On the intrinsic VHE properties of the BL Lac H 2356-304

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Summary:

- The high-energy-peaked (HBL) BL Lac H 2356-309 (z=0.165) has been detected at Very High Energies (VHE, >100 GeV) by HESS with high significance in the period 2004-2006, during which multi-wavelength campaigns were performed.

- Corrected for absorption on the Extragalactic Background Light (EBL), its VHE spectrum is flat (Γ~1.9-2) over 1 decade in energy, locating the Compton peak above 0.6-1 TeV. This is 1-to-2 orders of magnitude higher than claimed by HESS.

- The HESS modeling is not valid because it does not reproduce the main gamma-ray properties of this object. These seem intermediate between GeV-peaked and TeV-peaked HBL, and very different from its synchrotron emission.

Introduction

The BL Lac H 2356-309 (z=0.165) is a high-frequency-peaked blazar, so-called HBL or HSP type, and very bright in the X-ray band.

It was detected at VHE by HESS for the first time in 2004 (Aharonian et al 2006a, 2006b). Its hard VHE spectrum, harder than expected from the effects of gamma-gamma absorption on the diffuse EBL at its relatively high redshift, contributed to the discovery of a low intensity of the EBL in the component produced by the direct stellar light (Aharonian et al., Nature, 2006a).

Since 2004, it has been monitored for several years by HESS, with an average flux of ~1.6 % of the Crab flux (>240 GeV).
Three simultaneous multi-wavelength campaigns were performed in 2004 and 2005, with RXTE and XMM (Aharonian et al 2006b, Costamante et al. 2008).

Recently, the overall results of the campaigns, the VHE monitoring and a SSC (synchrotron self-Compton) modeling were published by the HESS Collaboration in Abramowski et al. 2010.

In this paper, the interpretation of the data is very different from what previously published, and is highly questionable. This poster presents the counter-arguments and try to provide a more accurate description of this object's gamma-ray properties (from HE to VHE).

General problem of plotting VHE data

When presenting the SEDs of TeV blazars, it is becoming customary **to plot only the observed (not EBL-corrected) data points**, and instead to absorb the possible model/curve, plotting at most the model curves before EBL absorption.

THIS IS A MISLEADING AND DANGEROUS HABIT, AND SHOULD BE AVOIDED !

Even if it is the safest method for a statistical analysis of the data and to derive the fitting parameters, for plotting purposes it does not accurately show the object SED features (misleading viewers on the true SED properties), and creates confusion when fitting a model (e.g. SSC) because all curves seem to fit well the data when spectra are very steep.

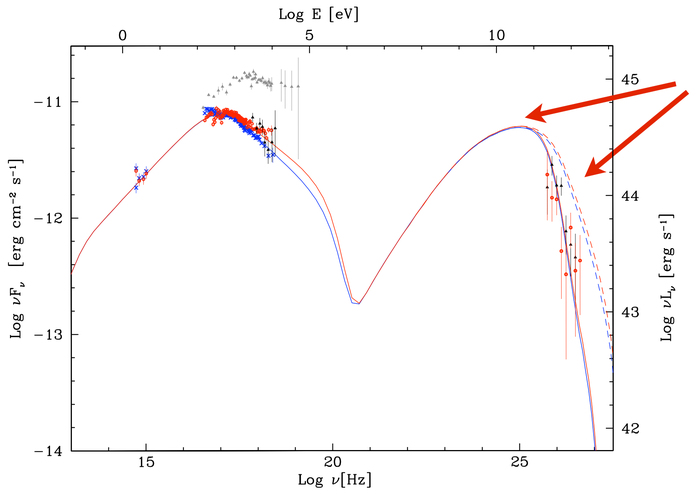
Correcting the data points for EBL (e.g. with tau calculated at the average photon energy in the bin, which provides equivalent fits to an absorbed model), and **plotting the EBL de-absorbed data/slope, provides a more accurate representation of the SOURCE real properties** (which is the focus of a SED study), and not those of intervening systems.

