Spectral properties of Bright Fermi-detected Blazars in the Gamma-ray band

L. Escande & B. Lott

CNRS/IN2P3, Université de Bordeaux, Centre d'Etudes Nucléaires Bordeaux Gradignan, UMR 5797, F-33175 Gradignan, France

escande@cenbg.in2p3.fr lott@cenbg.in2p3.fr

on behalf of the Fermi-LAT collaboration

Abstract

The gamma-ray spectral energy distributions of bright blazars of the LAT Bright AGNs Sample (LBAS) are investigated. Spectral properties (hardness, curvature and variability) established using a data set accumulated over 6 months of operation are presented and discussed for different blazar classes and subclasses: Flat Spectrum Radio Quasars- / BLLacs and Low-, Intermediate- and High-Synchrotron Peaked sources.

Motivation

In the LBAS (LAT Bright AGNs Sample) paper (Abdo et al., 2009a), a distinct spectral separation between FSRQs ans BLLacs was observed with FSRQs having significantly softer spectra. Moreover, for some bright sources that exhibited evident breaks or curvatures in their spectra, a PL model was clearly not the most appropriate choice. Our aim is to investigate the spectral properties of different blazar classes and subclasses in more details.

In this work we employ the conventional definition of BL Lac objects outlined in Stocke et al. (1991) ; Urry & Padovani (1995), Marcha et al. (1996). Sources were assigned to different subclasses (LSPs, ISPs and HSPs standing for Low-, Intermediate-, and High-Synchrotron Peaked sources respectively) according to the position of their Synchrotron peak established from radio, optical, UV and X-ray data : $\nu_{peak}<10^{14}$ Hz for LSPs, 10^{14} Hz$<\nu_{peak}<10^{15}$ Hz for ISPs and $\nu_{peak}>10^{15}$ Hz for HSPs (Abdo & al. 2009b).

