Abstract. Most of TeV detected extragalactic sources are BL Lac objects. They belong to the subclass of “high frequency peaked BL Lacs” (HBLs) exhibiting their spectral energy distributions with a lower energy peak in the X-ray band, interpreted as synchrotron emission. 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 with statistical/stochastic acceleration mechanisms for the emitting particles. Here, we present an extensive X-ray analysis of a sample of HBLs observed with XMM Newton and SWIFT but undetected at TeV energies (UBLs), to compare their spectral behavior with that of TBLs. We investigate the distributions of their spectral parameters, providing an interpretation of both the $E_p$ and $b$ distributions in terms of systematic and stochastic acceleration processes. We also compare the X-ray spectral behavior of UBLs with that in gamma-rays and propose a criterion to select the best HBLs candidates for future TeV observations.

1. Introduction
The great majority ($\geq 80\%$) of the extragalactic sources detected to April 2011 in $\gamma$ rays at TeV energies are BL Lac objects. BL Lacs come in two flavors: the “high-frequency peaked BL Lacs” (HBLs) in which the low energy component of the SED peaks between the UV band and X-rays, and the “low-frequency peaked BL Lacs” (LBLs) when the spectral energy distribution (SED) peak falls in the IR-optical range [22]. It is widely agreed that this low-energy component is produced by synchrotron radiation of ultrarelativistic electrons accelerated in the jets, while the high energy component is likely due to inverse-Compton scattering of the synchrotron photons by the same electron population (Synchrotron Self-Compton, SSC, see e.g. [12,15].

In the following, we distinguish the HBLs detected at TeV energies from those not yet detected; we refer to the former as TBLs, and to the latter as UBLs.

A useful phenomenological description of the BL Lac X-ray spectra was introduced by [13] in terms of a log-parabolic (LP) model (i.e., a parabolic shape in a double-log plot); subsequently, this model has been frequently adopted for the low energy bump, e.g., by [16],[26] and other authors. Recently, the high energy component at TeV energies has also been successfully modeled with the same spectral shape [1,2,3,5,17].
The LP model has been used also to describe the SED of other classes of jet-dominated sources: plerions [6], high frequency peaked (HFPs) radio sources [14], and, recently, Solar Flares [10] and Gamma-Ray Bursts (GRBs) [19,20].

Adopting the LP model, the X-ray SED of HBLs is described in terms of 3 parameters: (1) the peak energy, \( E_p \), in \( \nu F_\nu \) space, (2) the maximum height of the SED, \( S_p \), evaluated at \( E_p \) (or the corresponding peak luminosity \( L_p \simeq 4\pi D_L^2 S_p \), with \( D_L \) being the luminosity distance), and (3) the spectral curvature, \( b \), around \( E_p \) [18,27].

Extensive investigations of the TBLs, based on all the X-ray observations available in the BeppoSAX, XMM-Newton and Swift archives between 1997 and 2007, have shown that several TBLs trace two correlations in the \((E_p, L_p, b)\) parameter space: (1) the peak luminosity \( L_p \) increases with \( E_p \), as expected in the synchrotron scenario, (2) the curvature parameter \( b \) decreases as \( E_p \) increases [18] as expected in a stochastic acceleration scenario (e.g., [18,28]).

As a result, TBLs cover a well-constrained region in the \( E_p - b \) plane. The correlation between \( b \) and \( E_p \) is evident for the 16 TBLs in [18], whilst no clear trend in the \( E_p - L_p \) plane has been found for the whole sample.

Many HBLs have been targeted at TeV energies by HESS, Magic and VERITAS, but by no means all of them have been detected. It is striking that 19 out of 24 TBLs (to 2010, August 1st) belong to the Einstein Slew Survey Sample of BL Lacertae Objects (1ES, [8,24]), which includes only the brightest X-ray extragalactic sources at \( \sim 1 \) keV. The remaining TBLs belong to three different samples, namely: 1) The ROSAT All-Sky Survey-Green Bank BL Lac catalog (RGB, [30]); 2) The sedentary survey of extreme high energy peaked BL Lacs (SHBL1,[9]); 3) The Hubble Space Telescope Survey of BL Lacertae Objects; (HST, [25,29]). Consequently, we selected all the UBLs in the above four samples to search for possible differences between these sources and the TBLs.