It also achieves consistency with the conventions in the other energy bands:

a) in the Optical-UV bands, data are usually plotted with correction for Galactic extinction.

b) in the X-ray band, data/slopes are always shown with correction for Galactic or line-of-sight intervening column density N_H. (otherwise any extragalactic object would ALWAYS show a SED with fake peak typically at ~1-2 keV or more).

The HESS mistake: wrong assessment of the VHE gamma-ray properties !



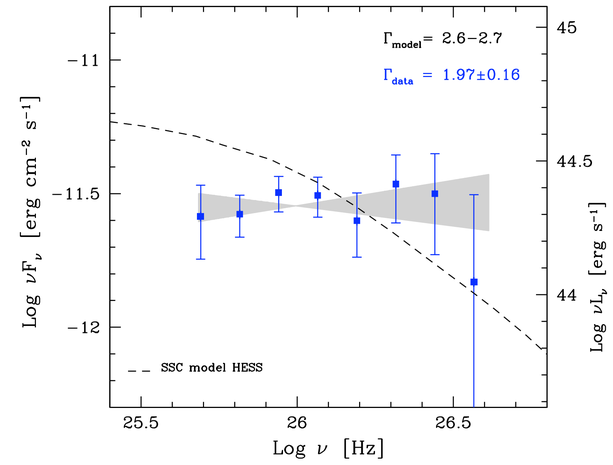
SED of H 2356-309 in different epochs, from the HESS paper (Abramowski et al. 2010). The XMM observations in 2005 are plotted in color, (on June 13 and June 15), together with the observed (not deabsorbed) HESS spectra in **2004 (black triangles)** and 2005 (red dots). The curves are fits of the respective SEDs in a single-zone SSC model, as derived by the HESS Collaboration, with (solid lines) and without (dashed lines) the EBL effects included (Franceschini et al 2008). The two fits are almost identical in the VHE range, and the SSC modeling by **HESS claims to represent well the SED with a Compton peak around 50- 100 GeV and a steep VHE slope (Γ~2.6-2.7). Wrong !**

Table 2. Results of power-law fits to the VHE spectra of H 2356–309.

Epoch	E_{min} [TeV]	E_{max} [TeV]	Γ	I_0^a [10^{-13} cm^{-2} s^{-1} TeV^{-1}]	χ^2	NDF	$P(\chi^2)$
2004 (AH06)[b]	0.165	1.041	$3.06 \pm 0.21_{stat} \pm 0.10_{syst}$	$3.08 \pm 0.75_{stat} \pm 0.62_{syst}$	3.9	6	0.69
2004[c]	0.200	1.500	$2.97 \pm 0.19_{stat} \pm 0.10_{syst}$	$4.69 \pm 0.86_{stat} \pm 0.94_{syst}$	7.8	5	0.17
2005	0.200	2.000	$2.99 \pm 0.39_{stat} \pm 0.10_{syst}$	$2.92 \pm 0.89_{stat} \pm 0.58_{syst}$	5.0	6	0.55
2006[d]	0.200	2.000	$3.43 \pm 0.41_{stat} \pm 0.10_{syst}$	$2.13 \pm 0.79_{stat} \pm 0.43_{syst}$	0.7	2	0.70
Total	0.200	2.000	$3.06 \pm 0.15_{stat} \pm 0.10_{syst}$	$3.29 \pm 0.45_{stat} \pm 0.66_{syst}$	5.7	6	0.47

Notes. [a] The differential flux normalization is calculated at 1 TeV. [b] The AH06 entry is the previously published HESS result (Aharonian et al. 2006a) for the 2004 data and is not corrected for long-term changes in the optical efficiency of the system. [c] This 2004 entry is derived from the exact same data as presented in AH06, but with a correction (see text) applied to account for the optical efficiency changes within the data. The 2005, 2006 and total entries also have this correction applied. [d] Due to low statistics, the 2006 spectrum is determined using 4 bins/decade in energy instead of the 8 bins/decade used for the other photon spectra.

Model is excluded by the data at ~99.99% confidence level !



