Near Infrared Background and the Epoch of Reionization
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Blazars and the Extragalactic Background Light

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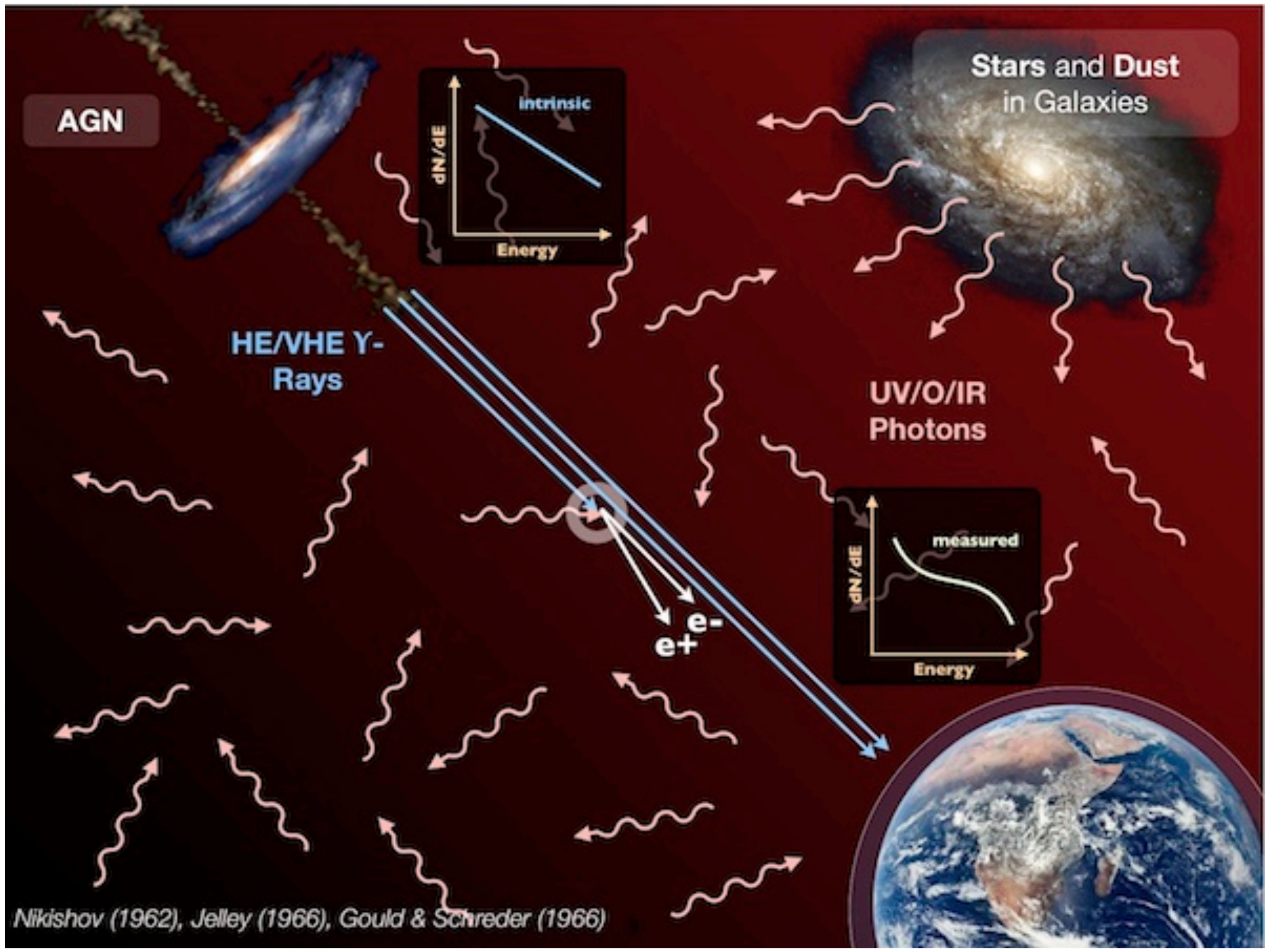
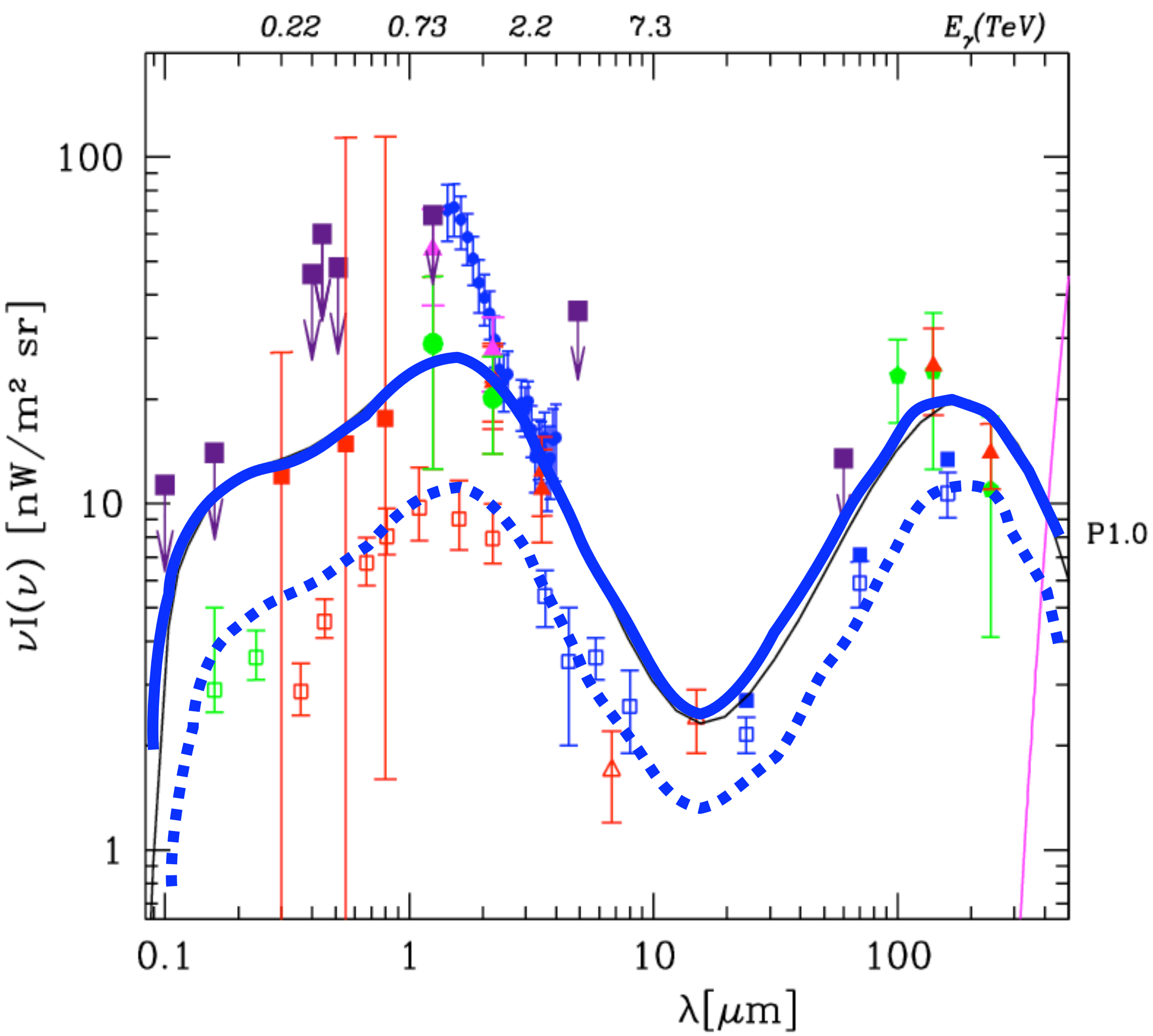


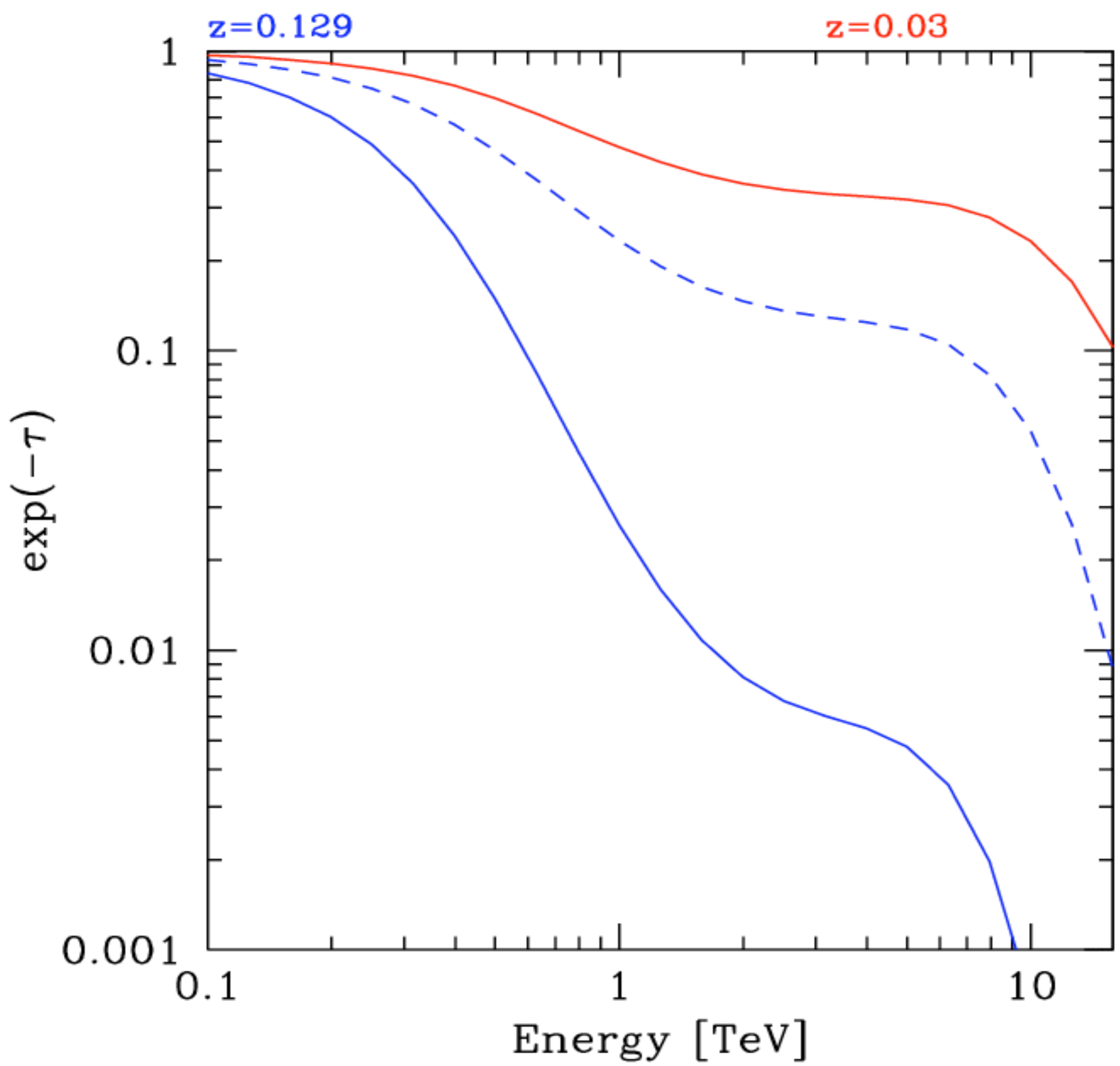
Blazars are excellent cosmological beamers of gamma-rays (but are NOT standard candles)

Part I: diagnostic of the EBL

Part II: validity of the constraints/assumptions

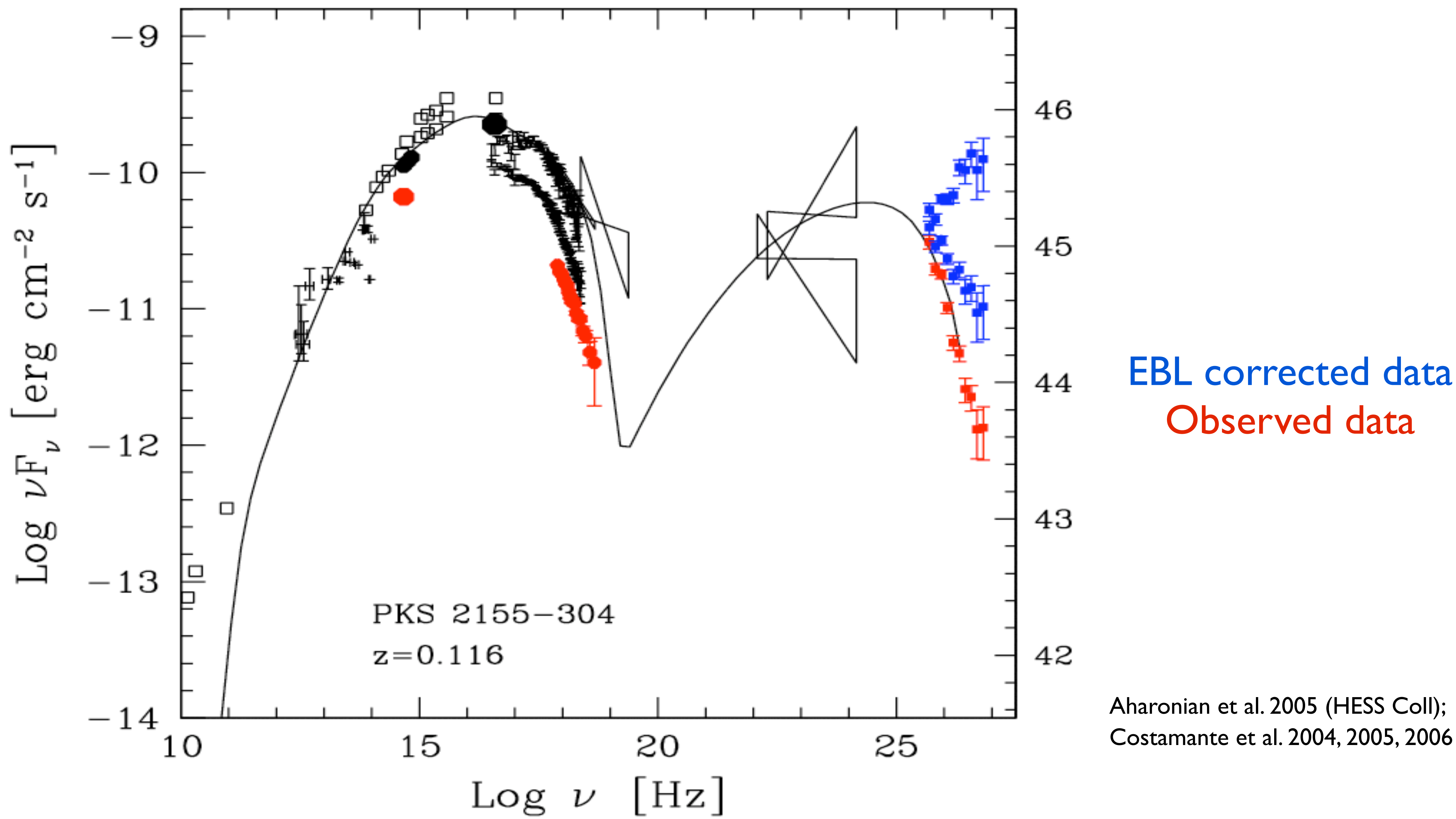
Diagnostic: how absorption deforms TeV spectra ?





1) complex shape, overall steepening ($\Gamma_{observed} > \Gamma_{intrinsic}$)

γ-γ interaction with EBL photons

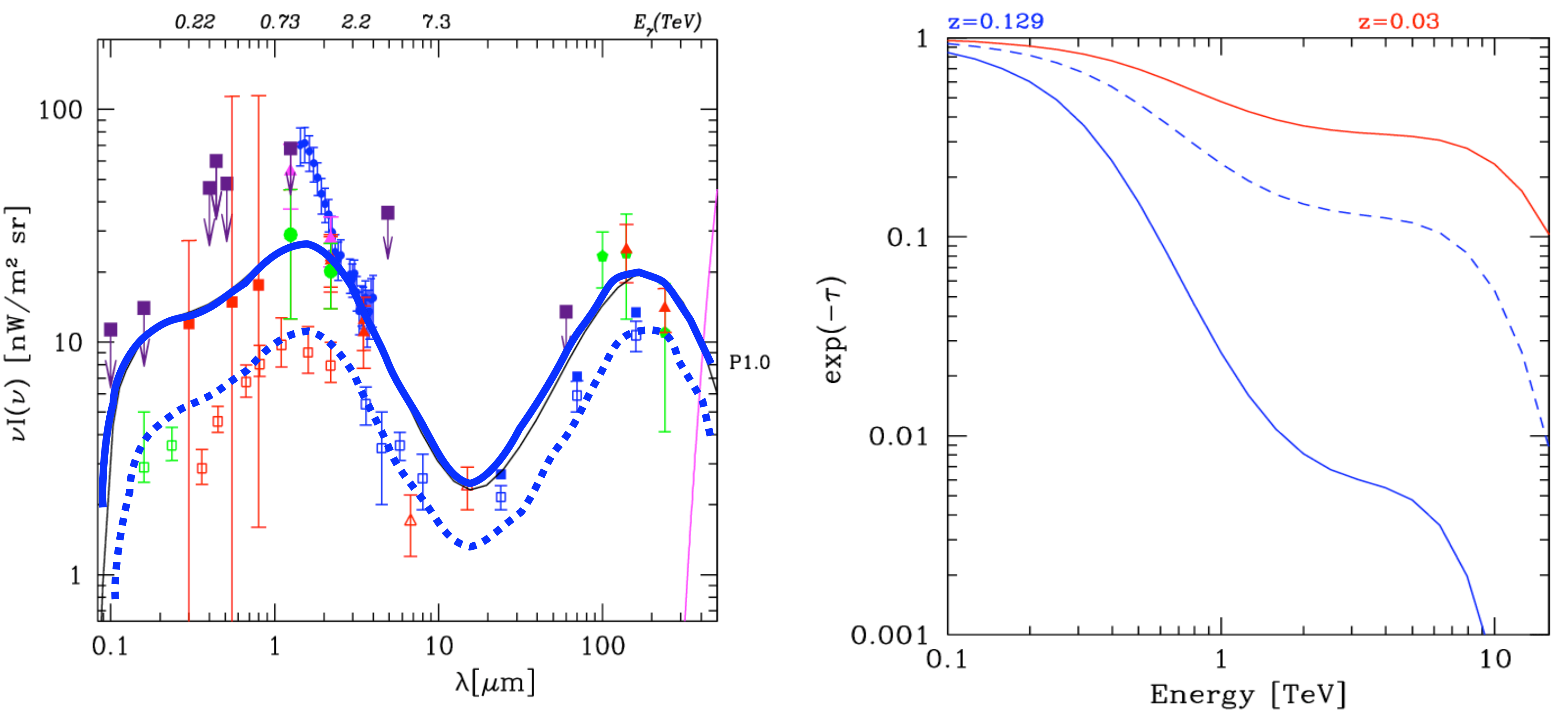


Aharonian et al. 2005 (HESS Coll);
Costamante et al. 2004, 2005, 2006

Soft intrinsic spectrum with low EBL or hard intrinsic spectrum with high EBL ?

