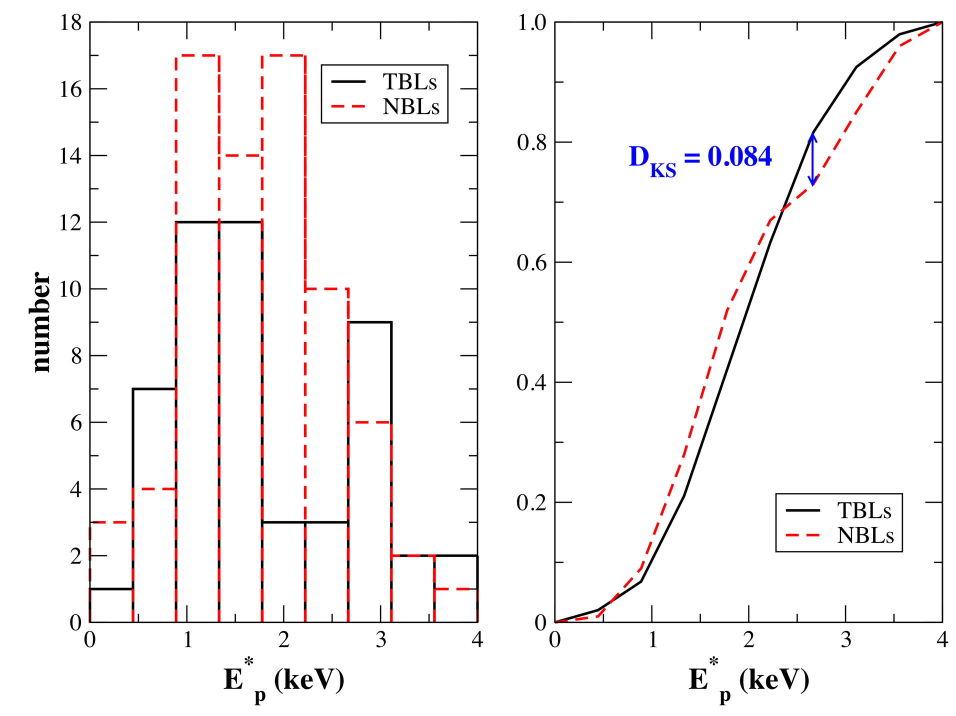
To compare the behavior of TBLs and NBLs, we selected a sample of NBLs on adopting the following criteria.

- We calculated the ratio Φ_{XR} between the X-ray flux F_X (0.1 - 2.4 keV) and the radio flux $S_{1.4}$ (at 1.4 GHz). We select BL Lacs with $\Phi_{XR} \geq 0.1$ that correspond to HBLs, according to the criterion established by Maselli et al. (2009).
- We restricted our sample to those sources with redshift $z \leq 0.539$, the highest redshift for an extragalactic TeV source (i.e., 3C 279).
- We considered only NBLs with X-ray observations, up to the end of October 2010, in the *XMM-Newton* or *Swift* archives that have an exposure longer than 150 s.

4 Results

4.1 Peak energy E_p

The E_p distribution for the NBLs is consistent with that of TBLs, exhibiting a peak around a value $\sim$ 1.75 keV (Figure 1, left panel). There is a hint of a difference above the E_p = 2.5 keV; a KS test (Figure 1, right panel) shows that the two distributions do not differ at a confidence level of 99%.