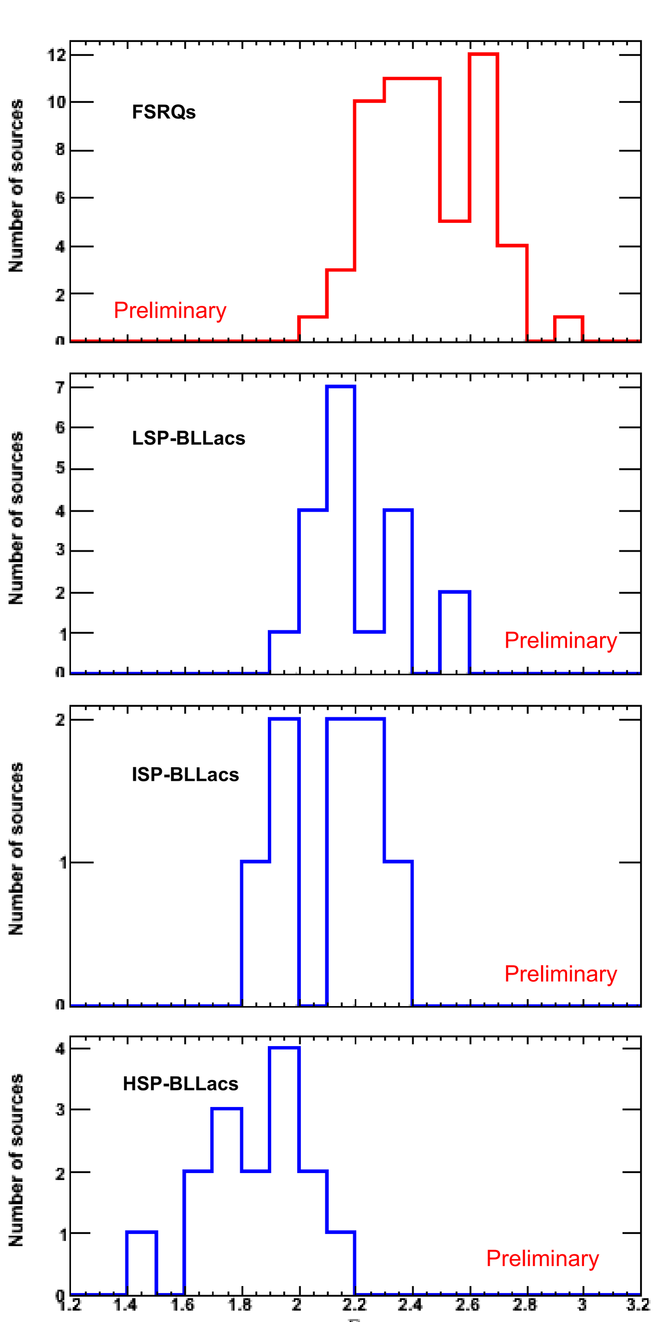
Data selection

The data were collected from Aug. 4 2008 to Feb. 1 2009 (about 6 months) in survey mode. Only photons with energies greater than 100 MeV were considered in this analysis to minimize systematics. The « diffuse » class event was considered and a selection on the zenith angle, < 105°, was applied. The v9r12 version of the Science Tools was used. The instrument response function set « P6_V3_DIFFUSE » was employed and photons were selected in a circular 7 deg-in-radius region of interest (ROI). The isotropic background was modeled by a power-law. We also modeled the galactic diffuse emission by GALPROP « gll_iem_v01 ».

Photon index distributions

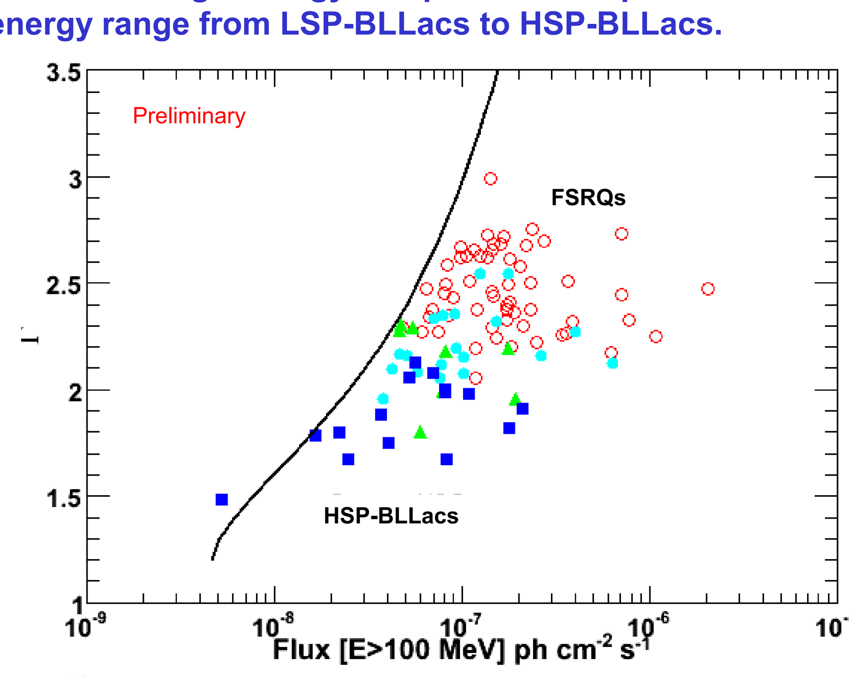
The remarkable spectral separation between FSRQs and BLLacs already found in Abdo et al. (2009a) is of course still observed for spectra averaged over a 6-month time span. Likewise, different BLLacs subclasses are associated with distinct photon index distributions in the Lat range.

Gamma-ray photon index distributions for the four blazar subclasses.



FSRQs are softer than BLLacs, with a gamma-ray photon index greater than 2, indicating that the peak of the high-energy component is always lower than 100 MeV.