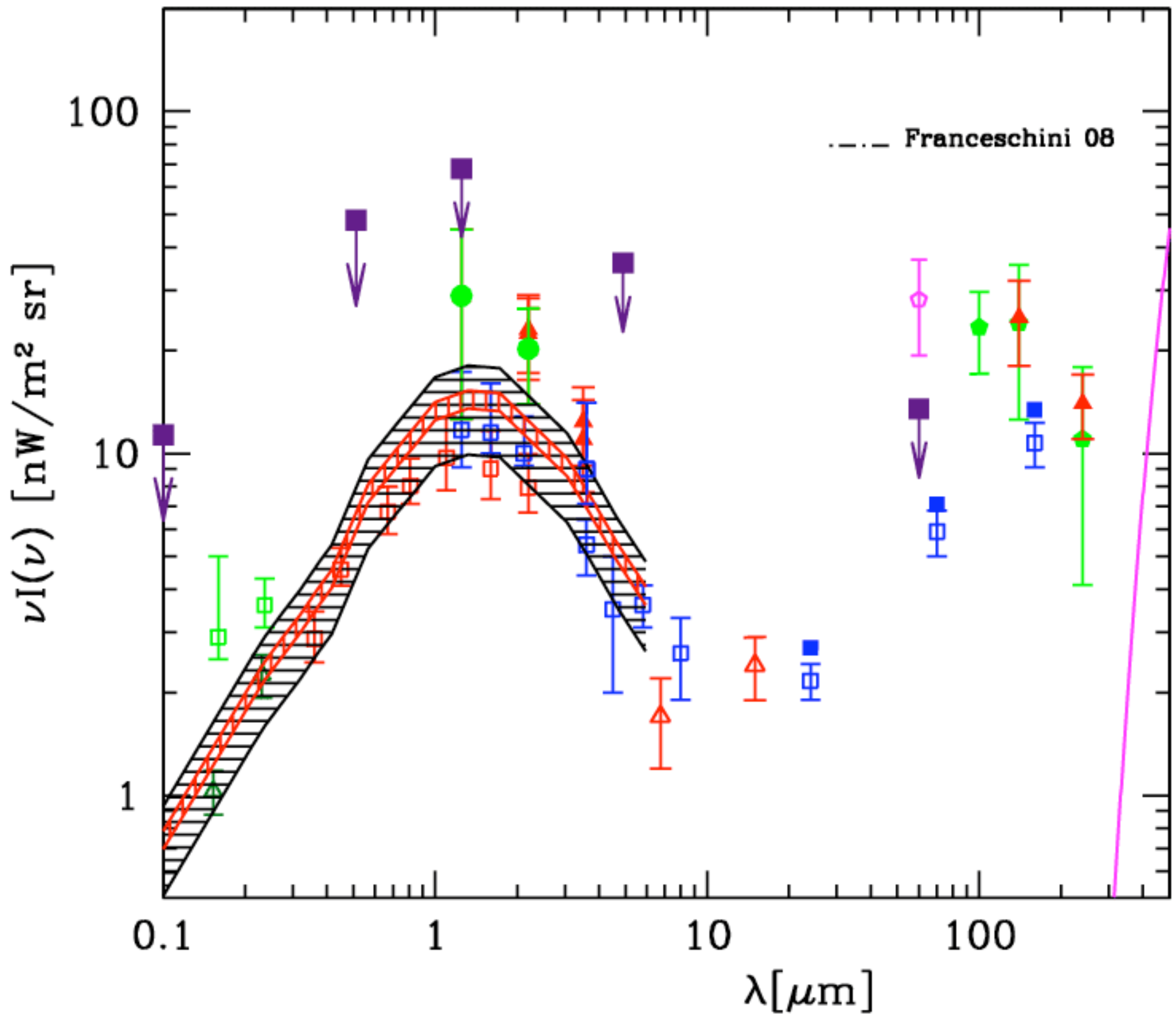
Constraints: from assumptions on the hardness of the intrinsic spectrum

Diagnostic: how absorption deforms TeV spectra ?



1) complex shape, overall steepening ($\Gamma_{observed} > \Gamma_{intrinsic}$)
2) redshift gives leverage: larger effects at larger distances.

Higher z does not always mean more stringent EBL constraint:



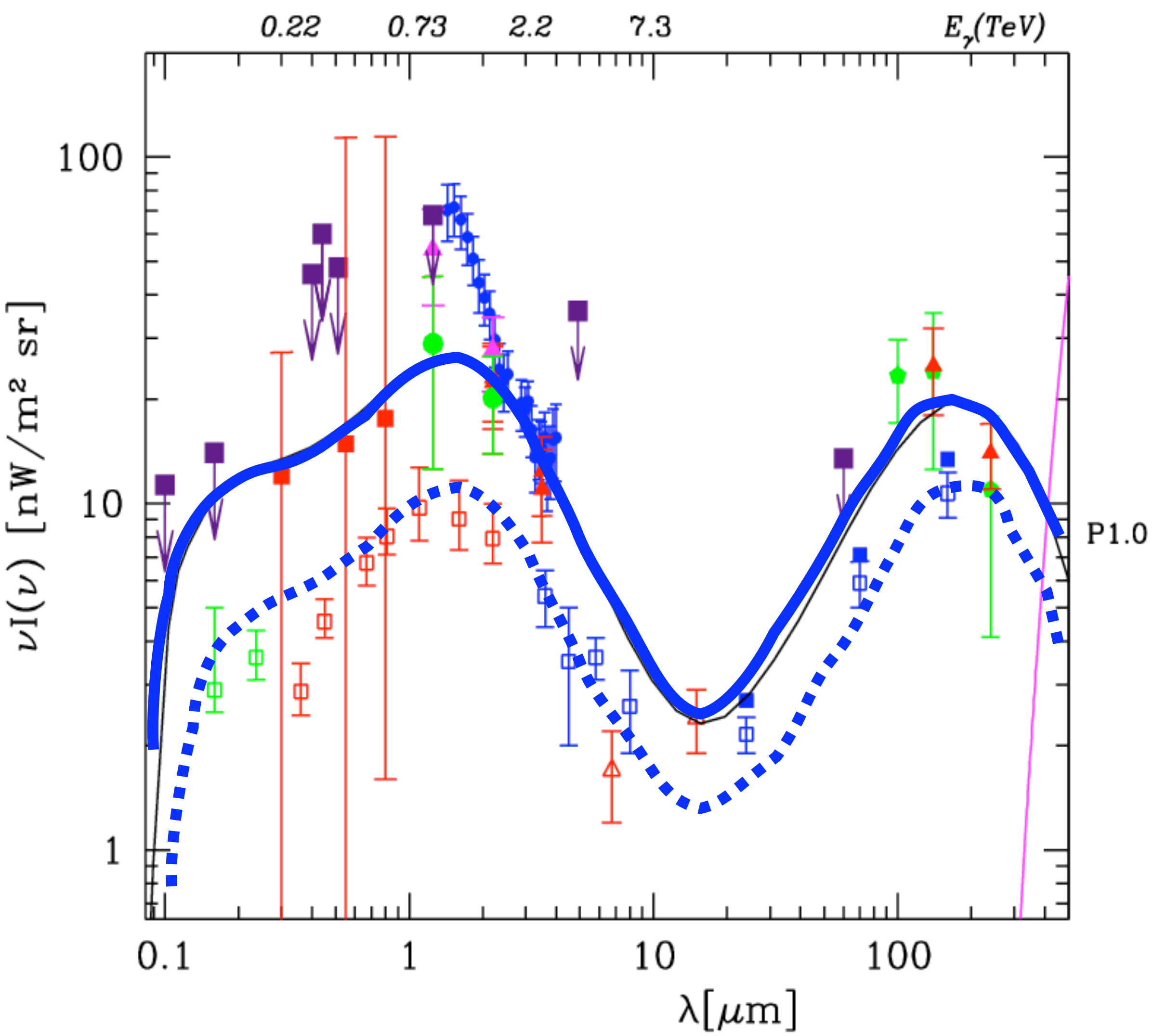
Compromise between z and statistics.

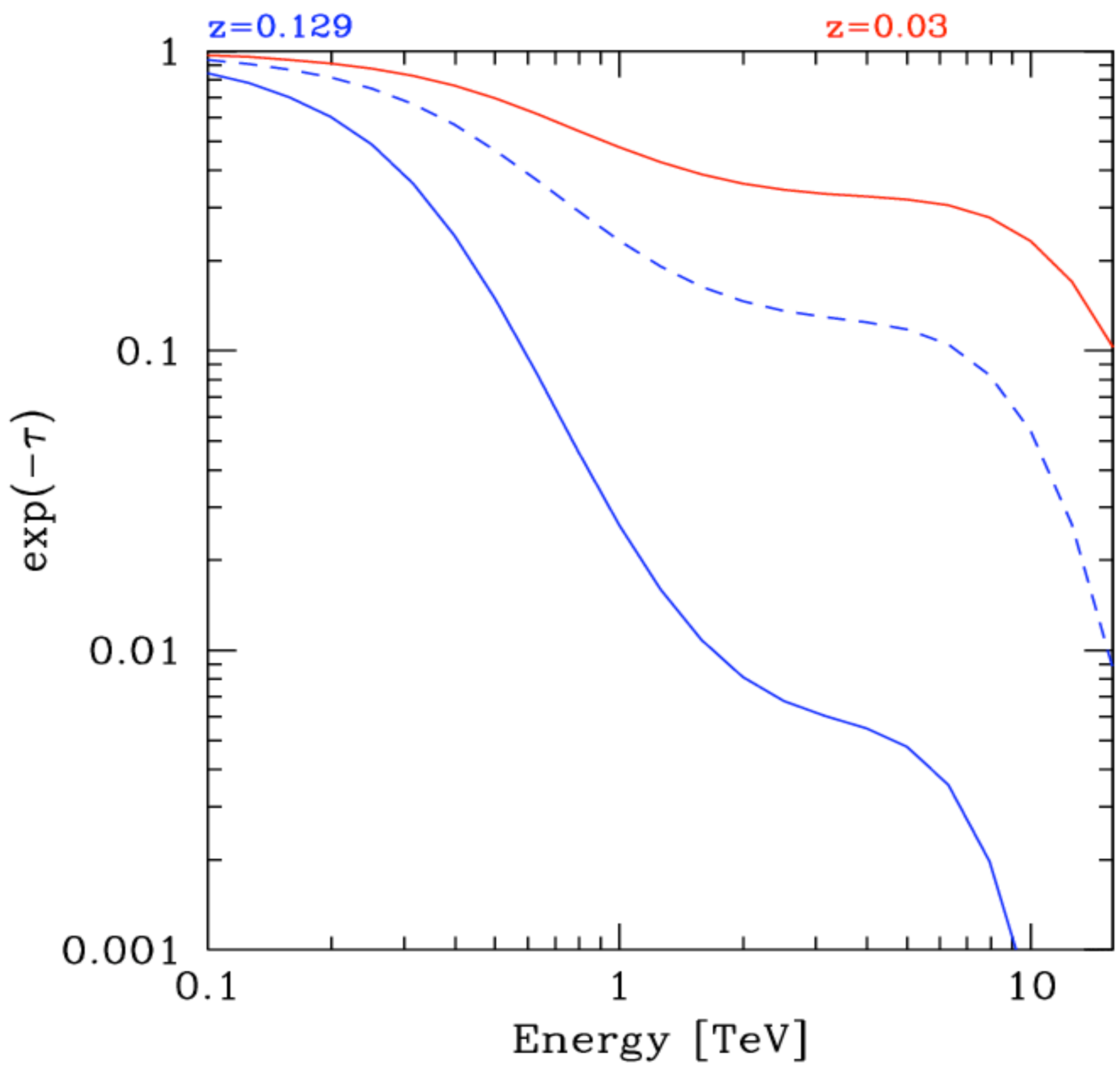
EBL limits with 1-sigma statistical bands from:

3C 279 (z=0.536) +/-1.0

1101-232 (z=0.186) +/-0.2

Diagnostic: how absorption deforms TeV spectra ?





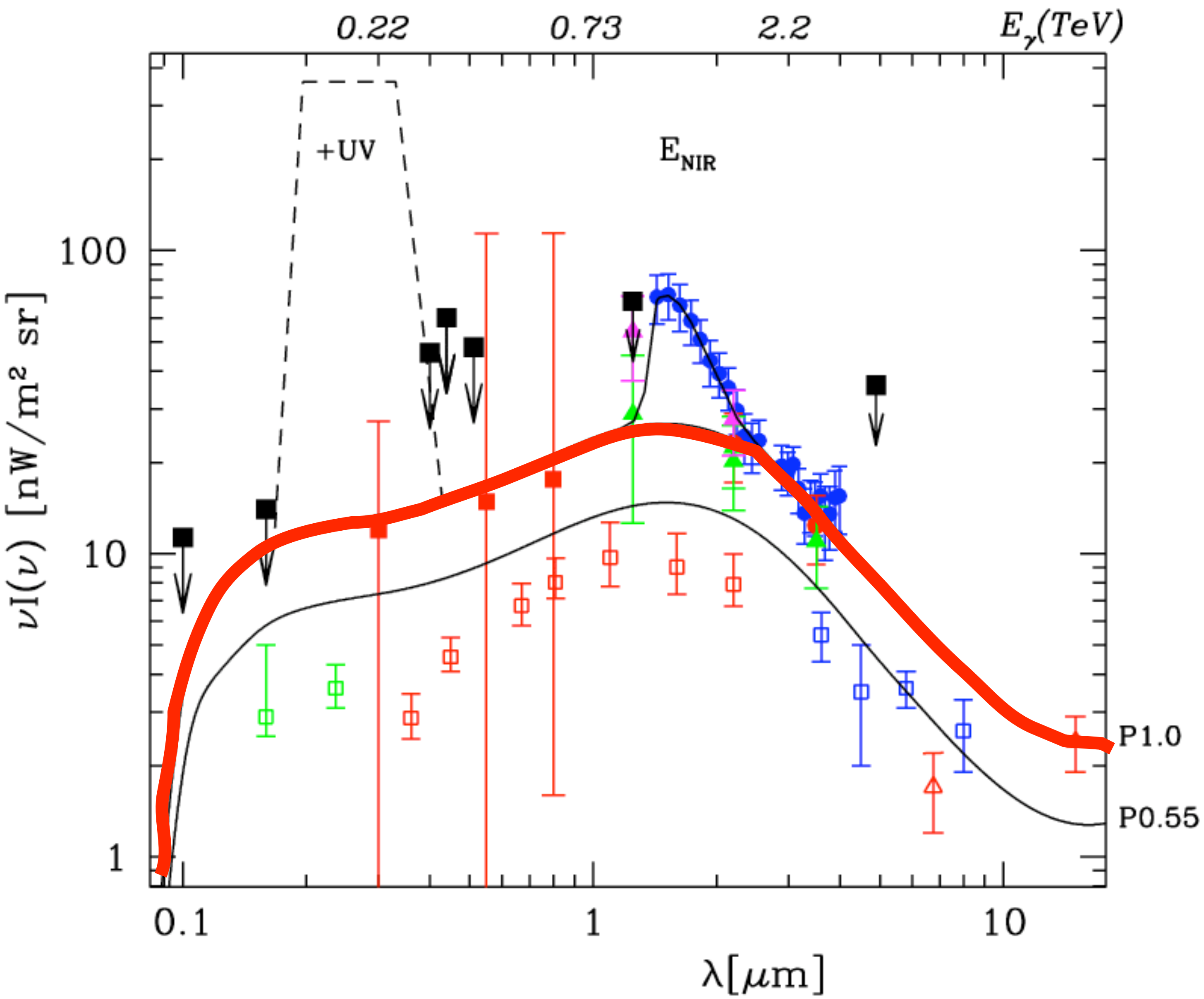
3) EBL number density $n(\varepsilon) \propto \varepsilon^{-\beta}$, $\varepsilon^2 n(\varepsilon) \propto \lambda^{\beta-2}$, $\tau(E) \propto E^{\beta-1}$

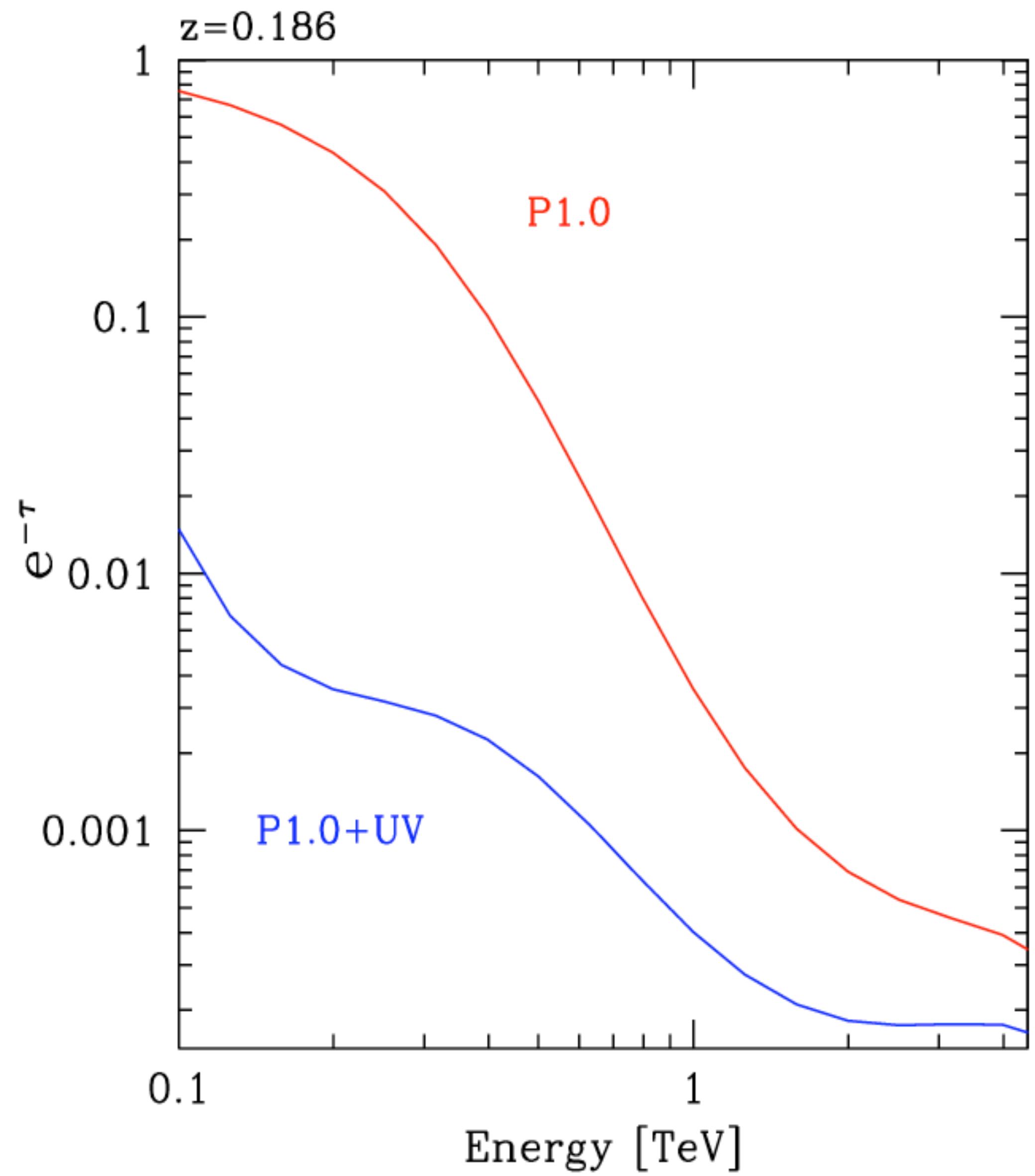
When $\beta = 1$ (i.e. EBL $\propto \lambda^{-1}$) --> τ becomes constant with E_γ !