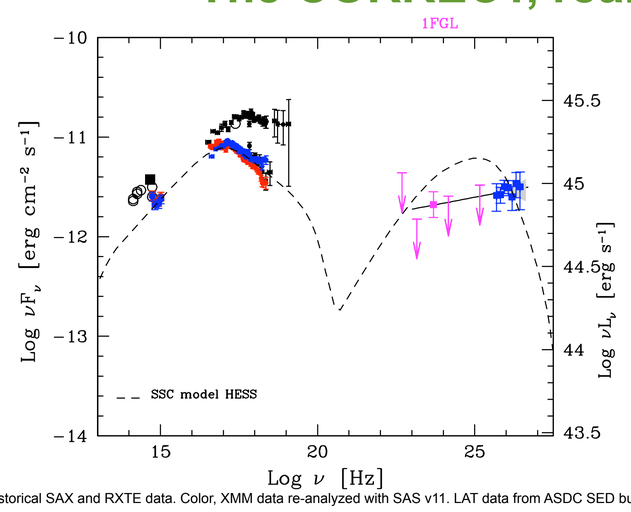
Zoom in the VHE band: in Blue, corrected for EBL absorption, is the overall 2004-2006 average HESS data (mostly dominated --90% of the excess-- by the 2004-2005 data set; in addition, the 2006 data set seems steeper than 2004-2005, so the real 2004-2005 spectrum is likely harder than the average one).

The MODEL intrinsic photon index is around 2.65-2.7 in the HESS energy band. The DATA photon index, corrected for EBL absorption using the model by Franceschini et al. 2008, is $\Gamma=1.97\pm0.16_{stat}$, or $\Gamma=1.91\pm0.18_{stat}$ excluding the last point (which is more of an upper limit). With a power-law model, the $\Delta\chi^2$ needed to recover the MODEL index is 15.0, corresponding to a probability of 1E-4 (1 param.).

One could argue that the HESS SSC modeling is for two different (single) epochs, and that the lower statistics of each single dataset makes both models more viable.
This is **not a valid argument**: since they have both identical slopes/characteristics, if they represented the real spectra they should fit well also the sum of the two states, which is not the case (see above).
If only one of the two were correct, the other should be much harder than 1.9, to compensate, but again this seems not the case (see Table left, where the 2004 and 2005 slopes are identical).

Simply stated, the model does not correspond to the data as observed, or to the object's SED properties, and thus the SSC analysis based on its parameters should be discarded.

The CORRECT, real SED properties of H 2356-309



Black, historical SAX and RXTE data. Color, XMM data re-analyzed with SAS v11. LAT data from ASDC SED builder.

The CORRECT intrinsic VHE properties of H 2356-304, as given by the HESS data, are:

1) a flat spectrum of index ~1.9-2 over the whole HESS band, which locates

2) the Compton peak either around 600 GeV (as determined by a log-parabolic fit), or above ~1 TeV (according to the power-law fit). The statistics do not allow yet to distinguish.

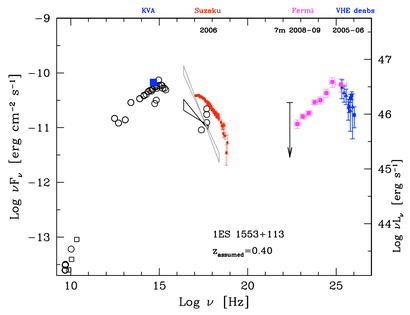
Quite interestingly, **the extrapolation** of the HESS 2004-2006 average spectrum t**o the Fermi-LAT band corresponds almost "spot on" to the one-year 1-FGL catalog fluxes** (2008-2009, TS=50, detection mainly 1-3 GeV; Abdo et al. 2010). A single power-law model over 3 decades in energy provides surprisingly a good fit (χ_r^2~0.3) with $\Gamma=1.94\pm0.03$.