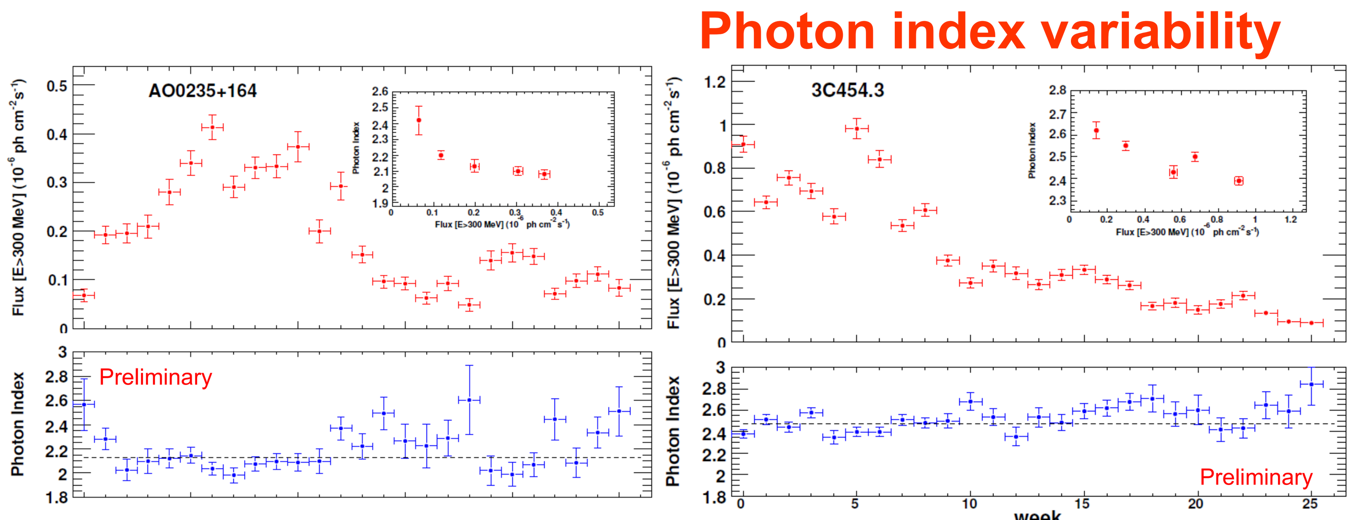
For BLLacs, the gamma-ray photon index correlates with the different BLLac subclasses which themselves are defined by the position of the synchrotron peak. The measured photon index shifts from Γ>2 to Γ<2, indicating that the peak energy of the SED high-energy component sweeps across the Fermi energy range from LSP-BLLacs to HSP-BLLacs.



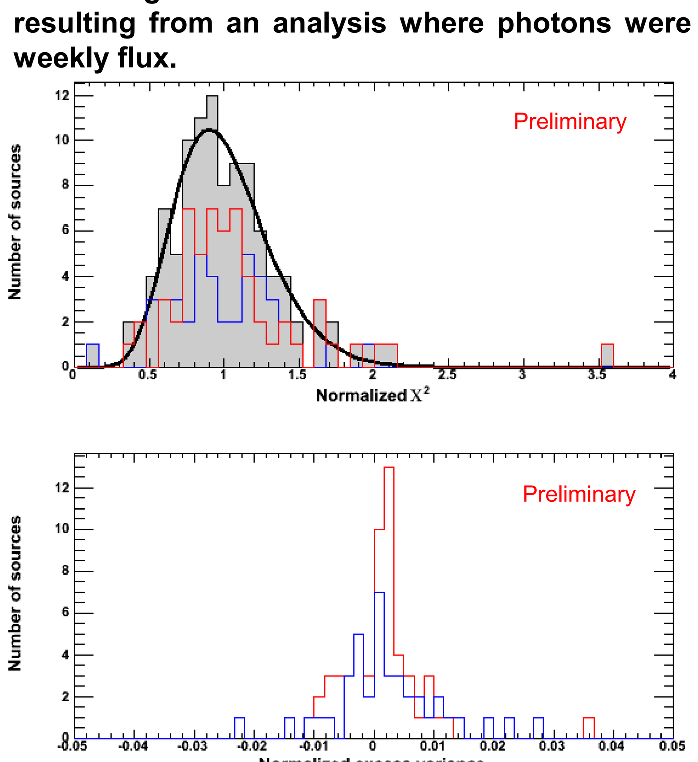
Photon index vs Flux (E>100 MeV) for the LBAS sources considered here. Red circles : FSRQ, open circles: BLLacs (cyan: LSP-BLLacs, green: ISP-BLLacs, blue : HSP-BLLacs). The solid curve represents the TS=100 limit for a 3 month period estimated for (l,b)=(80°, 40°).

This figure shows that the LBAS sample has an intrinsic bias as faint sources can more easily be detected if they are hard.

Photon index variability



Measured weakly fluxes and photon index for 3C454.3 and AO0235+164. A weak « harder when brighter » effect can be seen for both sources. The insets show the photon index resulting from an analysis where photons were sorted in five weekly-flux bins plotted vs the weekly flux.