Flattening feature ~2-8 TeV

see e.g. Aharonian 2001 (Hamburg ICRC report talk)

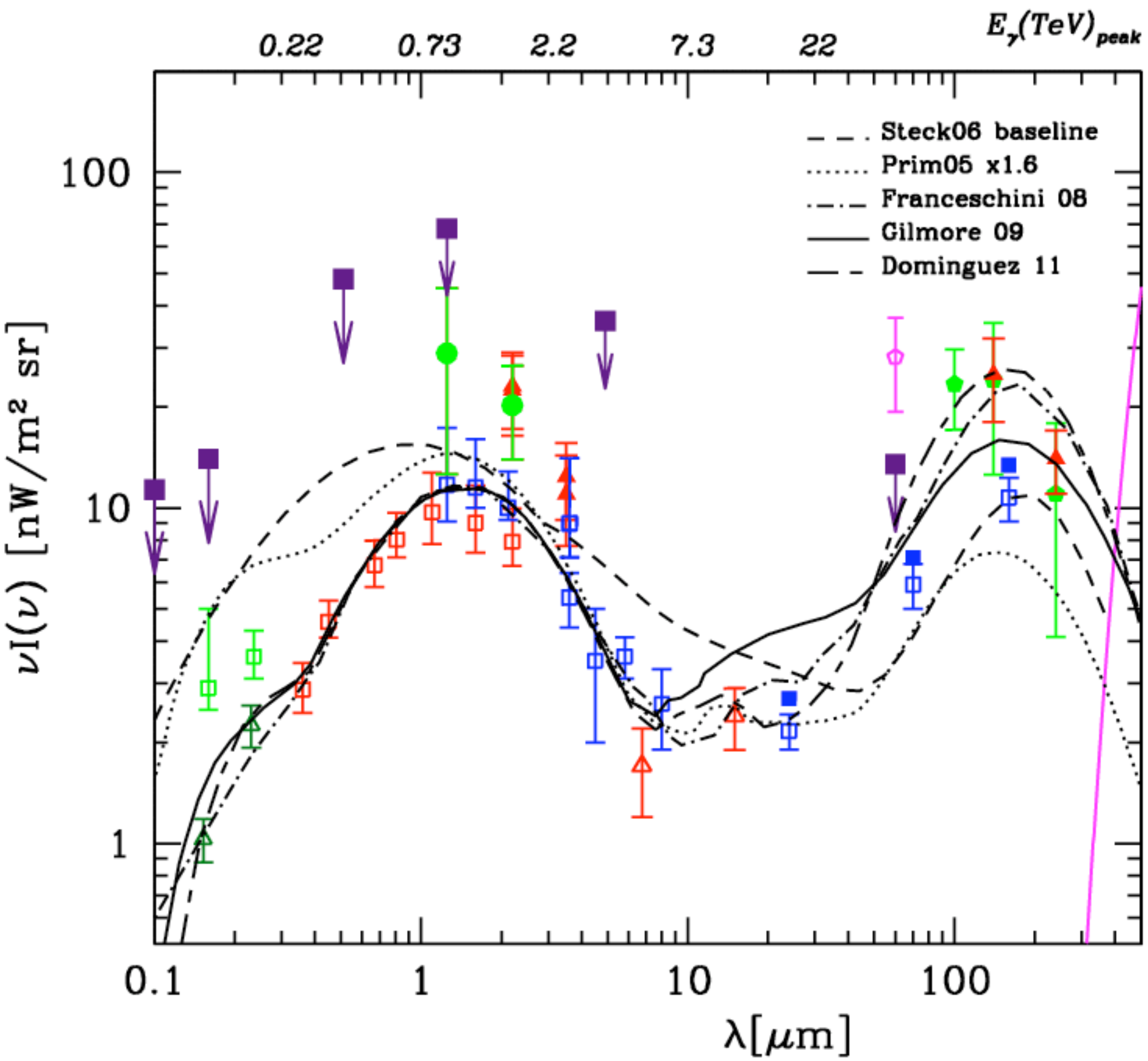
Spectral steepening depends on the EBL ratio between the two ends of the VHE observed band





EBL Limits are derived from the hardening of the VHE spectrum.
The hardening can be counteracted by a high UV/NIR ratio.
No constraint can be put on EBL without a specific model/assumption on the UV/NIR flux ratio !

Chain of Constraints



From assumption/limits on UV flux:

0.1-1 TeV spectra pin down the EBL flux at 1 micron.

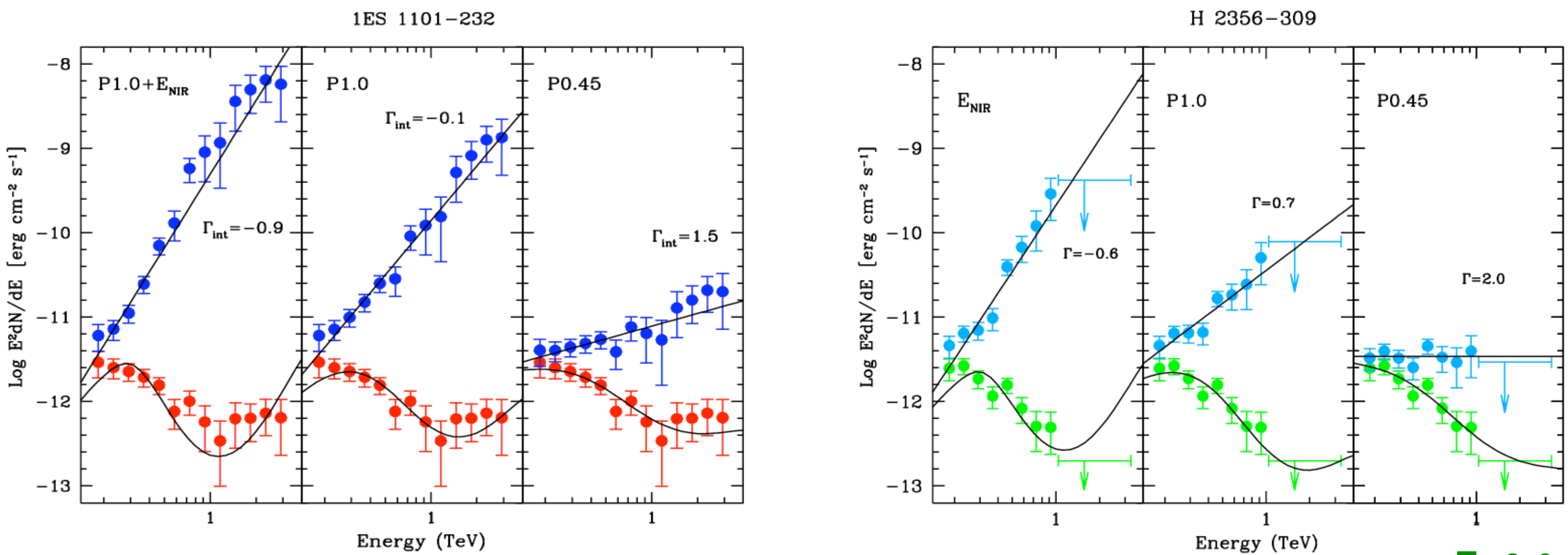
With constraint at 1 micron, 1-10 TeV spectra fix the slope/EBL flux up to 10 micron.

Limits at 10 micron constraints upturns in the 8-50 TV spectra

e.g. Costamante et al. 2004, Dwek & Krennrich 2005, Mazin & Raue 2007, Orr et al. 2011

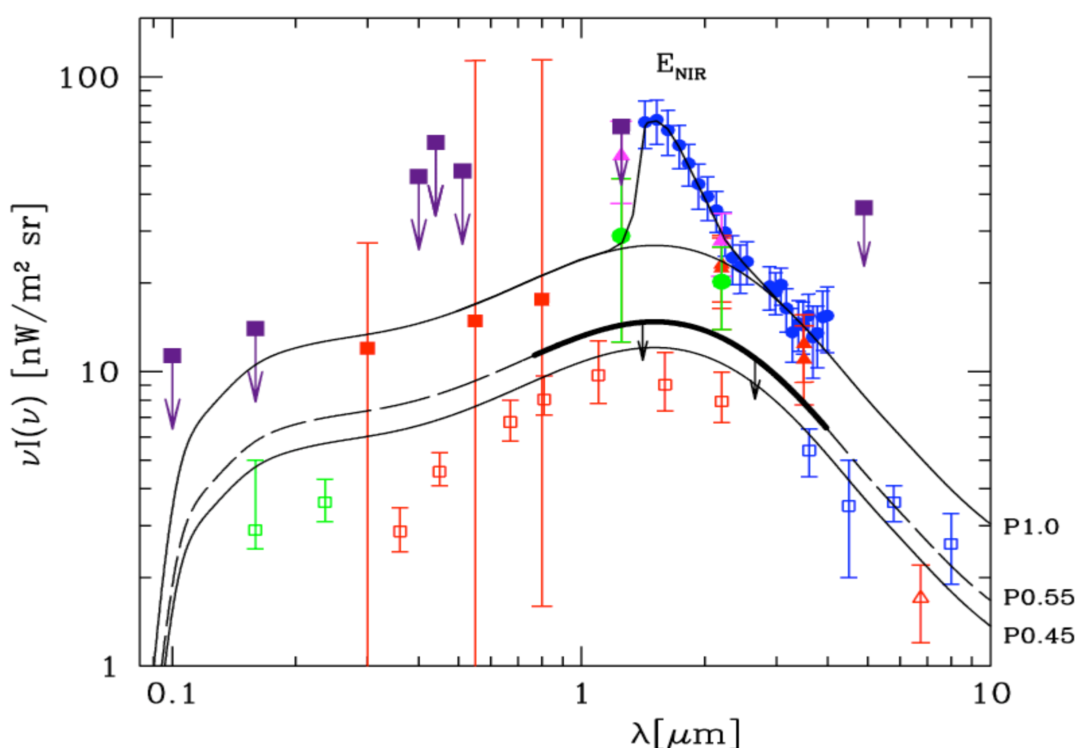
Breakthrough result in 2005 :

H.E.S.S. spectra of 1ES 1101-232 & H 2356-309



Γ=2.88 ±0.17
z = 0.186

Γ=3.06 ±0.21
z = 0.165



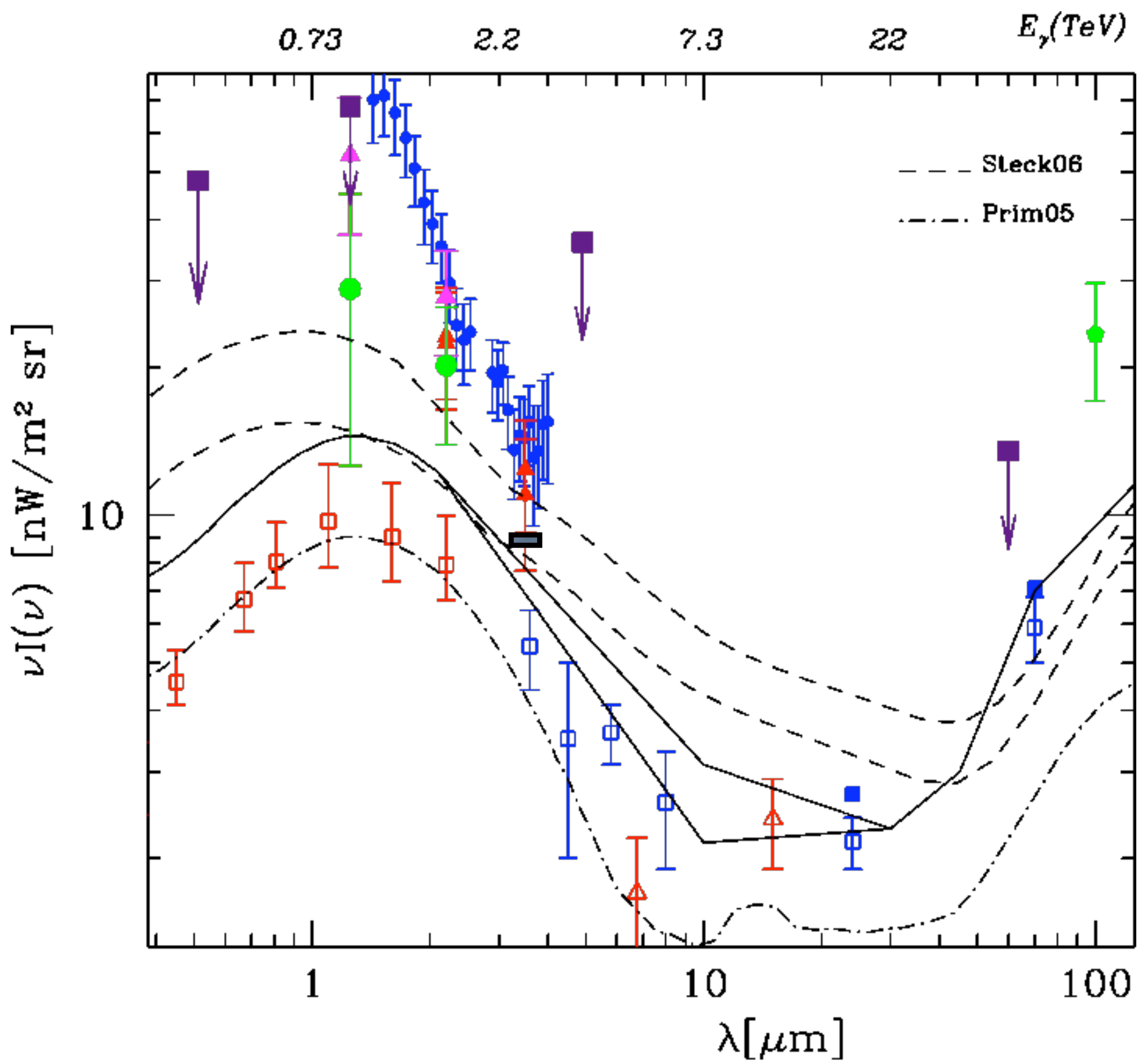
- EBL mainly done by normal galaxies
- Larger gamma-ray horizon
- Much less uncertainty on blazar spectra