In this conference proceeding, we report only the main results of our analysis, the details regarding the sample selection criteria, the data reduction and data analysis procedures adopted to perform our investigation are presented in [21].

2. HBLs Detectable at TeV Energies

From comparing the distribution of the X-ray spectral curvature and the GeV Fermi LAT detections, we propose criteria to predict which UBLs are more likely to be detectable at TeV energies. TeV energies lie beyond the inverse Compton peak of the HBL SEDs. Hence to be detectable they need both a high GeV flux level and a small GeV - TeV spectral curvature. In the SSC scenario, the X-ray spectral curvature, \( b \), of HBLs, evaluated at the synchrotron SED peak, \( E_p \), is a good predictor of the curvature of the inverse Compton peak at GeV - TeV energies, although they are not always identical [17]. We can define three levels of confidence (i.e., TeV classes) in the prediction of TeV detectability (see Table 1, Col. 12):

Class 1: the best candidates for the future TeV detections are provided by UBLs with a GeV Fermi LAT detection and a curvature, \( b \), lower than the characteristic value \( b_s = 0.55 \) in all the X-ray observations. We found that four UBLs satisfy both conditions and so are the most likely new TeV detectable extragalactic sources: BZB J0326+0225, BZB J0442-0018, BZB J0744+7433 and BZB J1743+1953. Spectral variability could limit this prediction but UBLs appear to be less variable in the X-ray band than TBLs (see Section 6.2)

Class 2: six more UBLs have some X-ray observations with \( b < b_s \), and are also detected by Fermi LAT and so are still TeV candidates: BZB J0208+3523, BZB J0442-0018, BZB J0744+7433 and BZB J1743+1953. The variability of \( b \) leads us to expect the discovery of other new TBLs when their X-ray spectrum has \( b < b_s \).

Class 3: UBLs with \( b \leq b_s \) in at least one X-ray observations and \( F_X \geq 10^{-11} \text{ erg s}^{-1} \text{ cm}^{-2} \)

\(^1\) http://www.asdc.asi.it/sedentary/
Table 1. UBLs selected.

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| BZB J0013-1854 | 0.094 | 420.1 | 2.13 | 2.24 | 4 | — | — | 3 |
| BZB J0123+3420 | 0.272 | 1359.7 | 5.20 | 5.74 | 17 | 1 | — | 3 |
| BZB J0201+0034 | 0.298 | 1511.2 | 2.23 | 2.71 | 1 | — | — | — |
| BZB J0208+3523 | 0.498 | 2499.3 | 2.67 | 5.05 | 2 | — | — | 3 |
| BZB J0325-1646 | 0.291 | 1470.1 | 3.27 | 10.1 | 3 | — | — | — |
| BZB J0326+0225 | 0.147 | 681.2 | 7.87 | 1.73 | 3 | y | 1 | — |
| BZB J0344+0018 | 0.449 | 2453.2 | 4.83 | 3.35 | 4 | — | y | 1 |
| BZB J0621-3411 | 0.049 | 212.0 | 14.4 | 0.16 | 3 | — | — | 3 |
| BZB J0744+7433 | 0.314 | 1606.0 | 3.28 | 2.74 | 1 | 2 | y | 1 |
| BZB J0751+1730 | 0.185 | 878.4 | 4.93 | 1.78 | 1 | — | — | — |
| BZB J0753+2921 | 0.163 | 752.9 | 3.44 | 0.28 | 1 | — | — | — |
| BZB J0847+1133 | 0.109 | 492.3 | 14.0 | 7.28 | 1 | — | — | — |
| BZB J0916+5238 | 0.190 | 905.0 | 1.43 | 0.53 | 1 | — | — | — |
| BZB J0952+7502 | 0.179 | 846.8 | 2.23 | 2.07 | 2 | — | — | — |
| BZB J1030+3119 | 0.143 | 660.9 | 8.48 | 1.37 | 2 | — | — | — |
| BZB J1042+1200 | 0.163 | 763.3 | 2.12 | 0.43 | 1 | — | — | — |
| BZB J1117+2014 | 0.139 | 640.7 | 1.35 | 3.26 | 1 | — | y | — |
| BZB J1136+6737 | 0.136 | 625.7 | 1.09 | 3.28 | 5 | y | 2 | — |
| BZB J1145+0340 | 0.167 | 874.0 | 2.22 | 2.28 | 2 | — | — | — |
| BZB J1254+0010 | 0.254 | 1258.9 | 2.86 | 2.75 | 1 | — | — | — |
| BZB J1257+6252 | 0.236 | 1155.7 | 3.82 | 17.3 | 1 | — | — | — |
| BZB J1258-3931 | 0.179 | 846.8 | 7.66 | 1.47 | 1 | — | — | — |
| BZB J1341+3959 | 0.172 | 810.0 | 0.80 | 1.26 | 4 | — | y | — |
| BZB J1417+2543 | 0.154 | 660.9 | 1.35 | 0.10 | 1 | — | — | — |
| BZB J1510+3335 | 0.114 | 516.7 | 1.54 | 3.16 | 1 | — | — | — |
| BZB J1534+3715 | 0.137 | 660.9 | 1.35 | 3.26 | 1 | — | — | — |
| BZB J1605+5421 | 0.212 | 1023.5 | 2.12 | 1.43 | 1 | — | — | — |
| BZB J1626+3513 | 0.497 | 2774.1 | 3.62 | 1.74 | 1 | — | — | — |
| BZB J1728+5013 | 0.185 | 878.4 | 4.93 | 1.78 | 1 | — | — | — |
| BZB J1743+1935 | 0.080 | 354.0 | 7.36 | 0.14 | 3 | y | 1 | — |
| BZB J1811+0915 | 0.449 | 2453.2 | 3.62 | 1.74 | 1 | — | — | — |
| BZB J1920+1707 | 0.169 | 794.4 | 2.91 | 5.92 | 2 | — | — | — |
| BZB J2025+3824 | 0.119 | 541.2 | 10.4 | 0.24 | 16 | y | 2 | — |
| BZB J2108+2210 | 0.137 | 630.7 | 1.86 | 7.12 | 1 | — | — | — |
| BZB J2332+3436 | 0.098 | 439.3 | 6.83 | 0.11 | 2 | y | — | — |
| BZB J2343+3439 | 0.366 | 1922.6 | 6.75 | 1.60 | 2 | y | — | — |