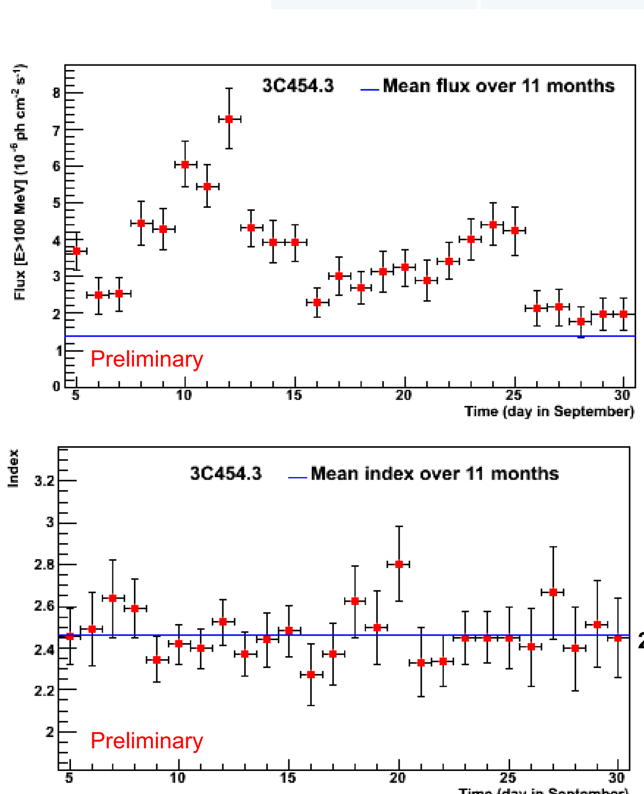


Top : Normalized χ^2 distributions of the weekly photon indices for FSRQs (red), BLLacs (blue) and all sources (black).

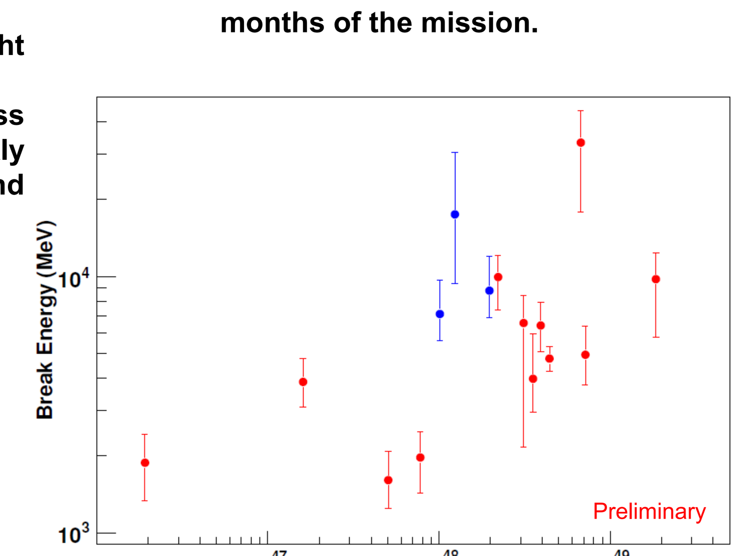
The means of these distributions are close to 1, as expected for a constant photon index, with no significant differences between FSRQs and BLLacs. These observations do demonstrate that the photon index in the GeV range is remarkably constant as a function of time and within a blazar (sub)class.

The farther point on the right represents PKS1502+106.

Bottom : Normalized excess variance distributions of the weekly photon indices for FSRQs (red) and BLLacs (blue).



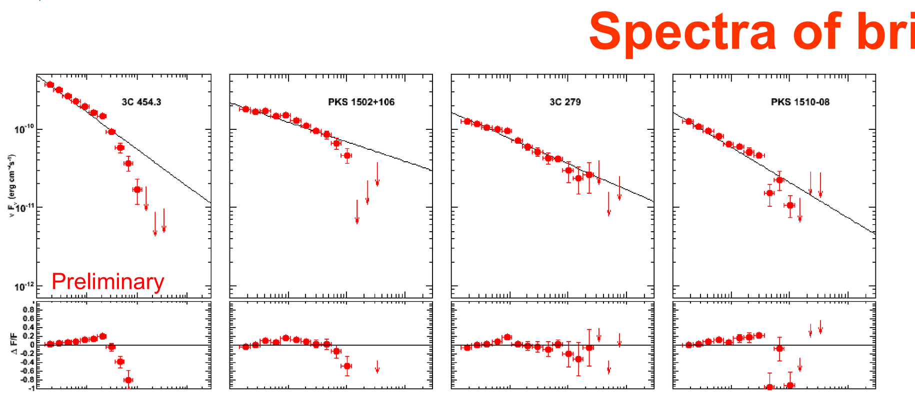
3C454.3 has recently experienced a period of strong flare which offered us an opportunity to test the strength of the correlation between the flux and the gamma spectral index. The blue lines correspond to the mean flux and the mean gamma spectral index calculated over the first eleven months of the mission.