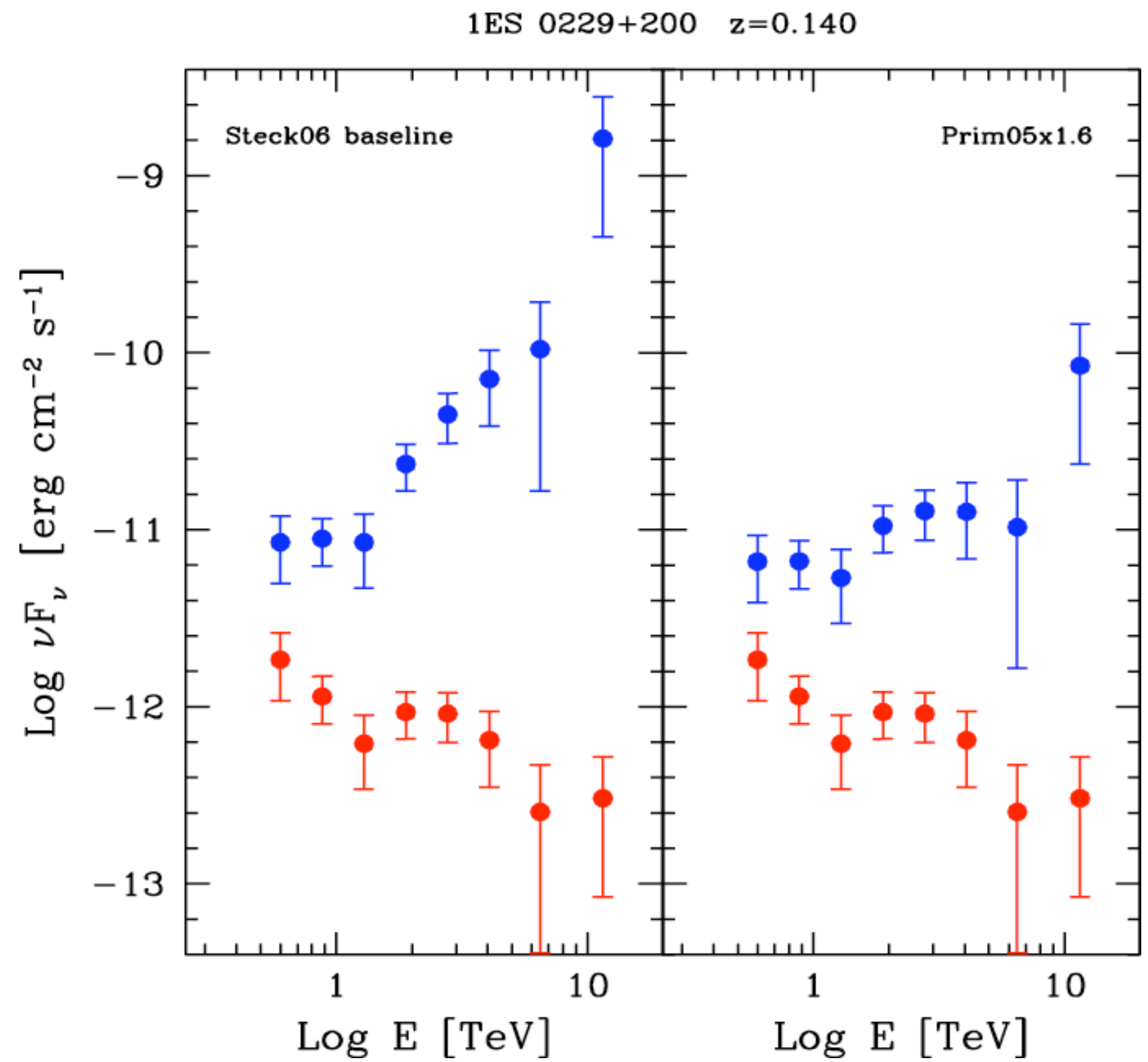
Aharonian et al. 2006 (HESS Coll), Nature

New constraints also in the NIR band:

H.E.S.S. spectrum of 1ES 0229+200 constrains EBL to slope λ^{-1}

(confirming previous HEGRA indication from 1ES 1426+428)

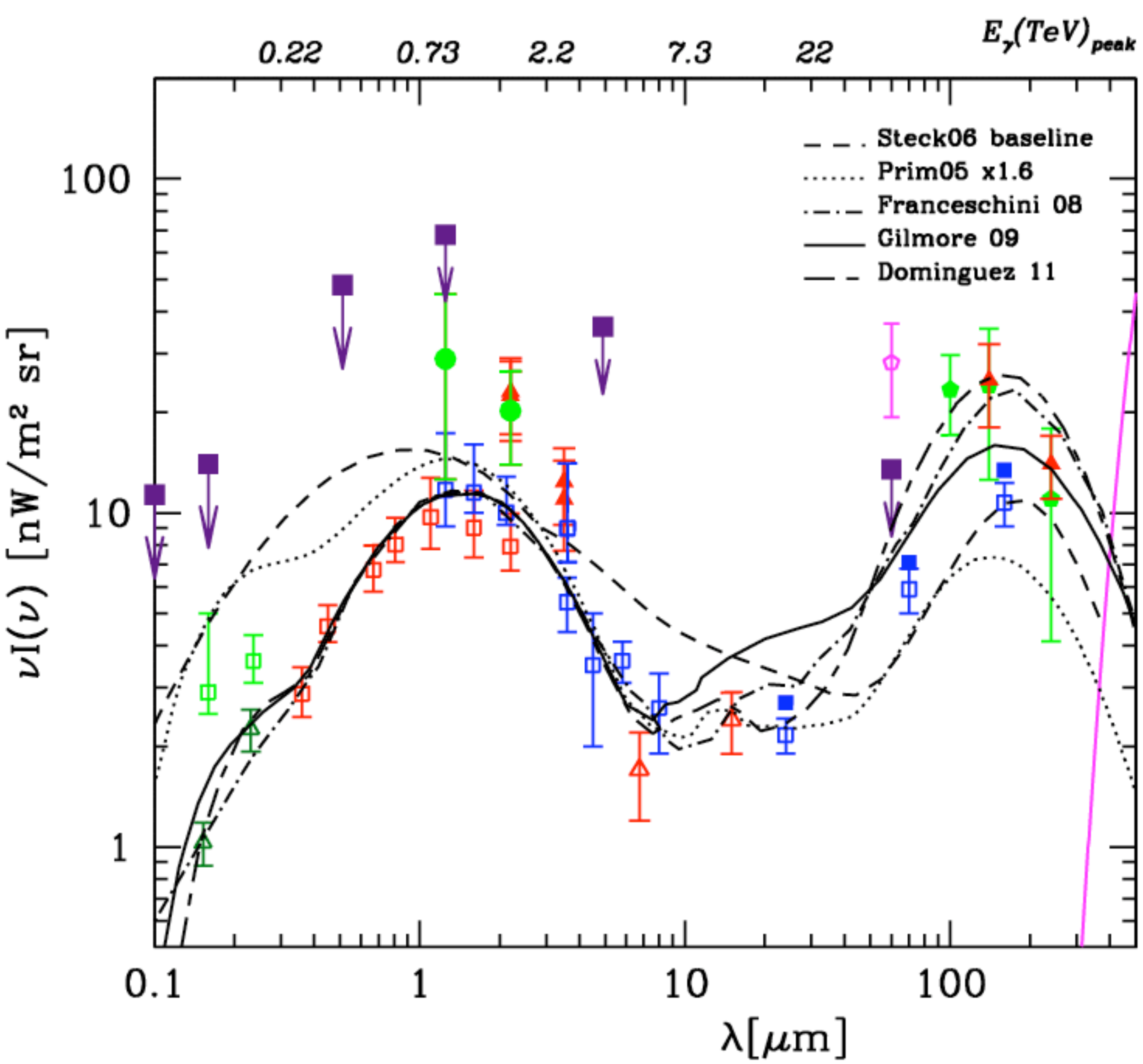


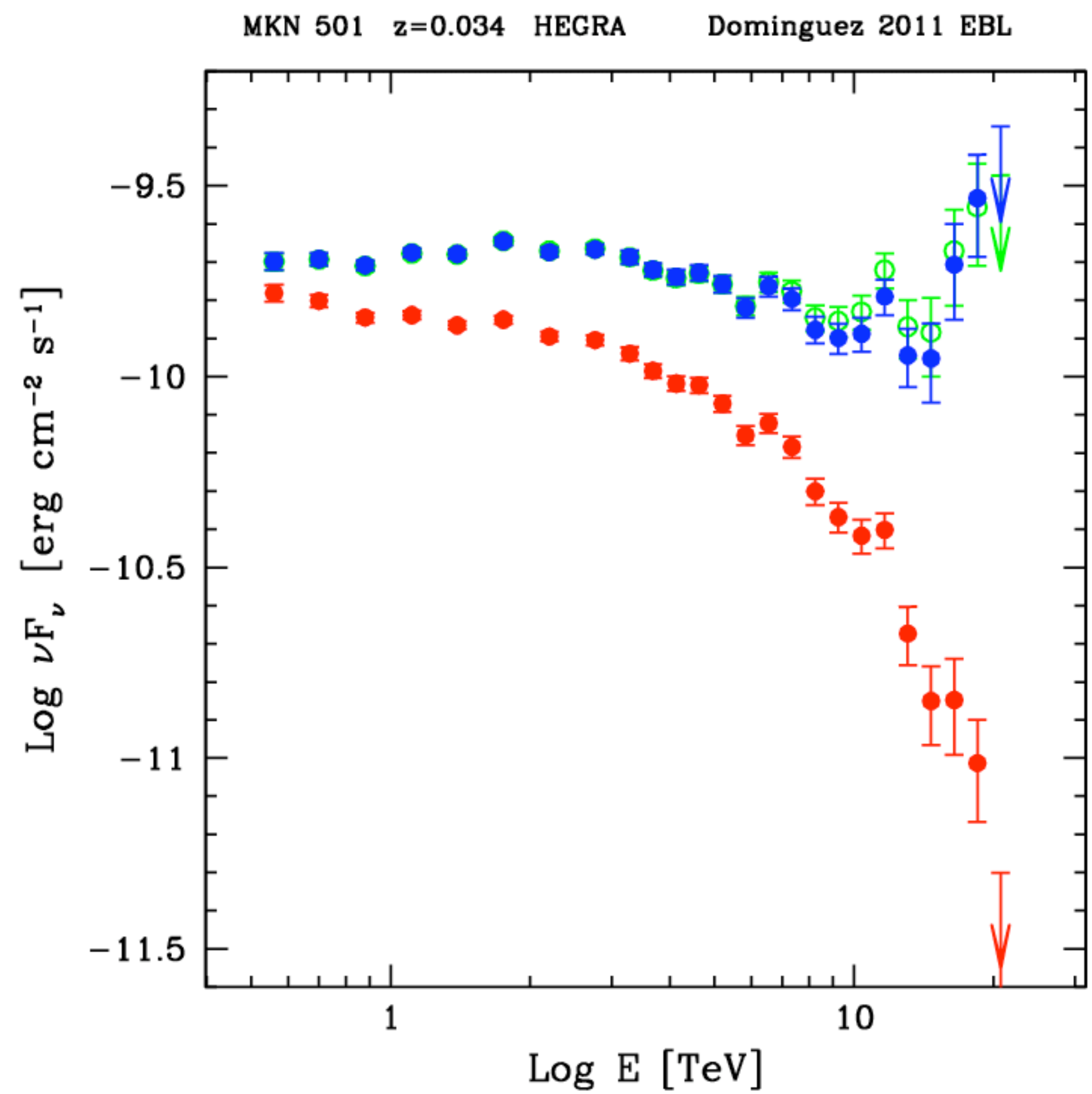


1ES 0229+200 (z=0.140)

H.E.S.S. (Aharonian et al 2007)

Limits or Problems at FIR:
TeV-IR bkg crisis, the sequel ?





$\Gamma = 1.5$

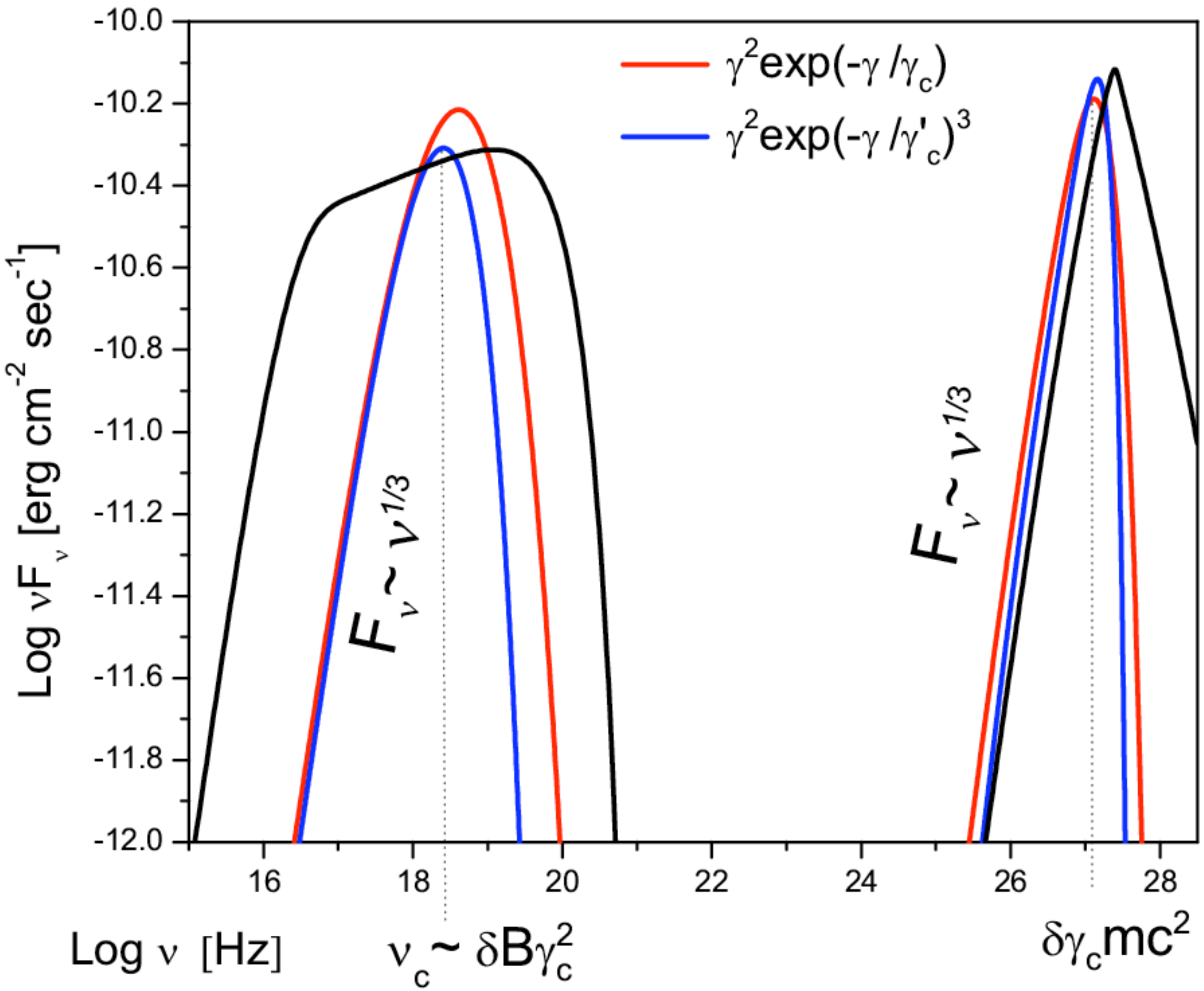
What is NOT: - it's not the hardest possible theoretical spectrum
- it's not the hardest imaginable spectrum in blazars
- it's not a sharp, "hard limit"

Examples: *- bulk-motion Comptonization* *(Aharonian et al 2001, 2006)*
- high-energy "low-energy cutoff" in particle spectrum *(Katarzynski et al 2007)*
- internal absorption on narrow-banded target field *(Aharonian et al 2008)*
- uncooled particle acceleration spectrum $\Rightarrow \Gamma \sim 1.2$ *(Aharonian et al 2006)*
- pile-up particle distributions or fine tuned shock-acceleration conditions
(e.g. Sauge & Henri 2004, Stecker et al 2007 but with $\Gamma > 1.2$*)*

Note however that even ~1.2 is not enough to change the conclusions on a low EBL
(see discussion in Aharonian et al 2006, Nature)

How to make very hard spectra (even less than 1.0) with one-zone SSC ?

comprehensive discussion in recent paper:

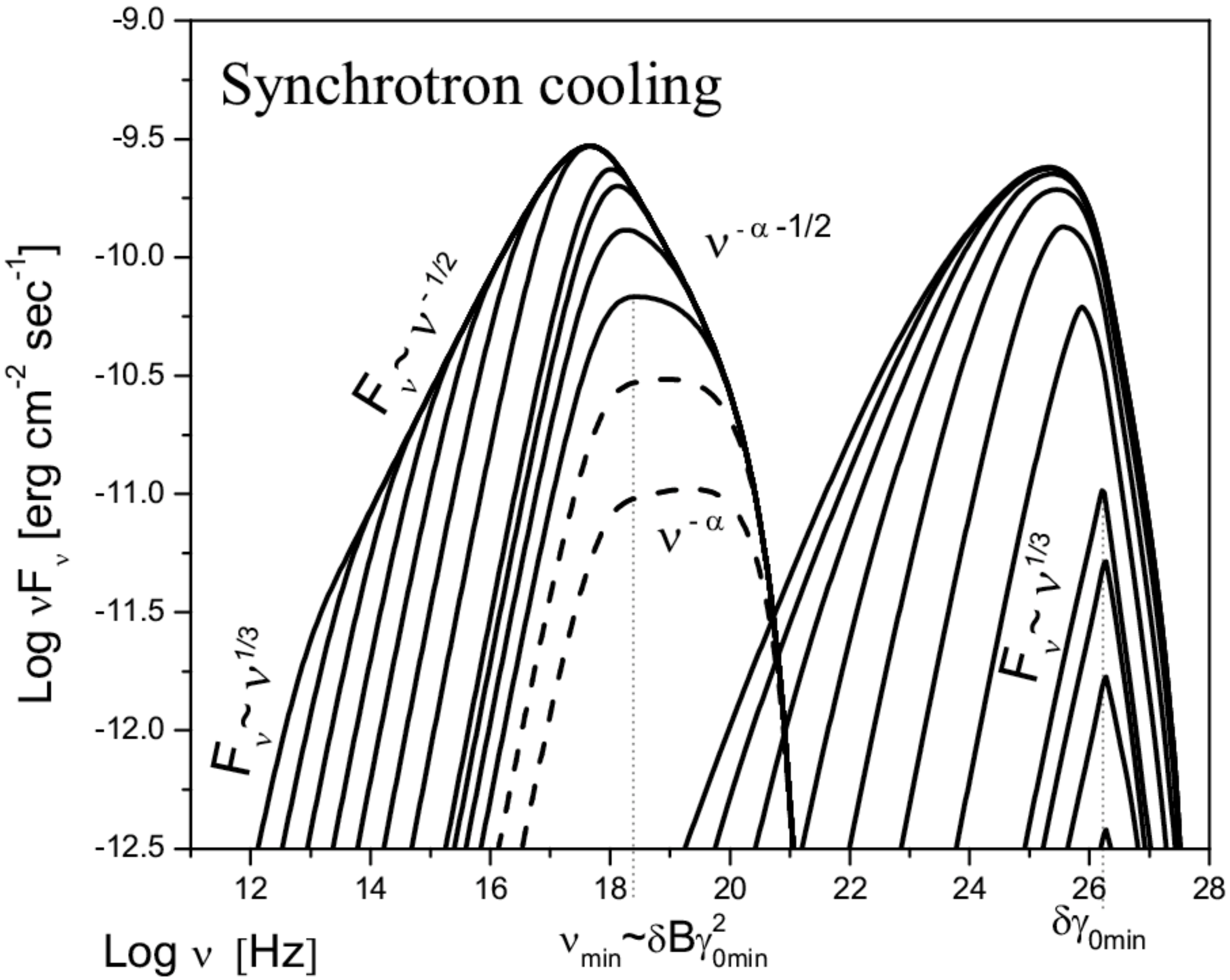


- Low-energy cutoff at high energies (Katarzynski 2007)