Col. (1) ROMA BZCAT source names. Col. (2) the name in the selected sample. Cols.(3,4) the right ascension and declination, respectively. Col. (4) gives the redshift (from ROMA BZCAT). Col. (5) reports the luminosity distance. Cols. (6) the Galactic column density along the line of sight [11]. Col. (7) the X-ray to radio flux ratio $\Phi_{XR}$ (see Section 2). Cols. (8,9) report the number of X-ray observations per satellite. Col. (11) indicates if the source has been detected in the Fermi LAT 1st year catalog, while Col. (12) the TeV candidate class derived from our analysis (see Section 6).

in the 0.5-10 keV energy range, but no LAT detection, make up our third class. The lower GeV normalization makes these less likely TeV candidates. However, in the single zone SSC scenario [23], the X-ray flux is similar to the detection threshold of 1yr Fermi LAT $\gamma$-ray flux [4] and the curvature is as broad as that of TBLs, we suggest that such UBLs can be detected at TeV energies. Five more UBLs fit class 3: BZB J0013-1854, BZB J0123+3420, BZB J0214+5144, BZB J0916+5238 and BZB J1510+3335.

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 (see the
**Figure 1.** Left panel) The X-ray $E_p$ distribution of UBLs (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, as described in Section 5. The maximum separation $D_{KS}$, of the two cumulative distributions, corresponding to the variable of the KS test, is also shown on the plot. Right panel) The X-ray curvature $b$ distribution of UBLs (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 corresponding boundary value of the curvature $b_*$ are also shown on the plot.

**3. Summary**

We have carried out an extensive X-ray spectral analysis of HBLs to compare the spectral behavior of those not detected at TeV energies (UBLs) with those already known as TeV emitters (TBLs). We analyzed all 135 X-ray observations of a sample of 47 UBLs present in the XMM-Newton and Swift archives up to August 2010.

We found that the $E_p$ distributions of UBLs and TBLs are similar, and symmetric around a value of a few keV for both subclasses. Instead the X-ray spectral curvature, $b$, of UBLs, is systematically lower than in TBLs, implying that the UBL X-ray spectra are narrower. In addition, in the first year Fermi catalog, we found that the UBL and TBL MeV-GeV $\gamma$-ray spectral behavior is similar, yet only $\sim 40\%$ of our selected UBLs have been detected in the Fermi LAT energy range vs 80\% of TBLs.