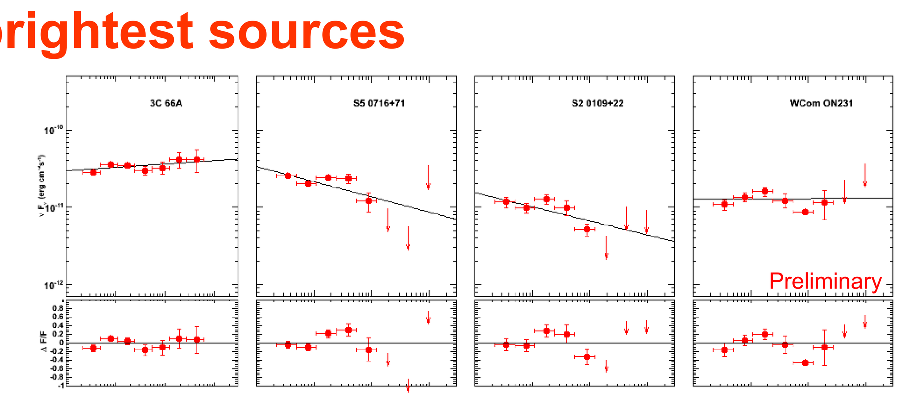
Break energy vs gamma-ray luminosity for FSRQs (red symbols) and LSP-BLLacs (blue symbols).

Results

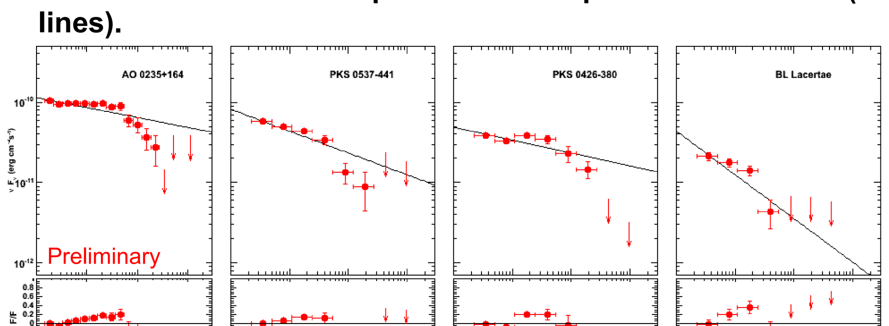
Spectra of brightest sources



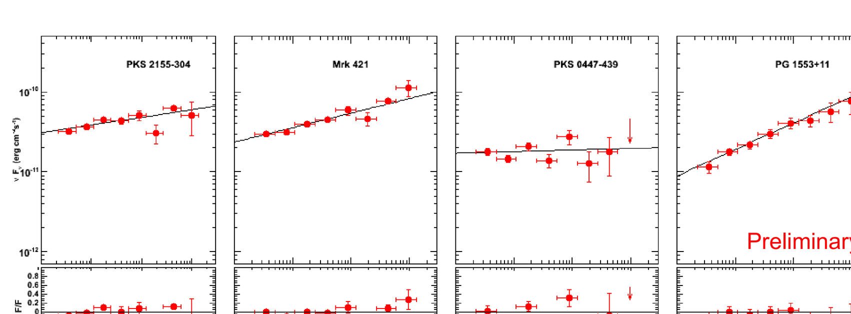
Gamma-ray spectra of the eight brightest FSRQs in the LBAS sample obtained for equispaced logarithmic bins (dot), together with residues with respect to fitted power-law model (solid lines).



Gamma-ray spectra of the eight brightest ISP-BLLacs.



Gamma-ray spectra of the eight brightest LSP-BLLacs.