- Maxwellian distribution (Sauge` & Henri 2004)

Lefa et al. 2011

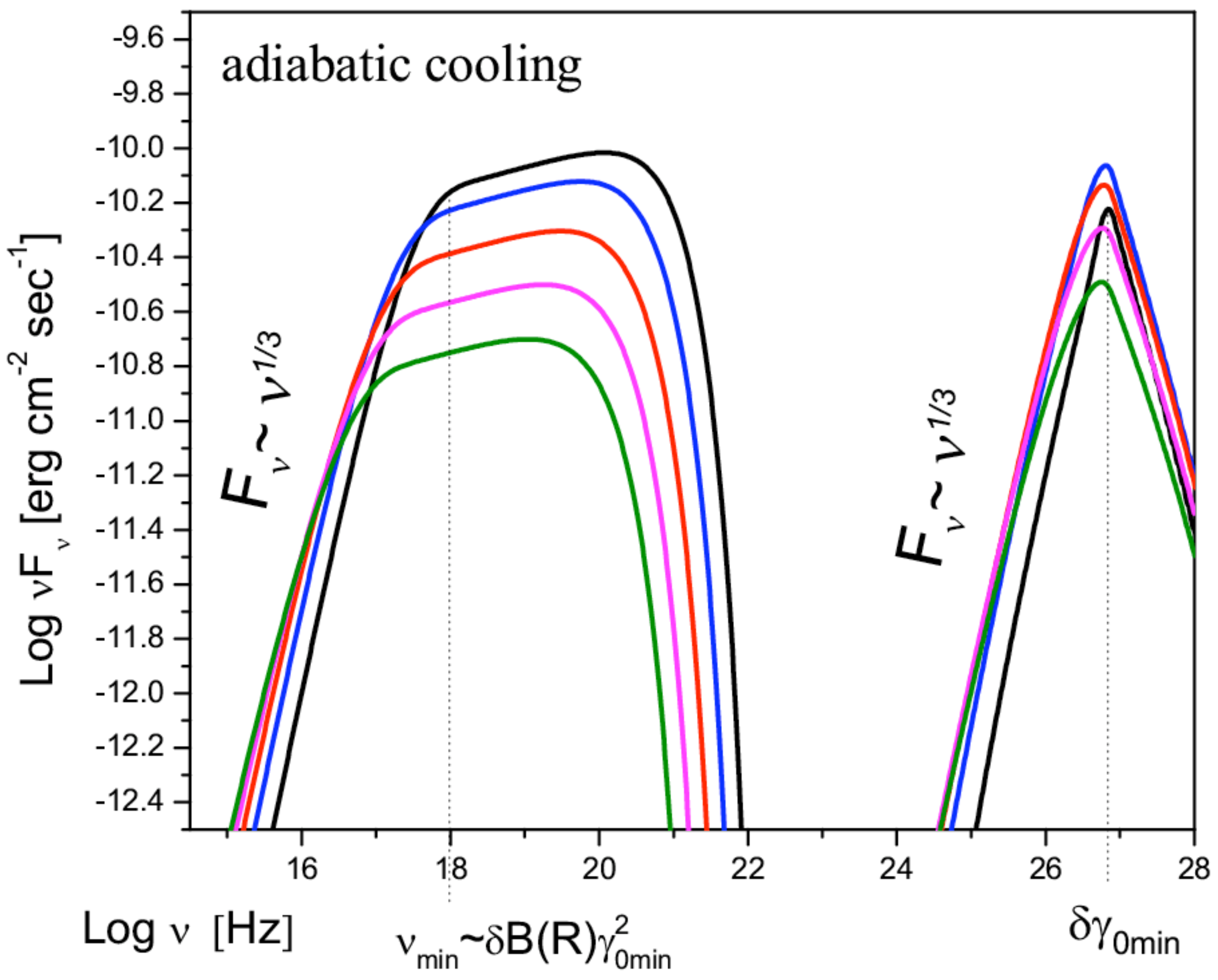
How to make very hard spectra with one-zone SSC ?



But, if cooling is dominated by synchrotron, SED goes quickly back to "usual" (broad-band and softer spectrum)

Lefa et al. 2011

How to make very hard spectra with one-zone SSC ?



To keep the hard features.

Lefa et al. 2011

$\Gamma = 1.5$

What it is: **It is a reference value,**
the borderline between reality and speculation.

- $\Gamma \geq 1.5$ is observationally confirmed and can be obtained theoretically in many circumstances (no special tuning);

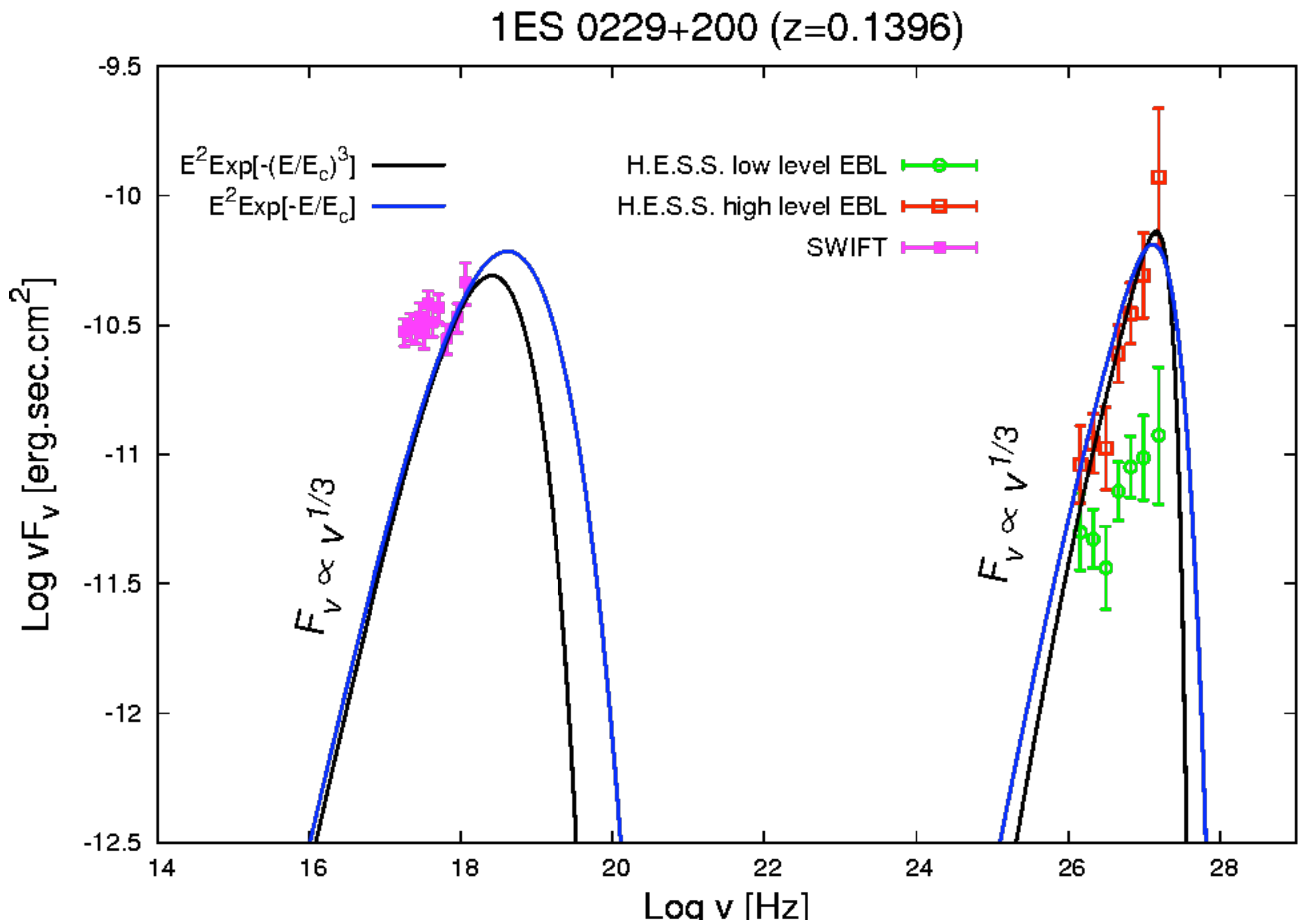
- $\Gamma < 1.5$ is *progressively* more unlikely: it requires either parameters pushed to the limits, or ad-hoc scenarios not yet supported by data.

Why a low EBL seems still the better solution ? (i.e. blazars seem to have $\Gamma \geq 1.5$)

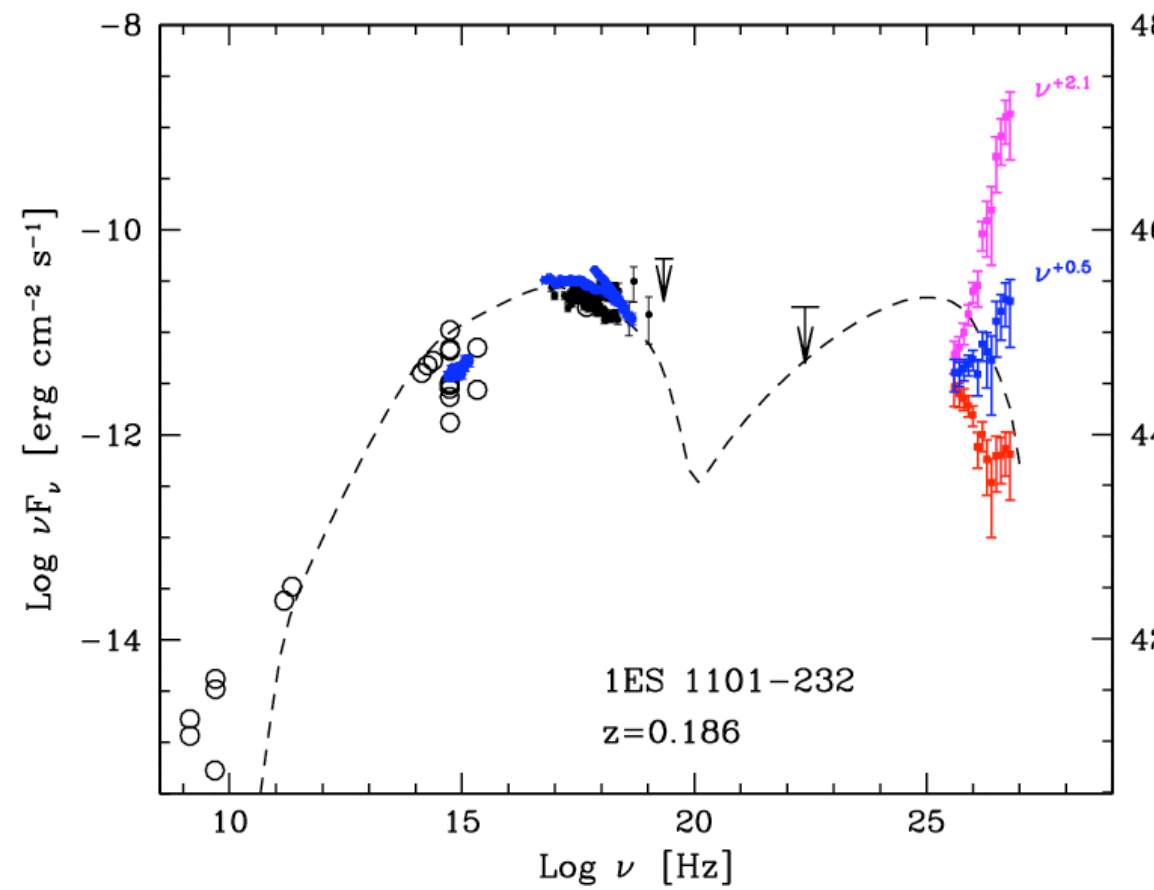
1) Synchrotron emission traces directly the particle spectrum. Models which require/assume very hard particle distributions should thus present very hard synchrotron emission as well, at least sometimes. So far, never observed in ~30 years of X-ray observations (always hidden below some other components, cosmic conspiracy ?)

2) A higher EBL (such that $\Gamma \sim 0.7$) would require a dramatic change of properties of blazars in a very narrow range of redshifts.

1) Why hard features seems always hidden below other components ?



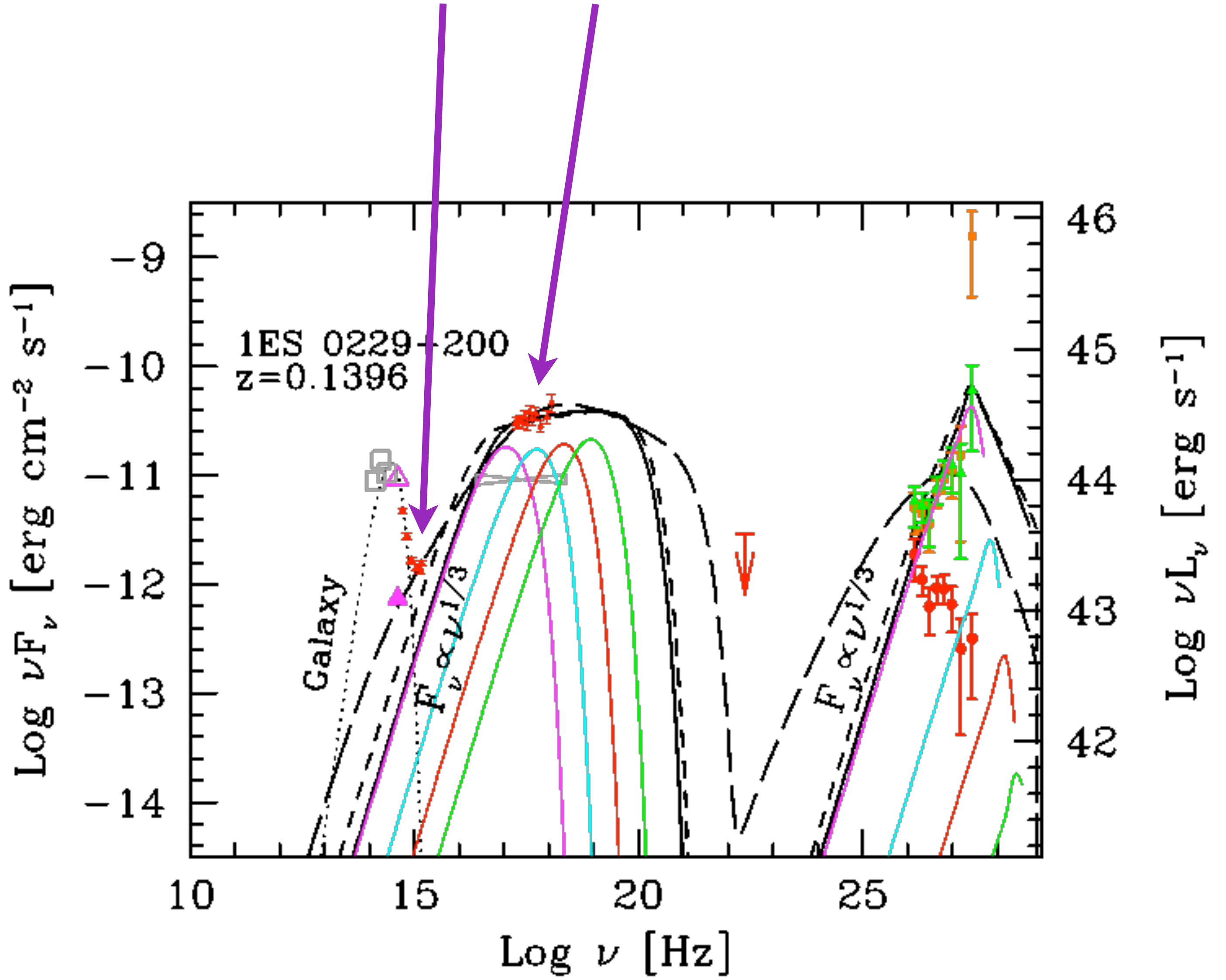
Lefa et al 2011



Costamante et al. 2009

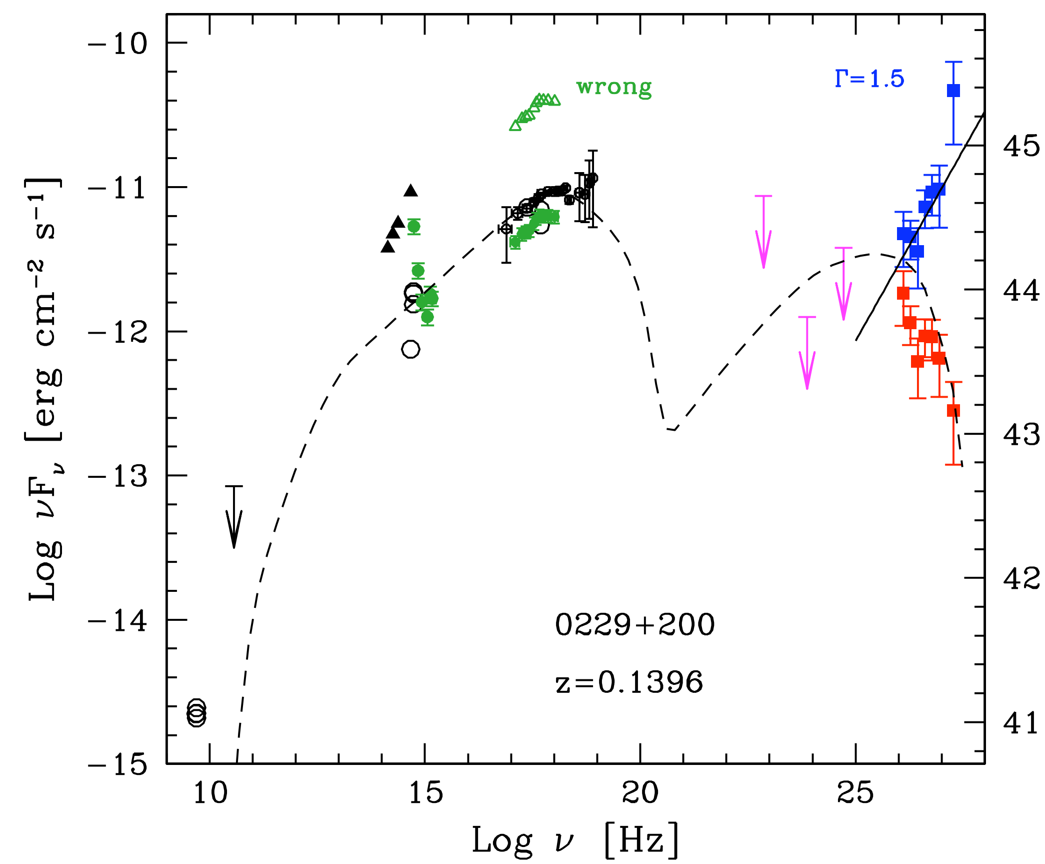
Never observed in X-rays/optical so far.