On the basis of our analysis, we have developed criteria to predict likely TBLs. We present three lists with different levels of confidence for TeV detectability based on MeV-GeV flux level and keV spectral curvature, comprising a total of 15 TeV candidates. By December 2010, four of our candidates have already been detected at TeV energies, landing support to our selection criteria.

A crucial check for our TeV candidate criteria will be provided by X-ray monitoring of candidates from the different TeV classes, with simultaneous GeV and TeV observations, to investigate the variability timescales of the spectral curvature.

*TeV CAT* for new announced TeV sources.

---

2 http://tevcat.uchicago.edu/
4. Acknowledgments

We are grateful to A. Beardmore for discussions regarding the Swift calibration. F. Massaro thanks D. Harris for helpful suggestions that improve the presentation and A. Siemiginowska and B. Refsdal for their useful advices on the use of the Sherpa software package. The work at SAO was supported by the NASA grant NNX10AD50G.

F. Massaro acknowledges the Foundation BLANCEFLOR Boncompagni-Ludovisi, née Bildt for the grant awarded him in 2010 to support his research. Part of this work is based on archival data, software or on-line services provided by the ASI Science Data Center (ASDC). This research has made use of data obtained through the High Energy Astrophysics Science Archive Research Center Online Service, provided by the NASA/Goddard Space Flight Center.

5. References

[1] Abdo, A. A. et al. 2011 ApJ submitted arXiv: 1106.1348
[2] Aleksic, J. et al. 2011 A&A submitted arXiv: 1106.1589
[3] Acciari, V. A. et al. 2011 A&A submitted arXiv: 1106.1210
[4] Atwood, W. B. et al. 2009, ApJ, 697, 1071
[5] Aharonian, F. et al. 2009, A&A, 502, 749
[6] Campana, R., Massaro, E., Mineo, T., 2009, A&A, 499, 847
[7] Dunkley, J., 2009 ApJ, 701, 1804
[8] Elvis, M., Plummer, D., Schachter, J., Fabbiani, G. 1992 ApJS, 80, 257
[9] Giommi, P., Piranomonte, S.; Perri, M.; Padovani, P., 2005, A&A, 434, 385
[10] Grigis, P. G. & Benz A. O. 2008 ApJ, 683, 1180
[11] Kalberla, P. M. W., Burton, W.B., Hartmann, D., 2005, A&A, 440, 775
[12] Inoue, S., Takahara F., 1996, ApJ, 463, 555
[13] Landau, R., Golish, B., Jones, T. J., et al. 1986, ApJ, 308, L78
[14] Maselli, A. & Massaro, E. 2009, AN, 330, 295
[15] Marscher, A. P., Gear, W. K. 1985, ApJ, 298, 114
[16] Massaro, E., Perri, M., Giommi, P., et al. 2004, A&A, 422, 103
[17] Massaro, E., Tramacere, A., Perri, M., Giommi, P., Tosti, G., 2006, A&A, 448, 861
[18] Massaro, F., Tramacere A., Cavaliere A., et al. A&A 2008a, 478, 395 (M08)
[19] Massaro, F., Grindlay, J. E., Paggi, A. 2010a, ApJL, 714, 299
[20] Massaro, F., & Grindlay, J. E. 2011a ApJ, 727L, 1
[21] Massaro, F., A. Paggi, Elvis, M., & A. Cavaliere, 2011b ApJ in press
[22] Padovani, P., & Giommi, P., 1995, MNRAS, 277, 1477
[23] Paggi, A., Massaro, F., Vittorini, V. et al. 2009 A&A, 504, 821
[24] Perlman, E. S. et al. 1996 ApJS, 104, 251
[25] Scarpa, R, et al. 1999 ApJ, 521, 134
[26] Tanihata, C., Kataoka, J., Takahashi, T., et al. 2004, ApJ, 601, 759,
[27] Tramacere, A., Massaro, F., Cavaliere, A., 2007, A&A, 466, 521
[28] Tramacere, A., Giommi, P., Perri, M. et al. 2009 A&A, 501, 879
[29] Urry, C. M. et al. 2000 ApJ, 532, 816
[30] Laurent-Muehleisen S. A. et al. 1999 ApJ, 525, 127