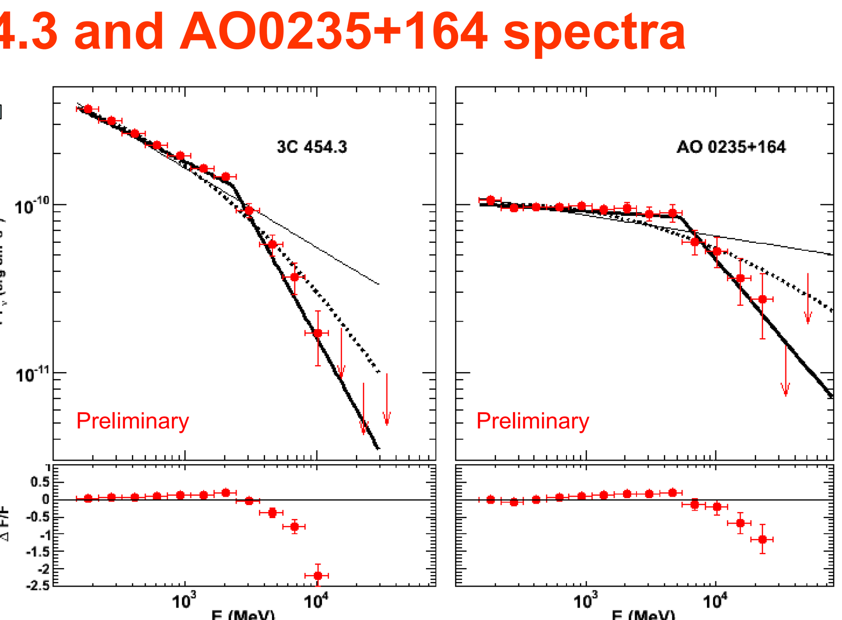


Gamma-ray spectra of the eight brightest HSP-BLLacs.

The brightest FSRQ, 3C454.3, exhibits a well pronounced break around 2 GeV as reported in Abdo et al. (2009b). Indications for breaks between 1 and 10 GeV are observed for essentially all of these FSRQ sources. The presence of a break is also clear for two of the brightest LSP-BLLacs : AO0235+164 ans PKS0537-441. Some ISP-BLLacs present clear signs of breaks (e.g. S50716+71, S20109+22). Finally, no bright HSP-BLLacs shows any evidence for a break in the LAT energy range which rules out any instrumental effect. A Klein-Nishina break is predicted to set in around 15δ/Γ(1+z) GeV, where Γ is the blob bulk Lorentz factor, which is significantly higher than the energies found here.

Detailed analysis of 3C454.3 and AO0235+164 spectra

Upper panels : spectra of 3C454.3 (left) and AO0235+164 (right) compared with different models : PL (thin solid), BPL (thick solid) and logparabola (dashed). For 3C454.3 and AO0235+164, the two brightest FSRQ source and LSP-BLLac source respectively, a broken power law gives the most acceptable model tested to the data.

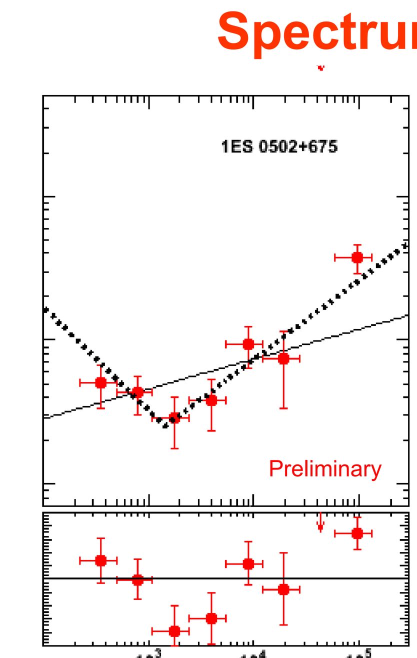


Parameters of BPL model :

Source	F[E>100 MeV]	Γ_1	Γ_2	E_{break} (GeV)
3C454.3	1.97+/-0.03	2.39+/-0.02	3.42+/-0.11	2.5+/-0.3
AO0235+164	0.60+/-0.02	2.05+/-0.02	2.95+/-0.16	4.5+1.5-1.0

The similarity of the break feature for two sources belonging to different subclasses, FSRQ and LSP-BLLac, with different line strengths seems to rule out any absorption effect related to the latter.

Spectrum of a special source



1ES0502+675, a particular HSP-BLLac, exhibits an unusual concave spectrum.

Conclusion

The average photon index of LBAS blazars are found to be Γ=2.46 for FSRQs, Γ=2.21 for LSP-BLLacs, Γ=2.13 for ISP-BLLacs and Γ=1.86 for HSP-BLLacs, with an rms of 0.16-0.18. Spectral breaks have been observed to be common features in FSRQs and present also in some bright LSP-BLLacs. The different spectral features reported here represent challenges for theoretical models aiming at describing the blazar phenomenon. Although the fairly strong correlation between photon index and blazar class fits well within pictures where the cooling due to strong ambient radiation fields limits the acceleration of particles at high energy, the near constancy of this photon index with time and flux variation provides new constraints on the emitting particle dynamics. Moreover, the fact that spectra for most FSRQs and some LSP-BLLacs are best modeled by a BPL with a break in the 1-10 GeV range is quite unexpected, the break representing a distinctive feature of these sources.

References

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