A possible observational evidence for synchrotron low-energy cutoff at high energies: Swift data on 0229+200



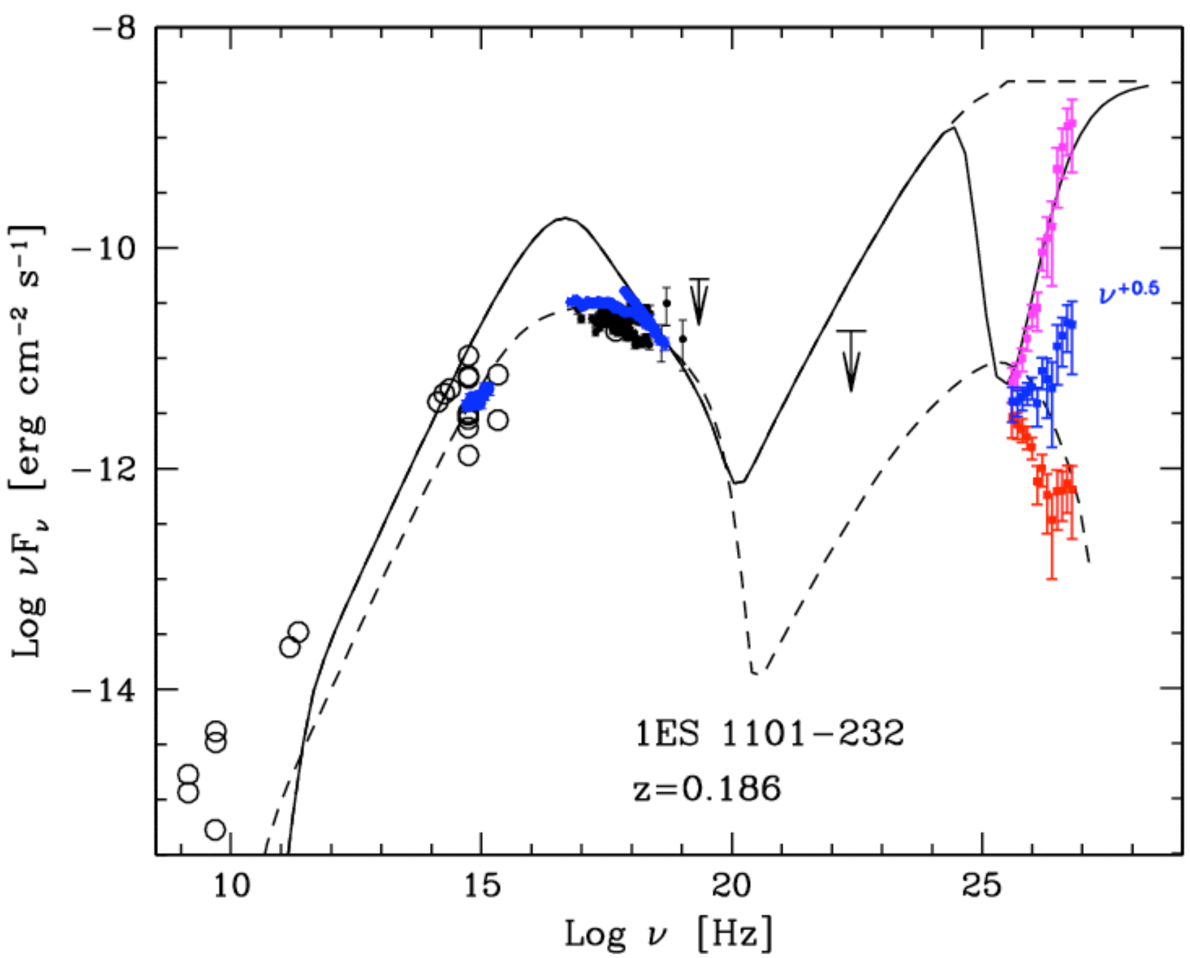
Tavecchio et al. 2009

Correct data:

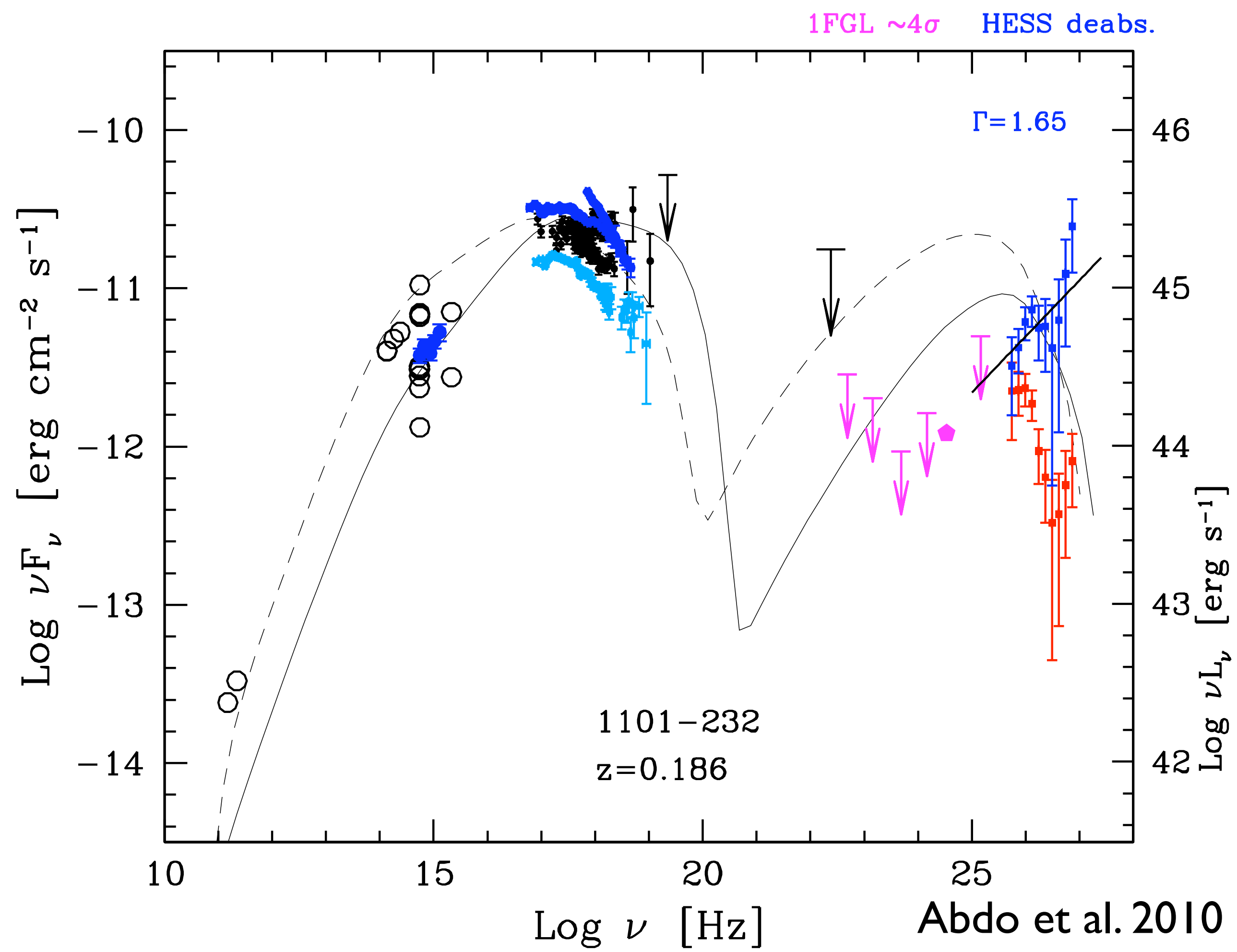


But no: there was an error in the X-ray effective area...

Hard spectra without invoking hard particle distributions: internal absorption on Planckian spectrum



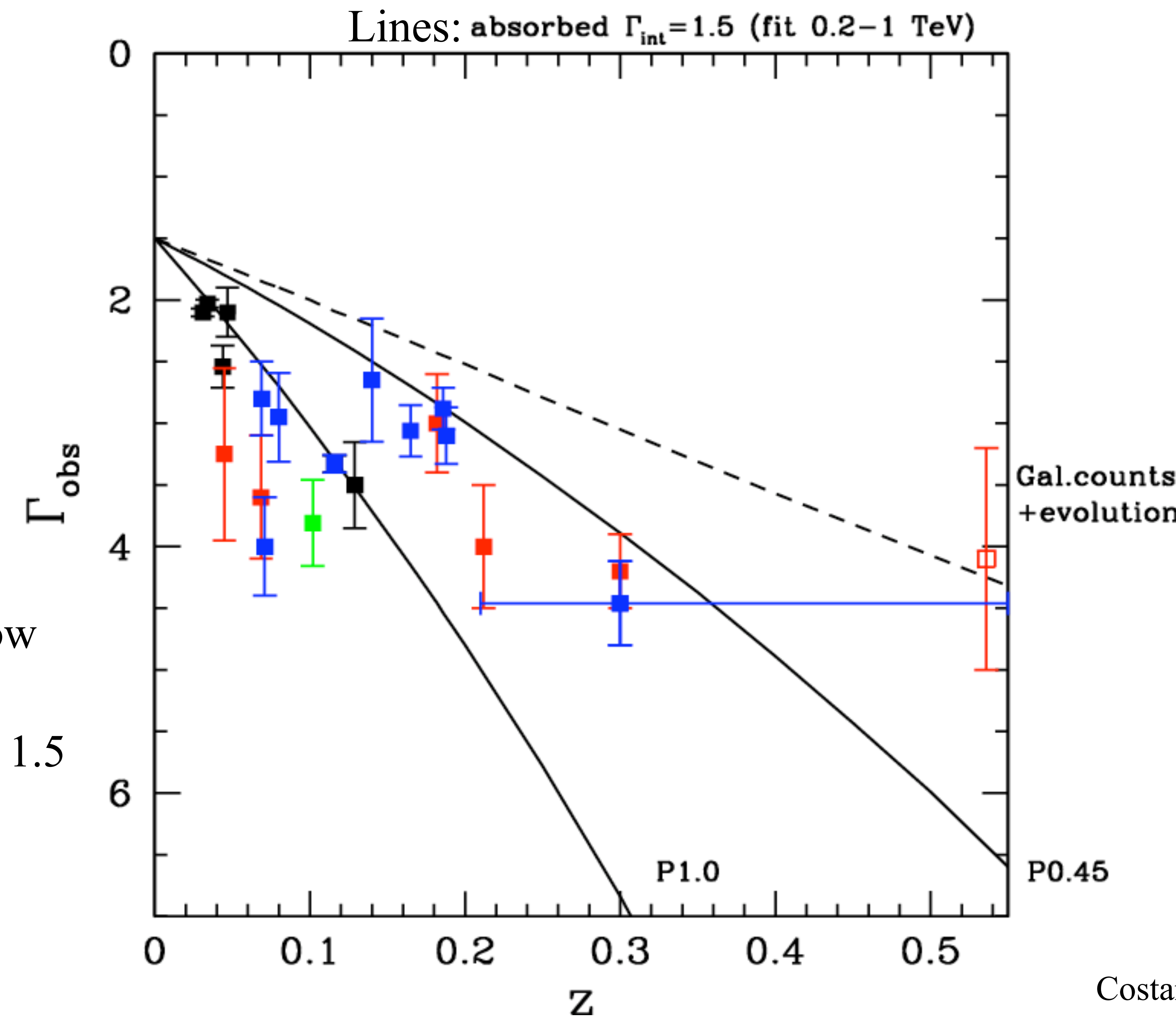
see Aharonian, Khangulyan, Costamante 2008



Abdo et al. 2010

But Fermi-LAT data seem now to exclude this...

2) A higher EBL (such that Γ ~0.7) would require a dramatic change of blazar properties in a very narrow range of redshifts.



Spectra above/below the lines means intrinsically > or < 1.5

3 different EBL levels

Costamante et al. 2006

CAVEAT on the GeV-TeV connection:

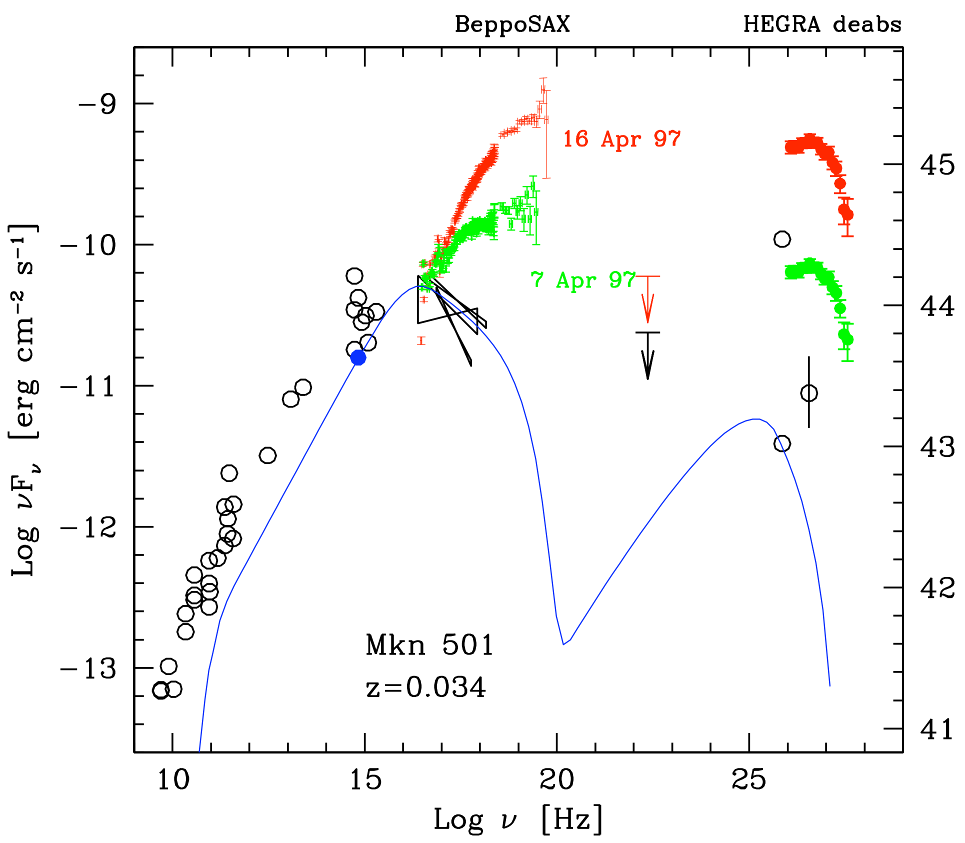
1) Fermi-LAT spectra extrapolatated to VHE as estimate or UL to the intrinsic spectrum (e.g. $\Gamma_{VHE} \geq \Gamma_{HE}$).

2) to anchor the SSC modeling and, from the synchrotron spectrum, to predict the intrinsic VHE spectrum.

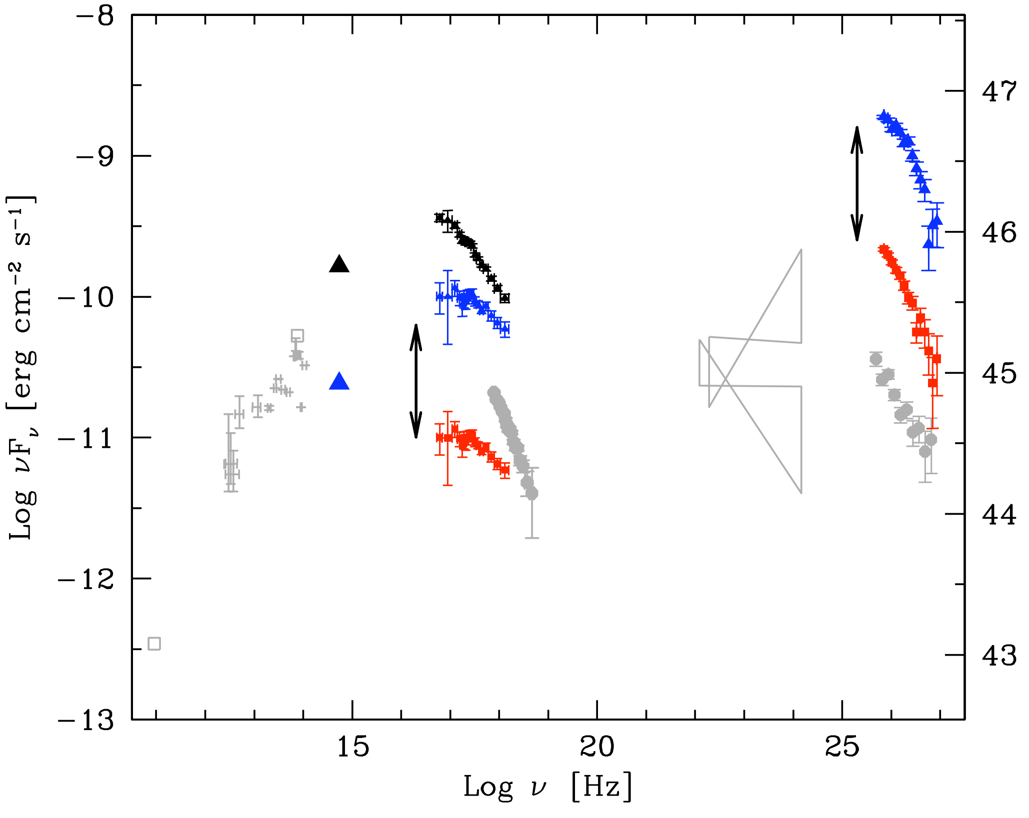
BUT...

