Analysis of the Spectral Energy Distributions of Fermi bright blazars

D. Gasparrini [1,2], S. Colafrancesco [1,3], S. Cutini [1,2], P. Giommi [1,3], S.Rainò [4,5], for the Fermi LAT collaboration

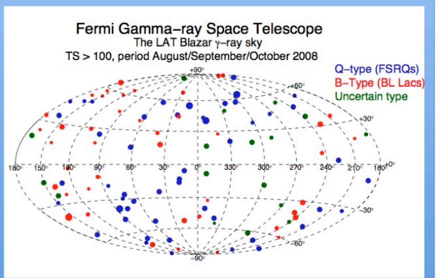
[1] Agenzia Spaziale Italiana (ASI) Science Data Center, I-00044 Frascati (Roma), Italy
[2] Consorzio Interuniversitario per la Fisica Spaziale (CIFS), I-10133 Torino, Italy
[3] Agenzia Spaziale Italiana (ASI), I-00198 Roma, Italy
[4] Dipartimento di Fisica, "M.Merlin" dell'Università e del Politecnico di Bari, Italy
[5] Istituto Nazionale di Fisica Nucleare, Sezione di Bari, 70126 Bari, Italy

Introduction

Blazars are a small fraction of all extragalactic sources but, unlike other objects, they are strong emitters across the entire electromagnetic spectrum. In this study we have conducted a detailed investigation of the broad-band spectral properties of the gamma-ray selected blazars of the Fermi LAT Bright AGN Sample (LBAS). By combining the accurately estimated Fermi gamma-ray spectra with Swift , radio, NIR-Optical and hard-X/gamma-ray data, collected within three months of the LBAS data taking period, we were able to assemble high-quality and quasi-simultaneous Spectral Energy Distributions (SED) for 48 LBAS blazars.

The sample:

The first results of the initial three months of operations of the Fermi gamma-ray observatory, from 4 August to 31 October 2008 are described in [1] who presented a list of 205 bright (>10σ) gamma-ray sources. A companion publication[2] studied the AGN content of this list associating 106 sources at |b| > 10° with AGN. This sample has been named the "LAT Bright AGN Sample" or LBAS.

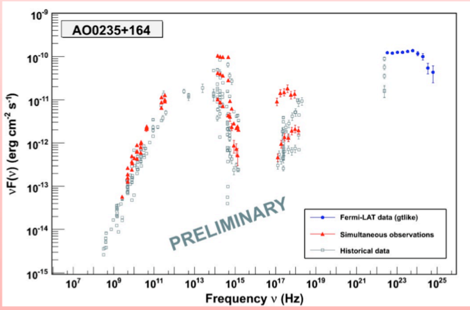


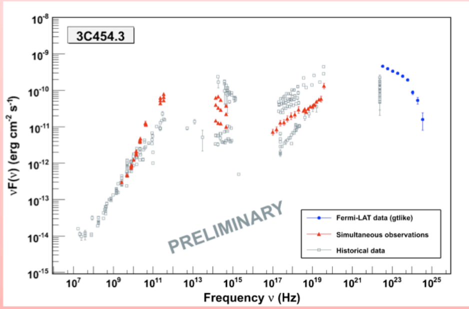
For 48 sources of the LBAS, we were able to combine Fermi-LAT three months gamma-rays data with simultaneous observations at other wavelengths [3].

Multi-frequency observations and Fermi-LAT analysis

Radio data come from OVRO[4] 40-m telescope (15 GHz), Effelsberg 100-m Radio Telescope (2.6 to 42 GHz, F-GAMMA project [5]), GASP-WEBT[6] (5 to 43 GHz and 230 to 345 GHz), RATAN-600[7] (1 to 22 GHz). NIR-Optical data come from GASP-WEBT collaboration, optical/UV data come from the Swift-UVOT [8], X-ray data come from Swift-XRT [8] and hard X-ray data from Swift-BAT survey[9].

Fermi-LAT data from 4 August to 30 October 2008 have been analyzed following two different methods. In the first case, spectra are reconstructed using Fermi science tool gtlike [10], where a parametric model is assumed in each individual energy bin for the source spectrum and for the background components and a maximum likelihood fit is performed. With the second method (whose results are not shown here), the spectra are evaluated using a deconvolution (unfolding) technique [11] based on the Bayes theorem, that allows to take energy dispersion into account. The results of the two different methods are consistent.



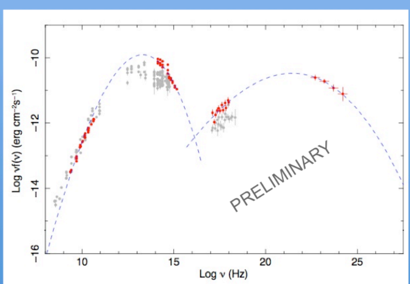


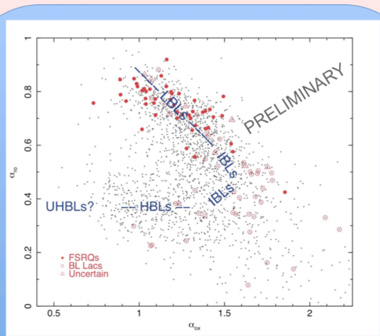
The figures above shows the SED of the Low- frequency peaked BL Lac (LBL) object AO 0235+164 and the SED of the well known Flat Spectrum Radio Quasar 3C 454.3.