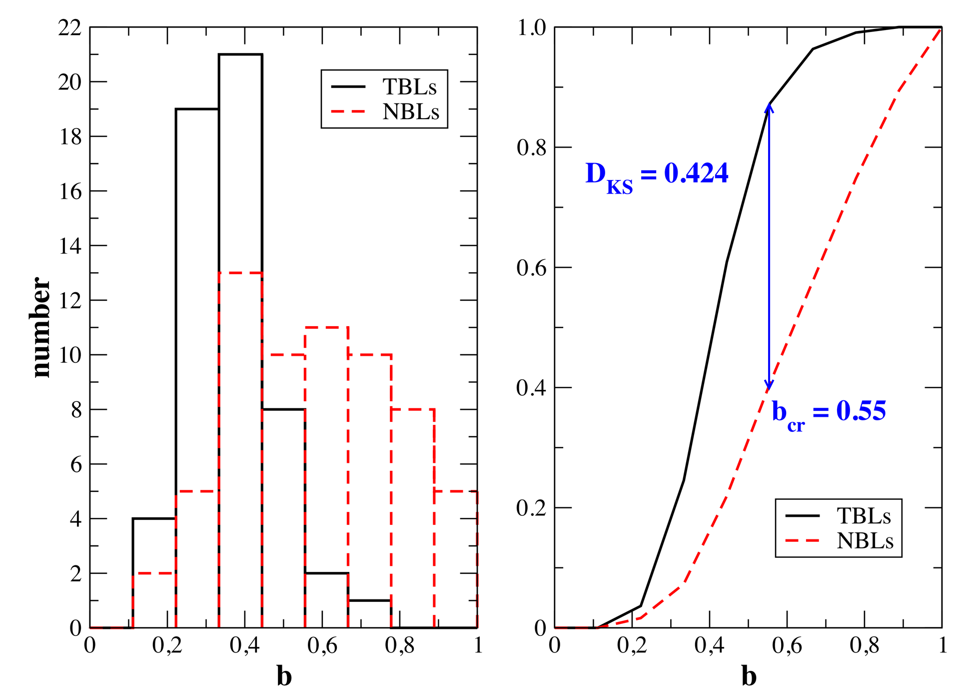
The X-ray E_p distribution of NBLs (red) and TBLs (black). The sample of TBLs considered here does not include Mrk 421 and PKS 2155-304 and giant flares of Mrk 501 and 1H 1426+421. The maximum separation D_{KS}, of the two cumulative distributions, correspondent to the variable of the KS test, is shown.

4.2 Spectral curvature b

There is a systematic *difference* in b values between TBLs and NBLs (Figure 2, left panel). It is clear that the curvature in the latter is systematically higher, indicating that the NBL X-ray spectra spectra are narrower around E_p than those of TBLs. Applying a KS test, the two distributions are different at a confidence level of 90%, and the maximum separation of the two b cumulative distributions occurs at the critical value b_{cr} = 0.55 (Figure 2, right panel).

4.3 Spectral parameter trends

There is no clear correlation for the NBLs between E_p and b, while for TBLs E_p and b anti-correlate (Massaro et al. 2008).



The X-ray curvature b distribution of NBLs (red) and TBLs (black). The sample of TBLs considered here does not include Mrk 421, PKS 2155-304 and the giant flares of Mrk 501 and 1H 1426+421, as described in Section 5. The maximum separation, D_{KS}, of the two cumulative distributions (i.e., the variable used for the KS test) and the critical value of the curvature b_{cr} are shown.