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

Mkn 501 in 1997



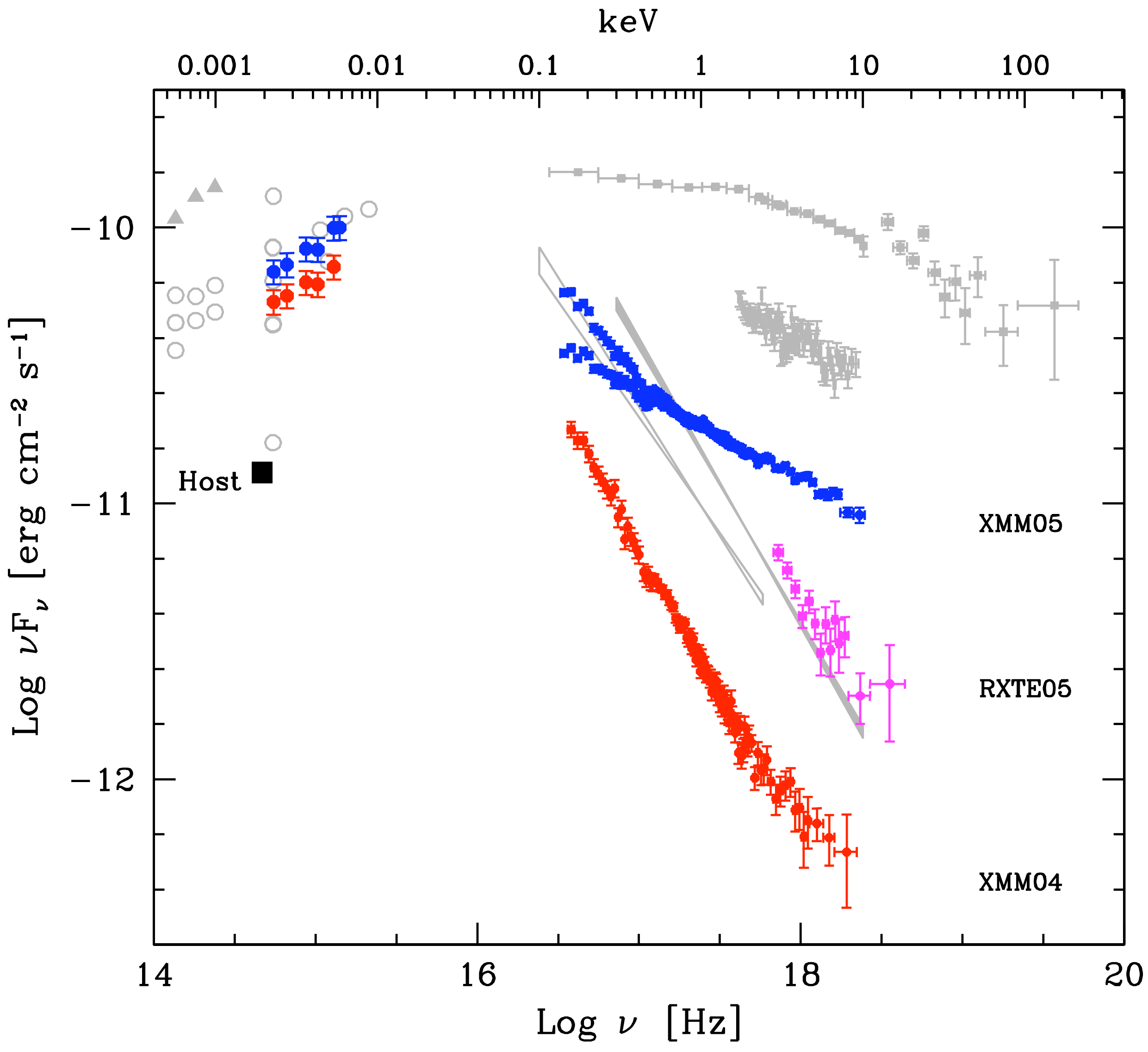
PKS 2155-304 in 2006



The same can happen in the Compton emission !

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

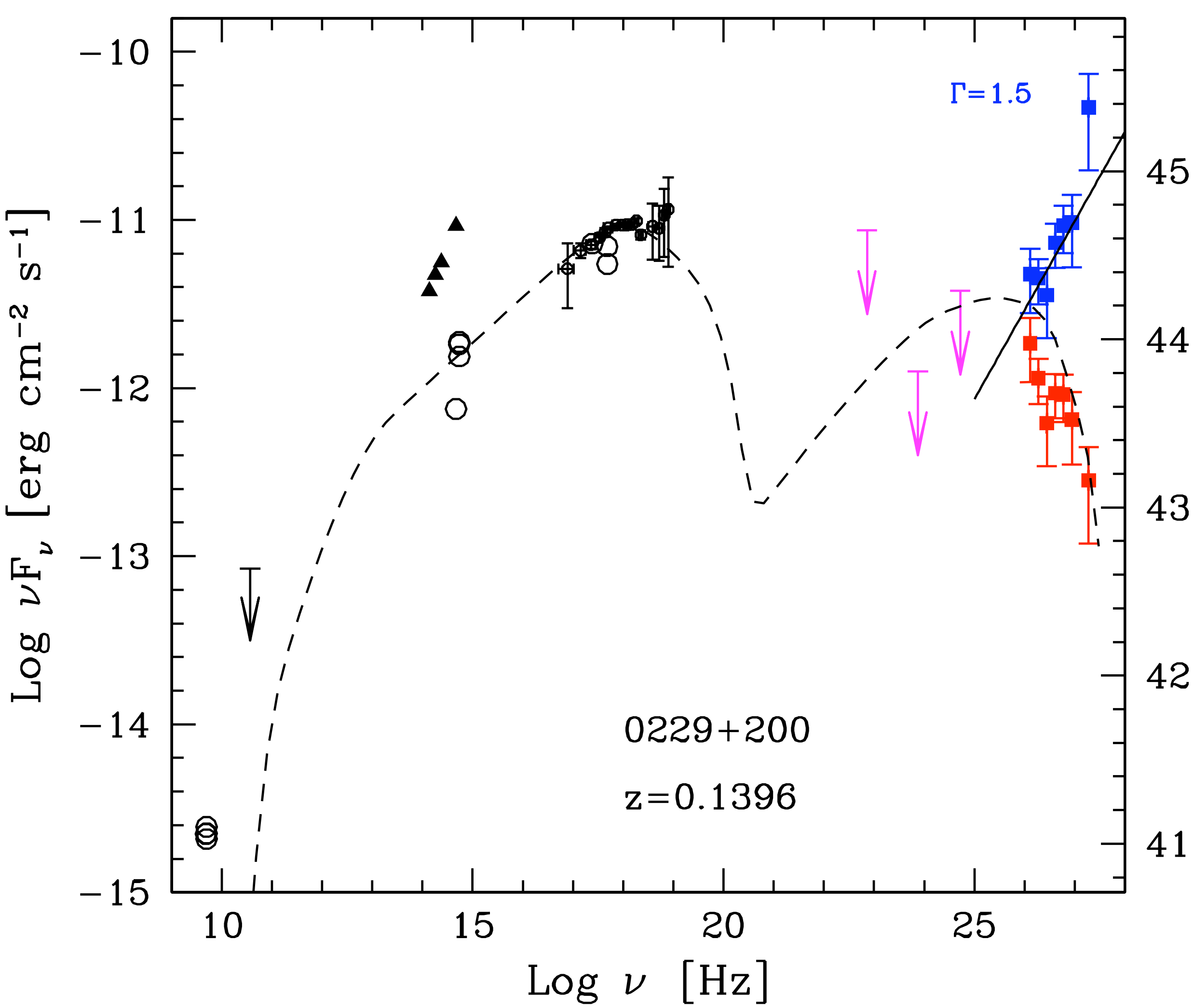
One of the most evident cases showed up in the 2004-2005 multi-wavelength campaigns on PKS 2005-489, in the synchrotron emission:

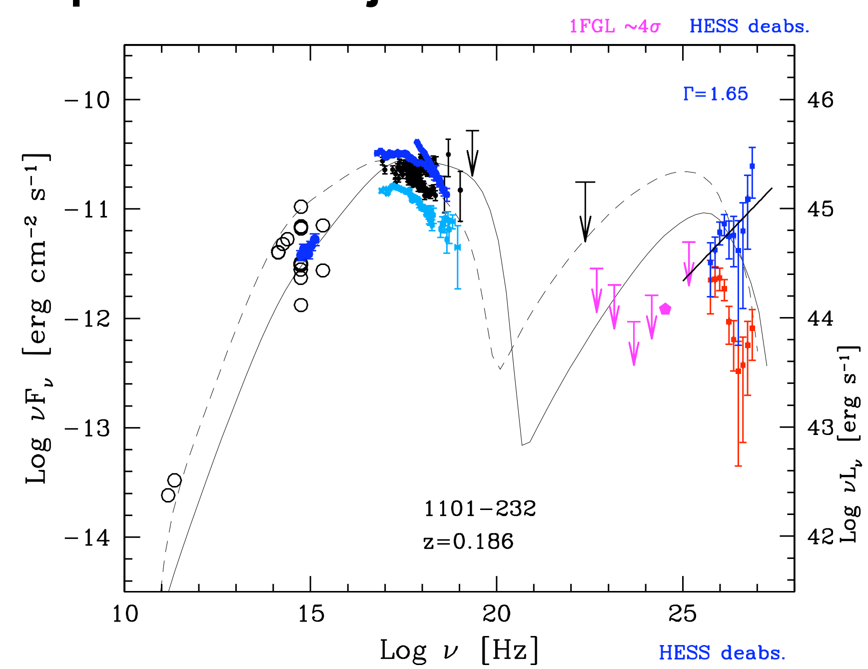


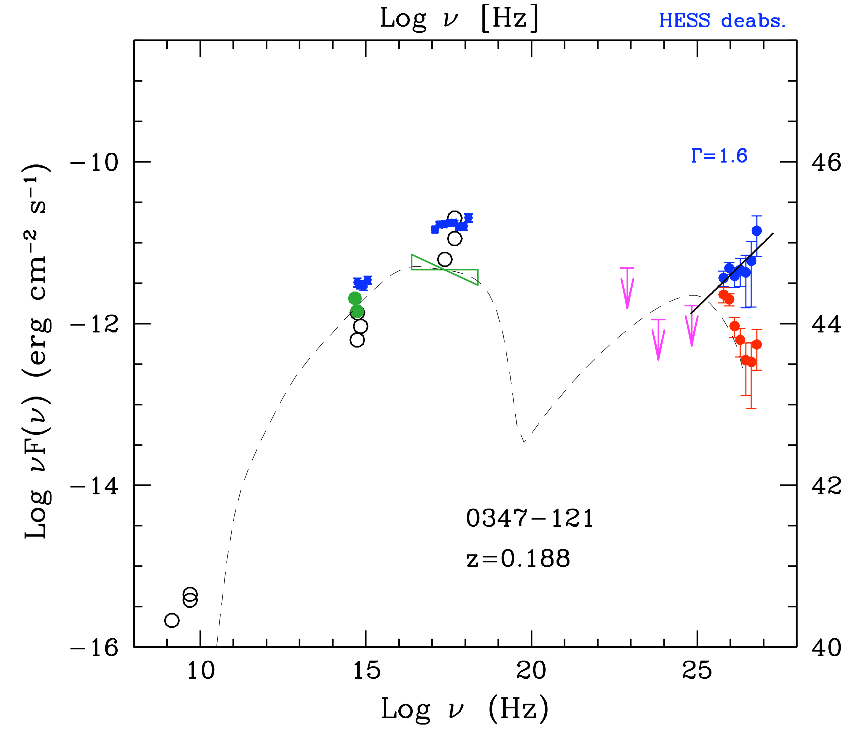
Aharonian et al. (HESS Coll.) 2010.

3) At VHE, intrinsic spectra as hard as Γ=1.5-1.6 are already observed (with lowest 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.



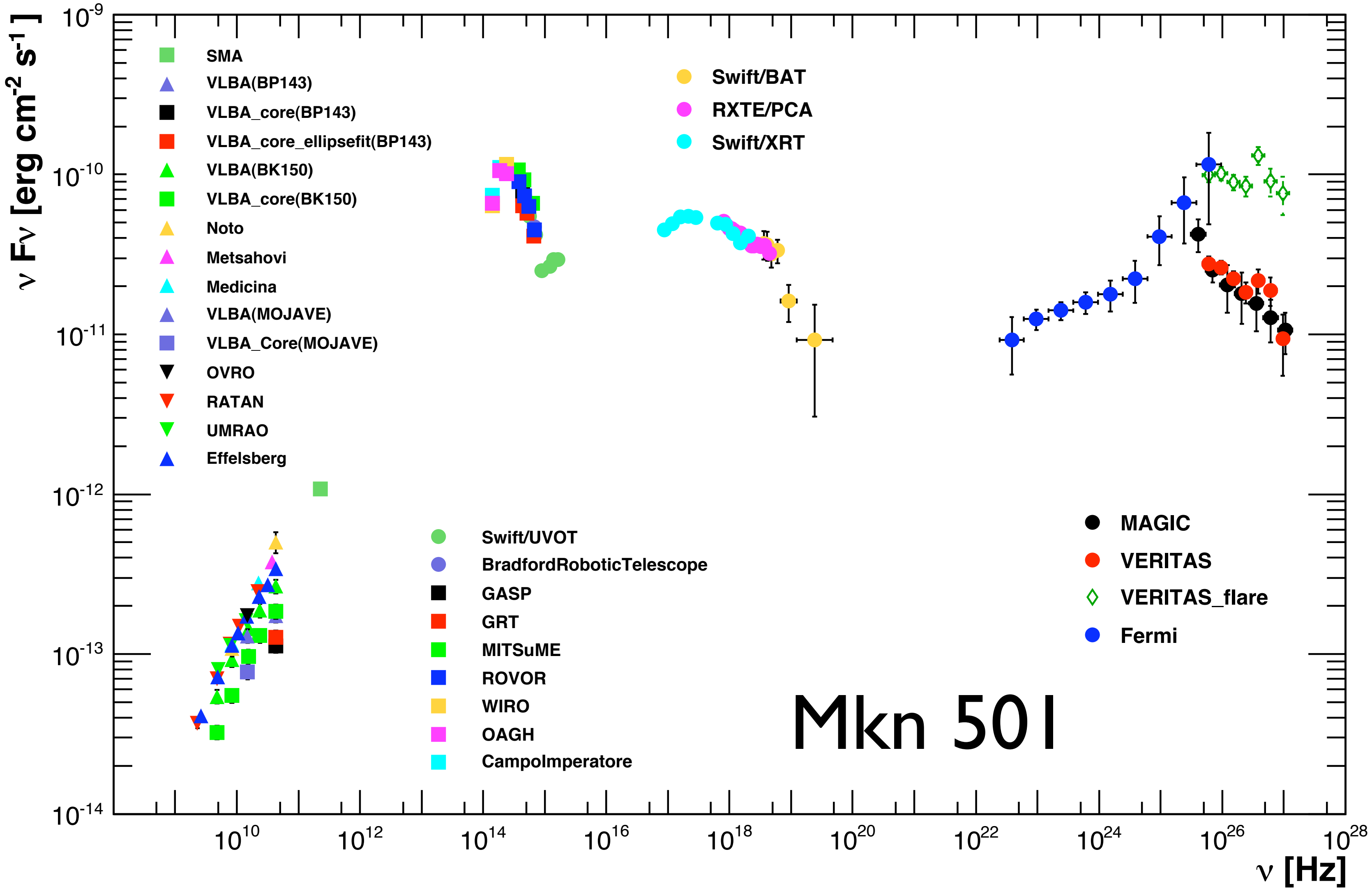




The SED of such components can remain hidden below a more "standard" emission and emerge/become dominant at VHE

1) + 2) + 3) =

The Fermi-LAT spectrum is neither a good estimate nor an upper limit for the VHE spectrum/emission

