# A Warning on the GeV-TeV Connection in Blazars


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## Summary:

**- Fermi-LAT spectra at high energies (HE, 0.1-100 GeV) are often extrapolated to very high energies (VHE, ≥100 GeV), and considered either a good estimate or an upper limit for the blazars intrinsic VHE spectrum.**

**-This assumption seems not well justified, neither theoretically nor observationally. Observations do indicate that VHE spectra could very well be harder than HE spectra, while they still corroborate the more general and robust Γ≥1.5 limit.**

**-Limits on the extragalactic background light (EBL) or on a source redshift based on such GeV-TeV assumption are generally not reliable, and should be considered with caution. It's now time to "fix" the EBL and learn more about blazars.**


## Introduction

Recently, the well-determined Fermi-LAT spectra (or Upper Limits, UL) in the MeV-GeV band for several TeV blazars are often used to derive stronger constraints on the diffuse extragalactic background light (EBL), or to constrain the distance for BL Lacs of uncertain redshift.
(e.g. Abdo et al. 2010b, Orr et al. 2011, several presentations of VHE Collaborations.)

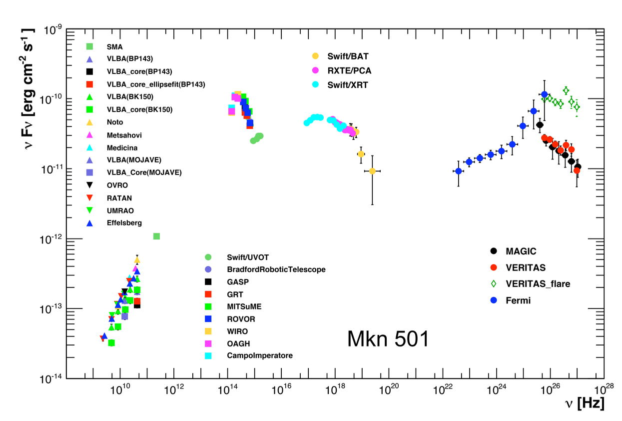
The underlying assumption of these studies is that the extrapolation of the Fermi-LAT spectrum to the VHE band is either a good estimate or an upper limit for the intrinsic VHE spectrum of the source, since they belong to the same SED hump.

However, the progress in the last decade shows that this assumption is not well justified anymore.

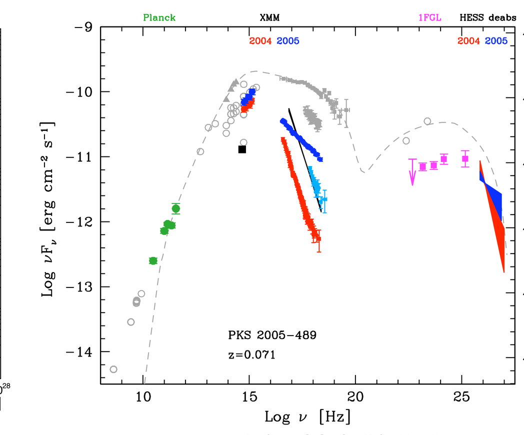
## Before EBL absorption, are VHE spectra usually different from HE (Fermi-LAT) spectra ? YES

Blazars display a wide range of SED peak energies, as well as of emission components (in time and space along the jet), and the VHE band samples the highest energies of the particle distribution. The extrapolation of the HE spectrum to the VHE band is in general NEVER a good assumption.

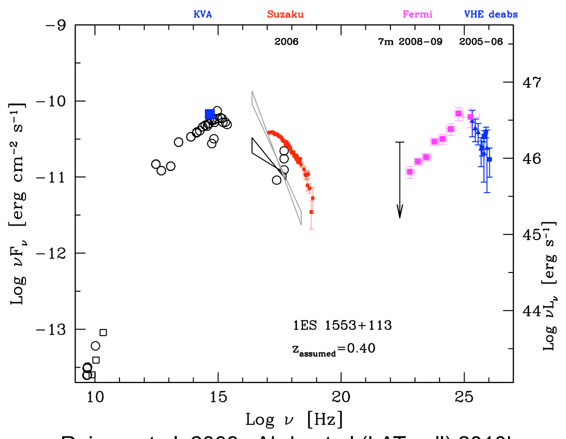
A) Can it be softer ? YES, directly observed in the majority of Fermi-bright HBL; e.g.:
(see Abdo et al. (LAT coll) 2010c)



Abdo et al. (LAT Coll.) 2011



Acero et al. (HESS Coll.) 2010



Reimer et al. 2009; Abdo et al.(LAT coll) 2010b
Redshift constraints from Danforth et al. 2010.