Blazar SED observational parameters

In all cases the overall shape of the SEDs exhibit the typical broad double hump distribution, where the first bump is attributed to synchrotron radiation and the second one is likely due to one or more components related to inverse Compton emission.

We estimate some key observational parameters that characterize the SED of our blazars: the peak frequency and peak flux of the synchrotron component (ν^S_{peak} , $\nu^S_{peak}F(\nu^S_{peak})$), and the peak frequency and flux of the inverse Compton part of the SED (ν^{IC}_{peak} and $\nu^{IC}_{peak}F(\nu^{IC}_{peak})$. The estimation of both the peak frequency and flux is obtained from the 48 SED fitting the single bump (synchrotron or Inverse Compton) with a 3rd degree polynomial function. The figure aside shows the SED of PKS0851+202 with the dashed line of the fits.





The α_{xo}-α_{ro} plot of the LBAS sample is shown above which also includes all blazars in the BZCat catalog[12] for which we have radio, optical and X-ray measurements (small red dots). Note that Fermi FSRQs (filled circles), like all FSRQs discovered in any other energy band, are exclusively located along the top-left / bottom-right band, whereas BL Lacs (open circles) can be found in all parts of the plane, albeit with a prevalence in the horizontal area defined by values of α_{ro} between 0.2 and 0.4, which is where HBL sources are located[13]. The area of the α_{xo}-α_{ro} space where the hypothetical population of UHBL (ultra high energy peaked) blazars, in which the synchrotron component would be so energetic to peak in the MeV region [14] could have been found, is empty, implying that these sources are either very rare, very weak or non existent[15].

As shown by [13], the peak of the synchrotron power ν^S_{peak} in the SED of a blazar determines its position in the α_{xo}-α_{ro} plane. In this way, starting from the α_{xo}-α_{ro} plot of all LBAS objects, we have calibrated this relationship using the ν^S_{peak} values directly measured from our 48 quasi-simultaneous SED and the corresponding α_{xo} and α_{ro} values.

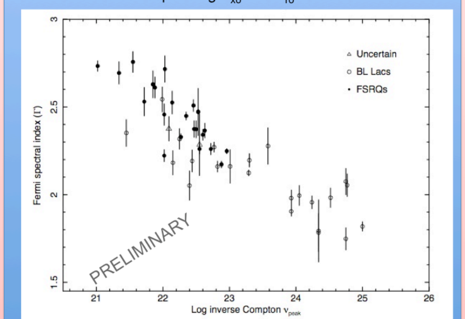


Figure above shows that ν^{IC}_{peak} for the 48 sources for which we have built the SEDs, is strongly correlated with their gamma-ray spectral slope (Γ) taken from [2]. Since the 48 objects for which we have quasi-simultaneous SEDs are representative of the entire LBAS sample the above correlation can be used to estimate the ν^{IC}_{peak} of the LBAS sources for which we have no simultaneous SEDs.

Conclusions

✓For the first time high-quality quasi-simultaneous SED of blazars are available for a considerable number of blazars and this subset is representative of the entire LBAS.

✓All Fermi bright blazars have broad-band spectral properties similar to radio and X-ray selected blazars (double bump SEDs, same area of α_{xo}-α_{ro} plane, no UHBLs…)

✓We have estimated the synchrotron and IC peak energy and intensities for all 106 sources in the LBAS sample. The distribution of the synchrotron peak frequency is very different for the FSRQ and BL Lac subsamples with values of ν^S_{peak} located between $10^{12.5}$ and $10^{14.5}$ Hz in FSRQ and between 10^{13} and 10^{17} Hz in BL Lacs.

References:
[1] A.A. Abdo et al., Astrophysical Journal Supplement, 183, 46-66, 2009
[2] A.A. Abdo et al., The Astrophysical Journal, 700, 597–622, 2009
[3] A.A. Abdo et al., The Spectral Energy Distributions of Fermi bright blazars, in preparation
[4] http://www.astro.caltech.edu/Fermi-GST
[5] L. Fuhrmann et al., The First GLAST Symposium, AIPC, 921, 249, 2007
[6] http://www.oato.inaf.it/blazars/webt
[7] D. V. Korolkov & Yu. N. Parijskij, Sky Telesc., 57, 324,1979
[8] N. Gehrels et al., The Astrophysical Journal, 611, 1005, 2004
[9] M. Ajello et al., The Astrophysical Journal, 673, 96, 2008
[10] http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone
[11] M.N. Mazziotta, A method to unfold the energy spectra of point like sources from the Fermi-LAT data, ICRC proceedings 2009
[12] E. Massaro et al., Astronomy and Astrophysics, 495, 2, 691-696, 2009
[13] P. Padovani & P. Giommi, The Astrophysical Journal, 444, 567, 1995
[14] G. Ghisellini, Astrophysical Letters and Communications, 39, 17, 1999
[15] L. Costamante, The First GLAST Symposium, AIPC, 921, 157-159, 2007