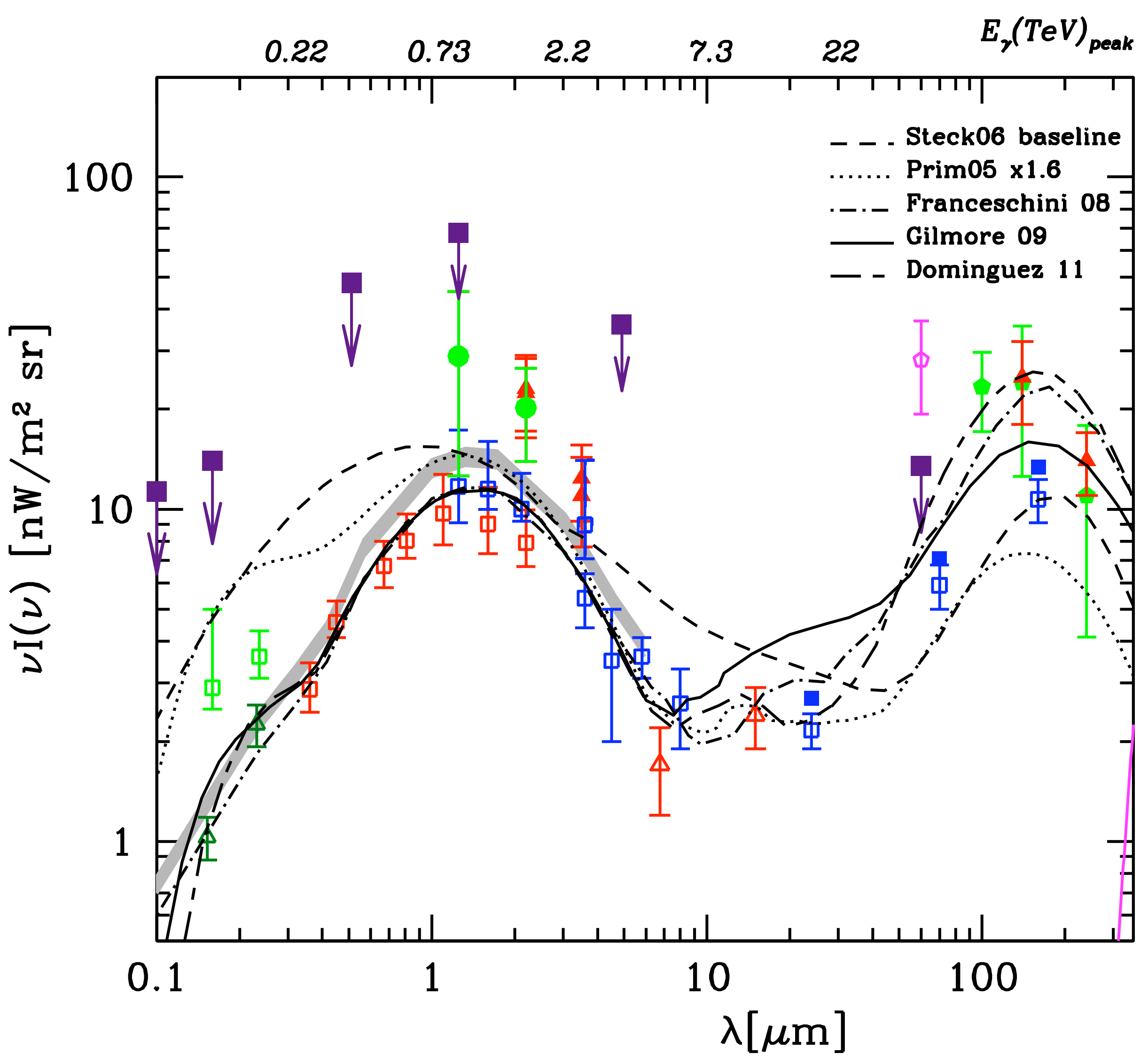


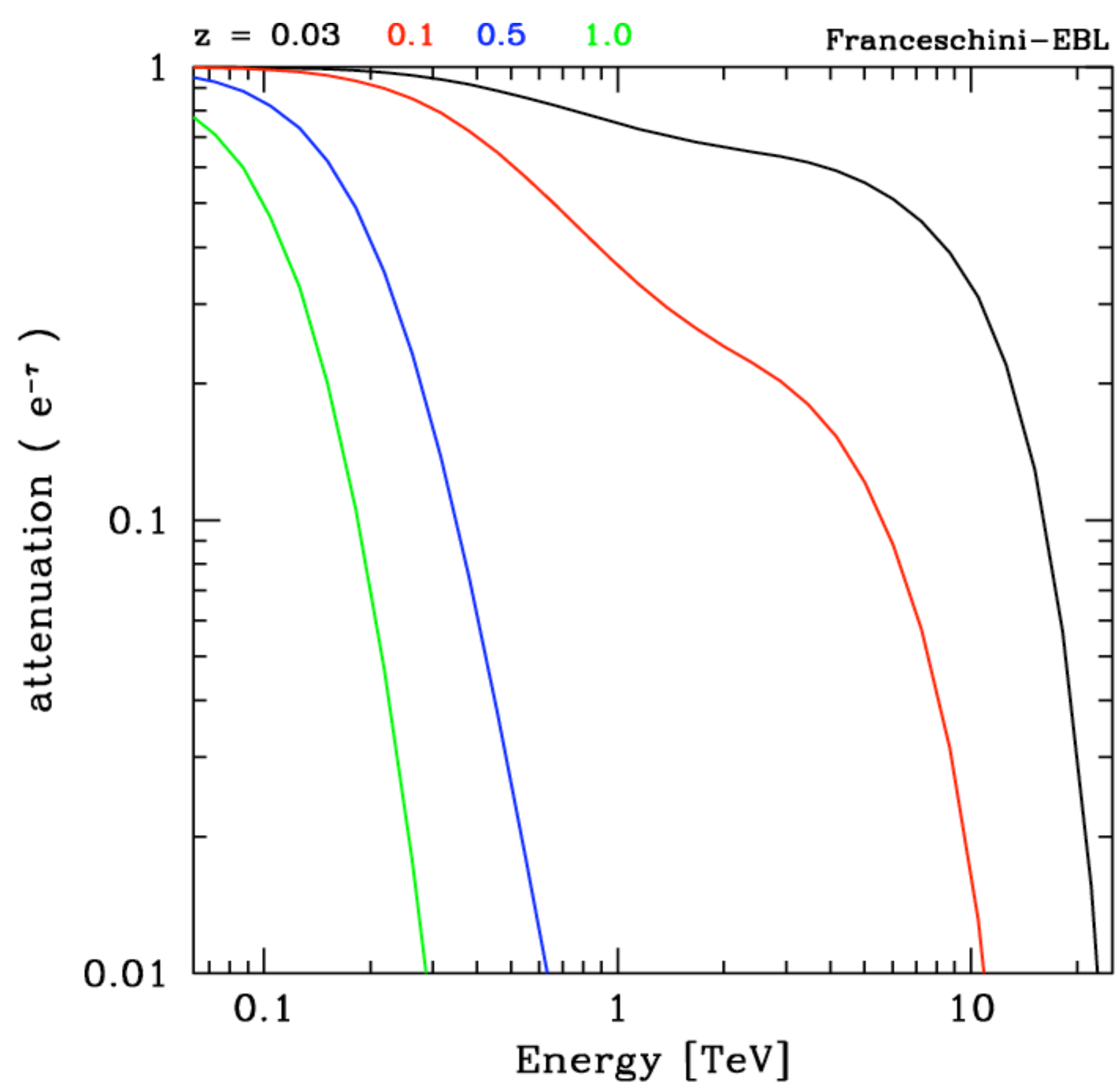
Abdo et al. 2010

We do not know yet how to reliably predict a VHE spectrum from the GeV band !

How can we test the EBL conclusions ?

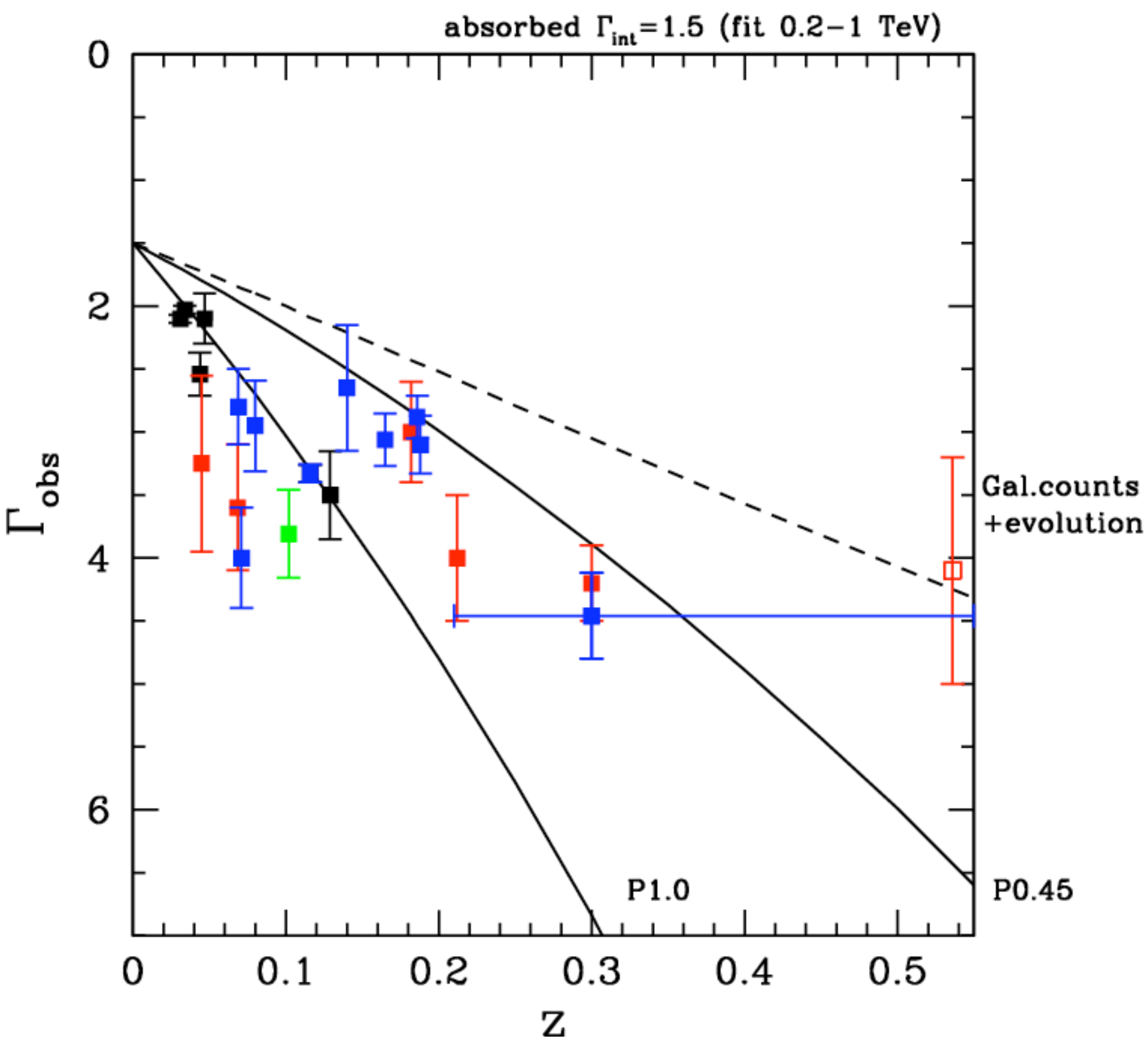
- Finding and monitoring low-redshift (=low attenuation) TeV BLLacs (look for $\Gamma_{observed} < 1$)
- Observing high redshift objects (z=0.5): Γ_{int}=1.5 ⇒ below gal. counts.



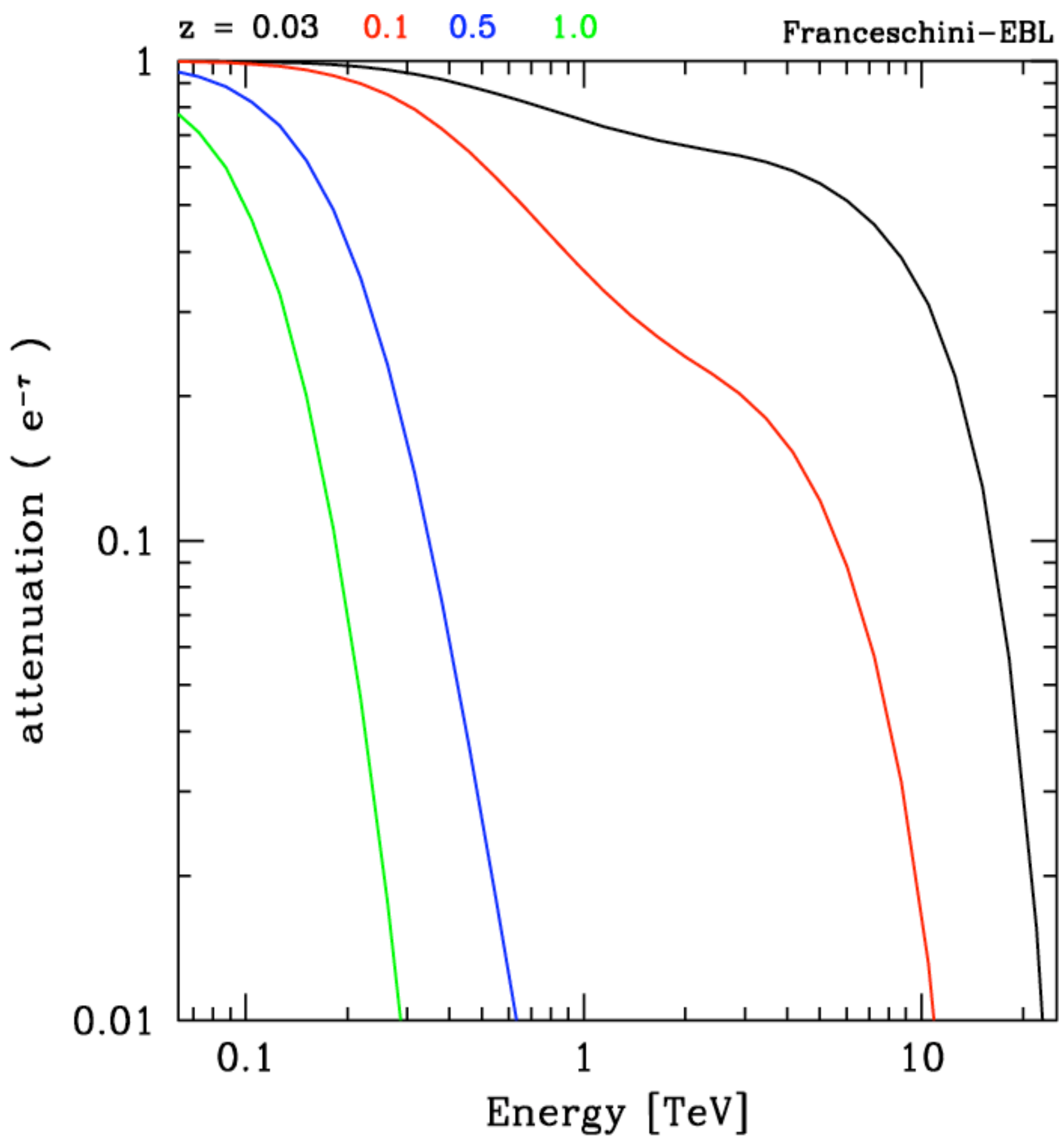


Photon-wise, NO need (yet) of new physics

At present, VHE detections and spectra are **ALL** consistent/explainable with a low EBL level and standard blazar physics. Not even for objects at z=1

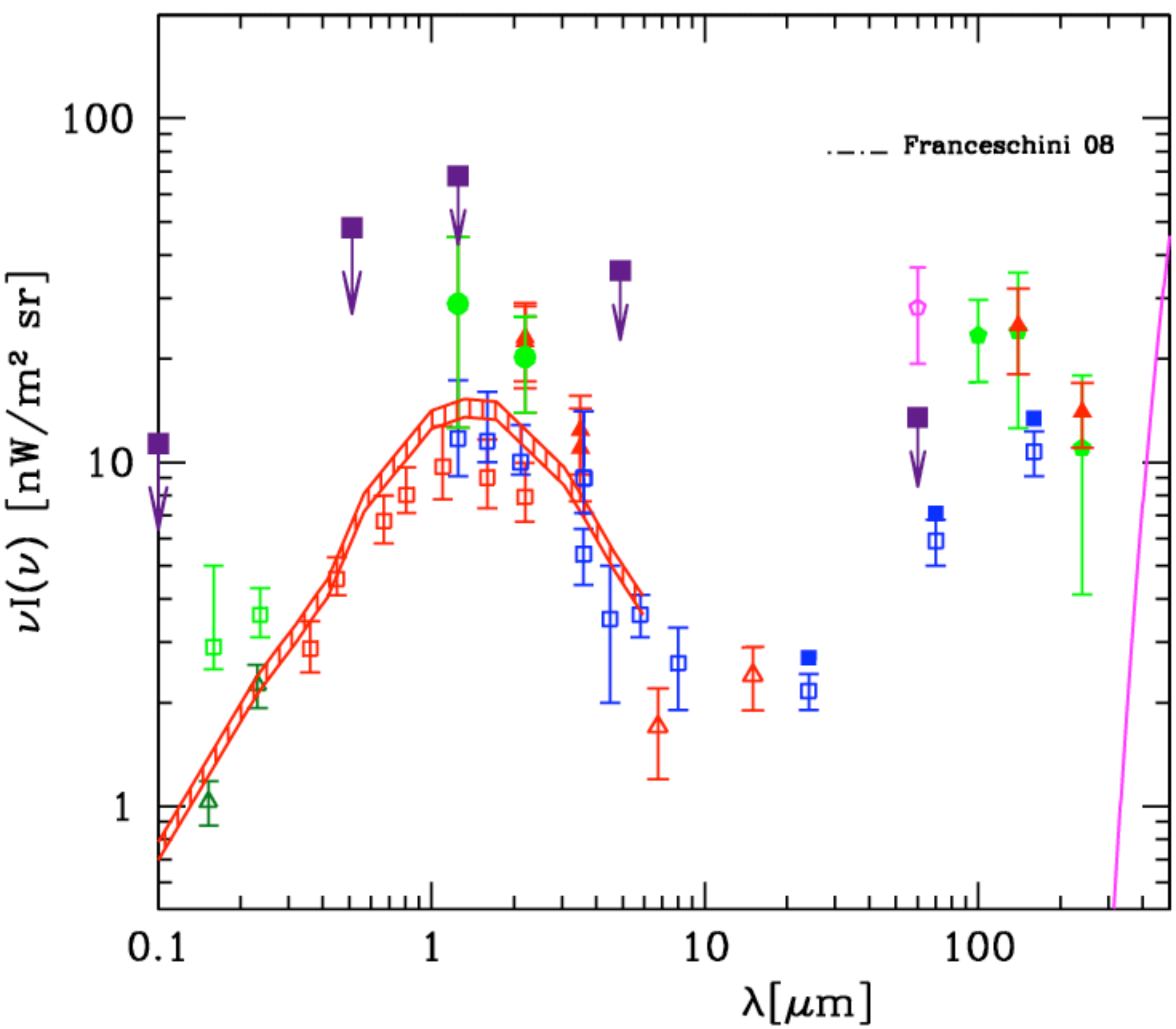


Costamante et al. 2006



I do not expect CTA to further constrain the EBL in the 0.4-8 micron region:

Ri-calculation limits from 1ES 1101-232:



new galaxy counts 1-3 micron: Keenan et al. 2010

1) There is nothing to constrain further !
The UL already match the lower limits from galaxy counts and all most recent calculations from galaxy evolution and SEDs

Instead, CTA will test our assumptions on blazar physics (e.g. the 1.5 or 2/3 limits, particle acceleration etc.).
It will confirm or falsify our assumptions.

2) even with gargantuan statistics, there is the unavoidable systematic of blazar knowledge/modeling: the small change of slope ($\Delta\Gamma$~0.1-0.3) induced by the small residual uncertainty between upper and lower limits, can typically be accomodated with slight changes in blazar parameters.

Conclusions from gamma-rays:

- A low EBL seems still the best explanation, despite our uncertainties on blazar physics (limit line still fuzzy).
- However, we do not yet understand basic aspects of the the acceleration/emission mechanisms in blazars.
- Do not take limits from Fermi-extrapolations too strictly (they are more guesses than limits).
- CTA will improve our blazar knowledge and assumptions, will likely not lower further down the present limits in the Opt-NIR (will improve a lot the MIR-FIR range).