On the Flux and Photon Index Distributions of Fermi-LAT Blazars

J. Singal, V. Petrosian, M. Ajello

Stanford / KIPAC / SLAC

We present a determination of the distributions of gamma-ray flux and photon index for the 352 blazars detected at greater than 7σ and above ±20º Galactic latitude by the Fermi-LAT in its first year catalog. Our method reconstructs the intrinsic distributions from the observed ones in a way that accounts robustly for the selection biases in the data and correlations among the variables. We find that for the population as a whole the intrinsic flux distribution can be represented by a broken power law of slopes -2.37±.13 and -1.70±.26, and the intrinsic photon index distribution can be represented by a Gaussian with mean 2.41±.13 and 1σ width of 0.25±.03. We also find the intrinsic distributions for the sub populations of BL Lac and FSRQ type blazars considered separately.

Fermi-LAT Blazars

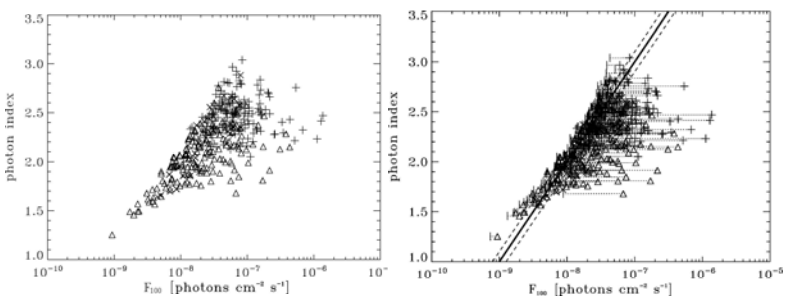

Figure 1: Left: Flux and photon index for the 352 Fermi blazars used in this analysis. BL Lac type blazars (n=163) are shown as triangles, FSRQ type blazars (n=161) are shown as vertical crosses, and blazars of unidentied or ambiguous type (n=28) are represented by Xs. Right: Same, but with the cutoff function shown, along with the approximate limiting flux for each object determined by the detection significan.ce

We use blazars from the first year Fermi-LAT extragalactic catalog.[2] Fermi-LAT observations are biased against soft spectrum blazar sources at fluxes below F_{100} =~10^{-7} photons cm^{-2} sec^{-1}. Because of this truncation in the data, and because of the possible inherent correlation between photon index (Γ) and flux (F_{100}), accessing the true distributions of photon index and flux requires care.

Methods

First we determine the correlation between α and F_{100} using the Spearman rank test (SRT) with the method of associated sets,[3,4] which can deal with truncated data. We approximate the cutoff function with a curve in the Γ,F_{100} plane as discussed in [1]. We then can take out the correlation to form a correlation reduced photon index:

$$\Gamma_{cr} = \Gamma - \beta \cdot Log\left(\frac{F_{100}}{F_{100-\min}}\right) \quad (1)$$

where β is the best fit correlation parameter. Then the distributions are separable:

$$G(F_{100}, \Gamma) = \psi(F_{100}) \times \hat{h}(\Gamma) \quad (2)$$

and the intrinsic photon index distribution can be recovered by

$$h(\Gamma) = \int_{F_{100}} \psi(F_{100})\, \hat{h}\left(\Gamma - \beta \cdot Log\left(\frac{F_{100}}{F_{100-\min}}\right)\right) dF_{100} \quad (3)$$

References: [1]J. Singal, V. Petrosian, & M. Ajello, 2011, *in prep*
[2]A. Abdo et al. 2010, *ApJ*, 715, 429; [3]B. Efron, & V. Petrosian,1992, ApJ, 399, 345;
[4]V. Petrosian,1992, in Statistical Challenges in Modern Astronomy, 173;
[5]Abdo, A., et al. 2010, *ApJ*, 720, 435 (''MA''), [6]Abdo, A., et al. 2010, *PhysRevLet*, 104, 101101

Distributions

We form the distributions $\psi(F_{100})$ and $\hat{h}(\Gamma)$ using the Lynden-Bell method modified with associated sets[3,4] to account for the truncation in the Γ,F_{100} plane. A full discussion is provided in [1].