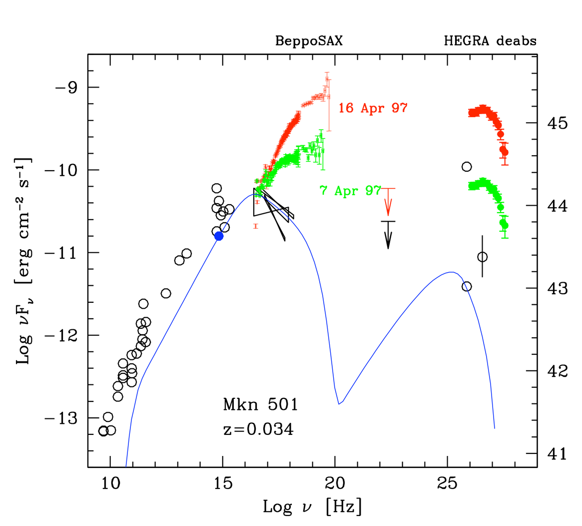
B) **But:** can it be harder ? **Can the Fermi-LAT spectral index be used as reasonable upper limit for the hardness of the VHE index ?**

Concave HE-VHE spectra have not been observed (yet) directly, but let's consider the observational (as well as theoretical) evidence...

## 1) BL Lacs show already multiple spectral components in their synchrotron emission

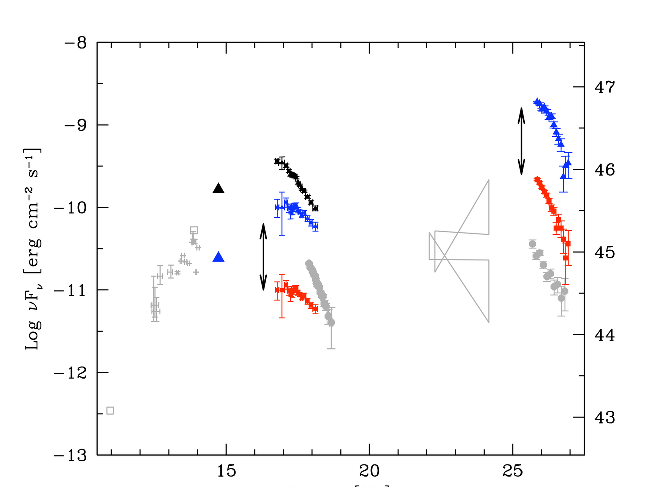
**which traces directly the different electron spectra. In many cases we have seen the superposition of two different emission components at high electron energies, with a new component emerging over a previous/steadier SED. Classical examples:**