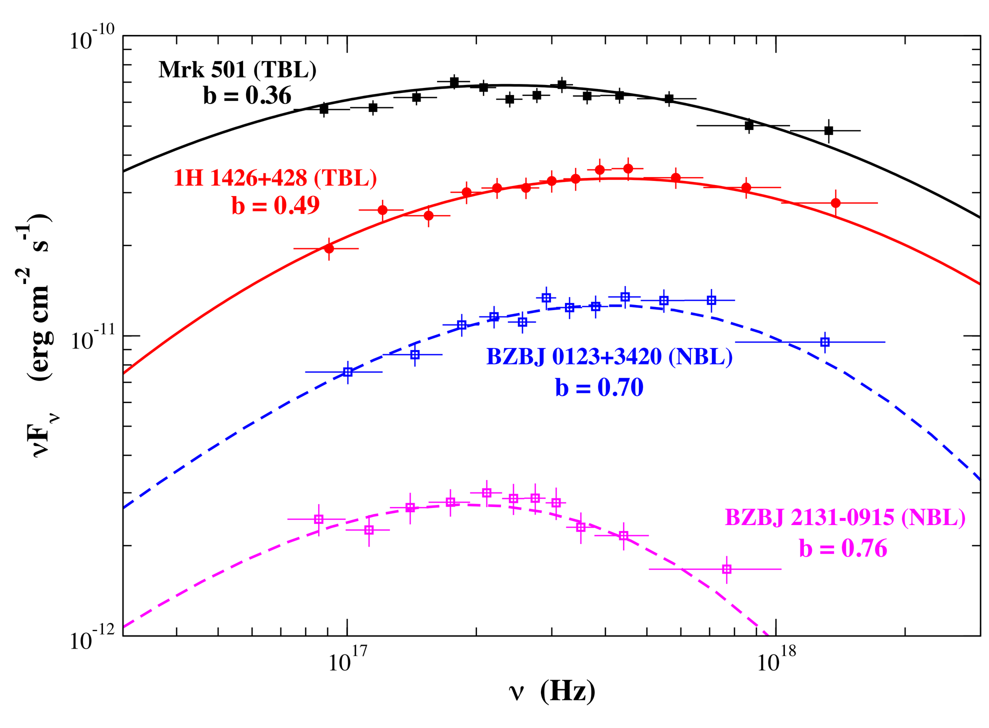
5 HBLs detectable at TeV energies

There are three levels of confidence (i.e., TeV classes) in our prediction:

1) We argue that best candidates for the future TeV detections are provided by NBLs with a GeV *Fermi* LAT detection and with a curvature b systematically lower than b_{cr}. This threshold corresponds to the maximum distance between the two cumulative b distributions (see Figure 2b). From our analysis we found that four NBLs are the most likely new TeV detectable extragalactic sources **(class 1): BZB J0326+0225, BZB J0442-0018, BZB J0744+7433 and BZB J1743+1953.**

2) Six more NBLs which have some X-ray observations with $b < b_{cr}$, and are also detected by *Fermi* LAT and so we consider TeV candidates of **class 2: BZB J0208+3523, BZB J1136+6737, BZB J1417+2543, BZB J1442+1200, BZB J1728+5013, BZB J2250+3824.**

3) The variability of b leads us to expect the discovery of new TBLs also if the X-ray spectrum has $b \leq b_{cr}$. Then, NBLs with $b \leq b_{cr}$ and $F_X \geq 10^{-11}$ erg s^{-1} cm^{-2}, but no LAT detection, make up our third class. The lower GeV normalization makes these less likely TeV candidates. However, based on the single zone SSC scenario Paggi et al. (2009), in which the X-ray flux is similar to the detectable LAT γ-ray flux ($\sim$ 1yr exposure Atwood et al. 2009) and the curvature is as broad as that of TBLs, we suggest that the NBL can be detected at TeV energies. Five more NBLs fit **class 3: BZB J0013-1854, BZB J0123+3420, BZB J0214+5144, BZB J1010-3119 and BZB J1253-3931.** [!htp]



The unfolded X-ray SEDs for 4 HBLs: 2 NBLs (dashed lines), BZBJ 0123+3420 (blue open squares, 2009-08-28) and BZBJ 2131-0915 (magenta open squares, 2009-03-30), in comparison with 2 archival observations of the TBLs (solid lines): Mrk 501 (black filled circles, 2006-20-07) and 1H 1426+428 (red filled circles, 2006-03-07). The TBL X-ray spectra are broader than the NBLs.

Our source selection was concluded at the beginning of August 2010. Since then, of the 15 total candidates, the sources BZB J1442+1200 and BZB J2250+3824 from our class 2 and BZB J0013-1854 and BZB J1010-3119 from class 3 have been detected at TeV energies.

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