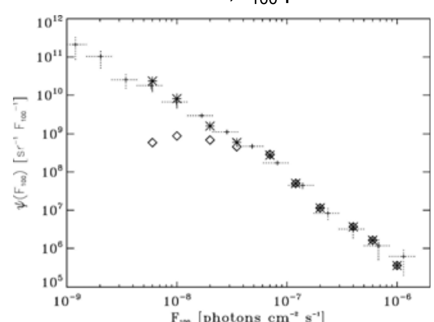

Figure 2: Observed (diamonds) and reconstructed intrinsic (stars) distribution of flux $\psi(F_{100})$ for the 352 Fermi blazars used in this analysis. We also plot $\psi(F_{100})$ as determined in MA [5] (small crosses), with error bars (dotted lines).

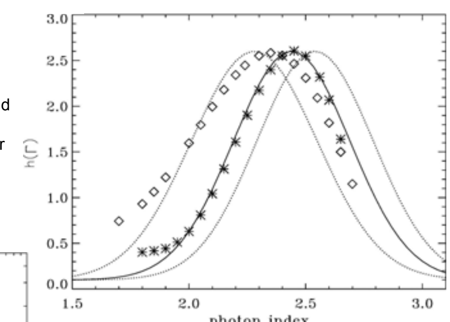

Figure 3: Observed (diamonds) and reconstructed intrinsic (stars) distribution of photon index h(Γ) for the 352 Fermi blazars used in this analysis.

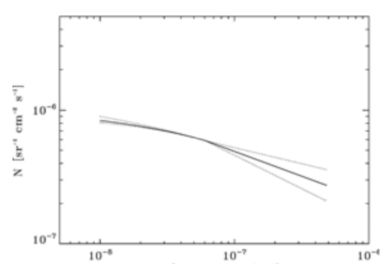

Figure 4: Estimate of the total cumulative photon density from blazars, The diffuse gamma-ray background would correspond to ~1 x10^{-5} cm^{-2} sec^{-1} sr^{-1} in these units.[6]

	n	β^a	$m_{above}{}^b$	$F_{break}{}^c$	$m_{below}{}^d$	μ^e	σ^f
Blazars[g] (this work)	352	0.02±0.08	-2.37±0.13	6.0	-1.70±0.26	2.41±0.13	0.25±0.03
Blazars[g] (MA)[5]	352	-	-2.48±0.13	7.39±1.01	-1.57±0.09	2.37±0.02	0.28±0.01
BL Lacs (this work)	163	0.04±0.09	-2.55±0.17	5.5	-1.61±0.27	2.13±0.13	0.24±0.02
BL Lacs (MA)[5]	163	-	-2.74±0.30	6.77±1.30	-1.72±0.14	2.18±0.02	0.23±0.01
FSRQs (this work)	161	-0.11±0.06	-2.22±0.09	6.0	-1.62±0.55	2.52±0.08	0.17±0.02
FSRQs (MA)[5]	161	-	-2.41±0.16	6.12±1.30	-0.70±0.30	2.48±0.02	0.18±0.01

[a] The correlation between photon index Γ and flux F_{100}. See Equation 1 and §3.1.
[b] The slope of the intrinsic flux distribution $\psi(F_{100})$ at fluxes above the break.
[c] The flux at which the power law break in $\psi(F_{100})$ occurs, in units of 10^{-8} photons cm^{-2} sec^{-1}. In MA this is a fit, while in this work it is a visual inspection, as precise location of the break is not important for this analysis.
[d] The slope of the intrinsic flux distribution $\psi(F_{100})$ at fluxes below the break.
[e] The mean of the Gaussian fit to the intrinsic photon index distribution $h(\Gamma)$. For the analysis here this includes the full range of results and their uncertainties when considering the 1σ range of β.
[f] The 1σ width of the Gaussian fit to the intrinsic photon index distribution $h(\Gamma)$.
[g] Including all FQRQs, BL Lacs, and 28 of unidentified type.