Mkn 501 in 1997



Pian et al. 1998, Aharonian et al. (HEGRA Coll.) 2001

PKS 2155-304 in 2006



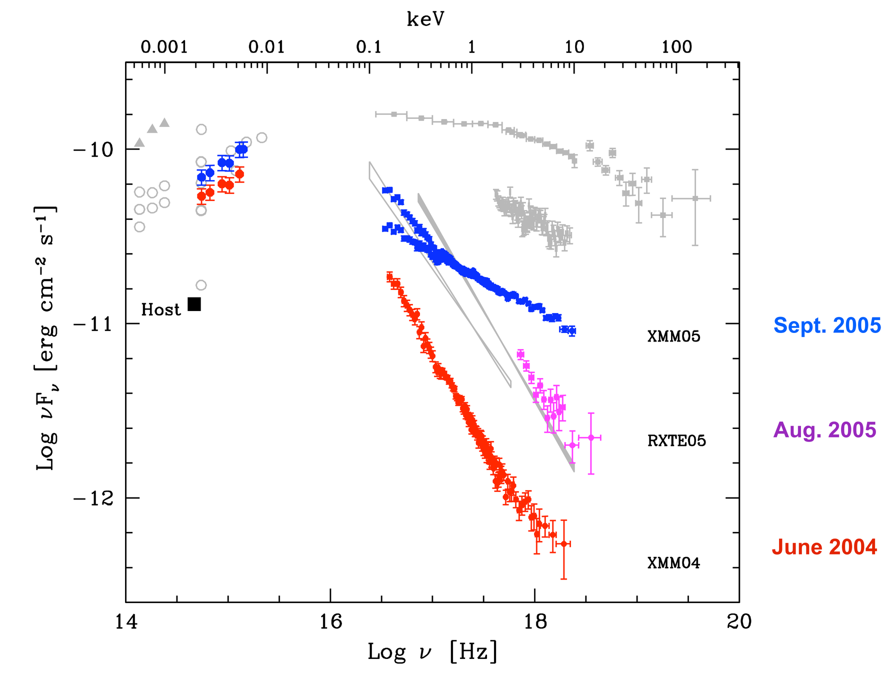
Aharonian et al. (HESS Coll.) 2009

Interpretation of the peculiar spectral and timing properties of the 2006 VHE flare as superposition of two SEDs from two different zones. The observed SED cannot be explained with a single SSC component.

The same can happen in the Compton emission.

## 2) Multiple components are seen also outside flaring episodes, on long (year) timescales

**One of the most evident cases showed up in the 2004-2005 multiwavelength campaigns on PKS 2005-489, in the synchrotron emission:**