With the big caveat of the non-simultaneity of the gamma-ray data, and of the different integration times of the Optical-to-X-ray data vs gamma-ray data, such a gamma-ray spectrum is not easy to model within one-zone SSC scenarios, given the very different (and more peaked) synchrotron emission (which reveals directly the slopes of the electron spectrum).
The overall, average SED seems however synchrotron dominated (and so the electron cooling).

The Compton-peak properties of H 2356-309 seem intermediate between two types of HBL objects:

The ~100 GeV-peaked HBL

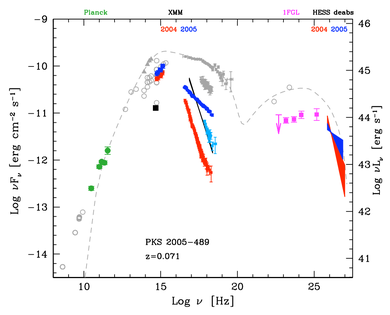
- soft intrinsic VHE spectra (Γ > 2-2.2)
- bright in Fermi (Compton peak closer to Fermi band), easily detected



At VHE, all EBL-corrected data with Franceschini 2008.

For 1ES 1553+113, redshift constrained with HST/Cos data (Danforth et al. 2010). Fermi-LAT data and analysis, plus other data, from Abdo et al. 2010b.

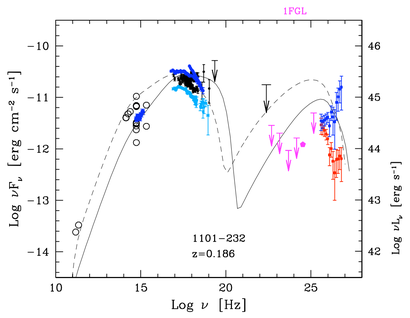
For PKS 2155-304, data and analysis from Acero et al. 2010, updated with Abdo et al. 2010a and Planck catalog.



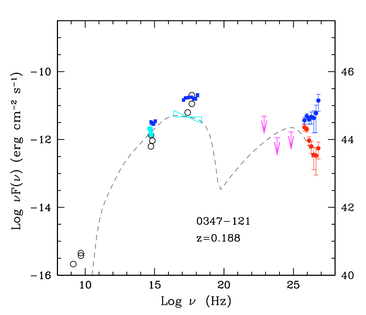
Relatively easy to model with usual, standard SSC parameters

The TeV-peaked HBL

- hard intrinsic VHE spectra, with any EBL model (Γ < 2 ; Compton peak > few TeV)
- weak/undetected in Fermi (Fermi band more in the valley between the two SED peaks)



Note: at VHE, for these two examples: red, observed data. Blue, EBL-corrected data with Franceschini 2008.



A real, difficult challenge for SSC models !! Best territory for new insights on emission mechanisms.

References: Abdo et al. (LAT Collab.) 2010a, ApJ 715, 429 (1FGL); Abdo et al. (LAT Collab.) 2010b, ApJ 708, 1310 (data on 1ES 1553+113); Abramowski et al. (HESS Collab.) 2010, A&A, 516, 56; Acero et al. (HESS Collab.) 2010, A&A, 511, 52; (data on PKS 2005-489); Aharonian et al. (HESS Collab.) 2006a, Nature, 440 1018; Aharonian et al. (HESS Collab) 2006b, A&A, 455, 461; Costamante et al. 2001, A&A, 371, 512 (SED data); Costamante et al. 2008 (HESS Collab.), Proceedings ICRC, Vol 3, p945-948; Danforth et al. 2010, ApJ, 720, 976 (redshift constraints on 1ES 1553+113); Franceschini et al. 2008, A&A, 487, 837; Tavecchio et al. 2011, MNRAS, in press (arXiv:1009.1048) ; Katarzynski et al. 2005, A&A, 433, 479.

Disclaimer: As one of the main co-authors of the HESS paper on H 2356-309, these findings were provided to the HESS collaboration, both months before and also after the publication date, to no positive effect. My co-authorship of the HESS paper, therefore, is intended as mainly data-related, as proposer and PI of the multi-wavelengths campaigns and for providing the X-ray data analysis. It does not extend to the interpretation, which I did not and do not agree with.