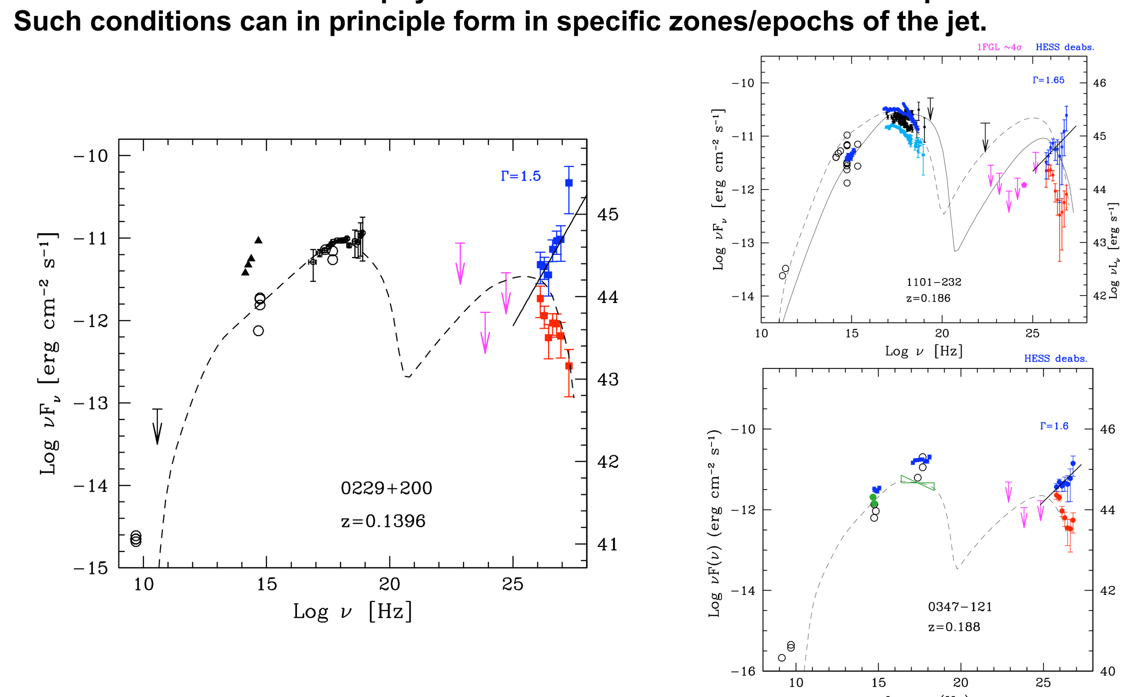



SED of PKS 2005-489 zoomed in the optical-X-ray band. Blue data correspond to the XMM spectrum in 2005 corrected for two different estimates of Galactic Nh (5.08 or 3.93 E20 cm-2). Even with the lowest Galactic column density, in 2005 the X-ray spectrum cannot be joined to the UV data from the OM with a single smooth spectral component. The X-ray band was becoming more and more dominated by a new harder emission component emerging in the SED, which probably reached its maximum in June 2009 (Kaufmann et al. 2009; Abramowski et al. 2011).

From Aharonian et al. (HESS Coll.) 2010.

## 3) At VHE, intrinsic spectra as hard as Γ=1.5-1.6 are already observed (with a low EBL level).

**This demonstrates that the physical conditions in blazars do allow spectra as hard as 1.5. Such conditions can in principle form in specific zones/epochs of the jet.**




Examples of SED of selected HBL, characterized by hard TeV spectra with every level of the EBL. The VHE spectra (blue points) plotted here are corrected for gamma-gamma absorption on photons of the EBL according to Franceschini et al 2008 (very similar results are obtained using EBL calculations by Dominguez et al 2011). Higher levels of the EBL would make the intrinsic spectra even harder.

Data and historical modeling from Costamante et al. 2001, 2002; Abdo et al. (LAT Coll.) 2010, Aharonian et al. (HESS Col.l) 2007a, 2007b, 2007c, Ghisellini et al. 2002, Reimer et al. 2008, Tavecchio et al. 2011.

The SED of such components can remain hidden below a more "standard" emission and emerge/become dominant only at VHE

## 1) + 2) + 3) = Spectra at VHE can very well be harder than at HE !!

Over such a wide range of energies (5 orders of magnitude !), it seems not only possible but even likely that in some cases, a combination of different spectral components (either in time or from different particle populations or different emission mechanisms for the same particles) can result in concave overall spectra.

*It seems only a matter of time (and statistics) before upturns somewhere in the overall 100 MeV - 10 TeV band are directly and significantly detected in the simultaneous gamma-ray spectrum of some blazars.*
**It should NOT be surprising ! The observational ingredients are all there !**

**Thus, in general, Fermi-LAT spectra cannot be reliably used as UL to:**
**➪ derive constraints on redshift / distances**
**➪ put stronger limits on the intensity of the EBL**

The results would be as weak/unreliable as their assumptions.

## For EBL studies, the Γ=1.5 limit for the intrinsic photon index is still a more robust benchmark

- Though it is not a "hard" limit (theoretically there are many mechanisms to obtain harder spectra), at present it still represents the borderline between observational reality and speculation.

- So far, intrinsic spectra with Γ<1.5 (±0.2) have never been observed in blazars at high electron energies (e.g. $\gamma > 10^3$), neither in the synchrotron nor inverse Compton emission (Γ ~1.2-1 was observed at X-ray energies in low-energy-peaked blazars, but as a low-energy cutoff at low electron energies; therefore, this could become a possible feature in the Fermi-LAT band, for some TeV-peaked sources, but would not invalidate per se the 1.5 limit at VHE).

- Cosmic conspiracy: an hypothetical VHE spectrum with intrinsic slope Γ<1.5 could be easily revealed, if the 1.5 limit required an EBL flux below the lower limits by galaxy counts. But so far all VHE spectra are compatible with the redshift–Γ relation of a low EBL absorption and Γ≥1.5.

Aharonian et al. (HESS Coll.), Nature, 2006. Costamante et al. 2007.

At present the EBL spectrum between 0.1 and 10 μm is known within a factor of 2, much better than blazars' high-energy emission: it's time to "assume" the EBL and focus to understand better the blazar properties.

References: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