BLAZARS: do we really understand them ?

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Leptonic scenarios

IR radiation
Hot Dust

Broad Line
Region clouds

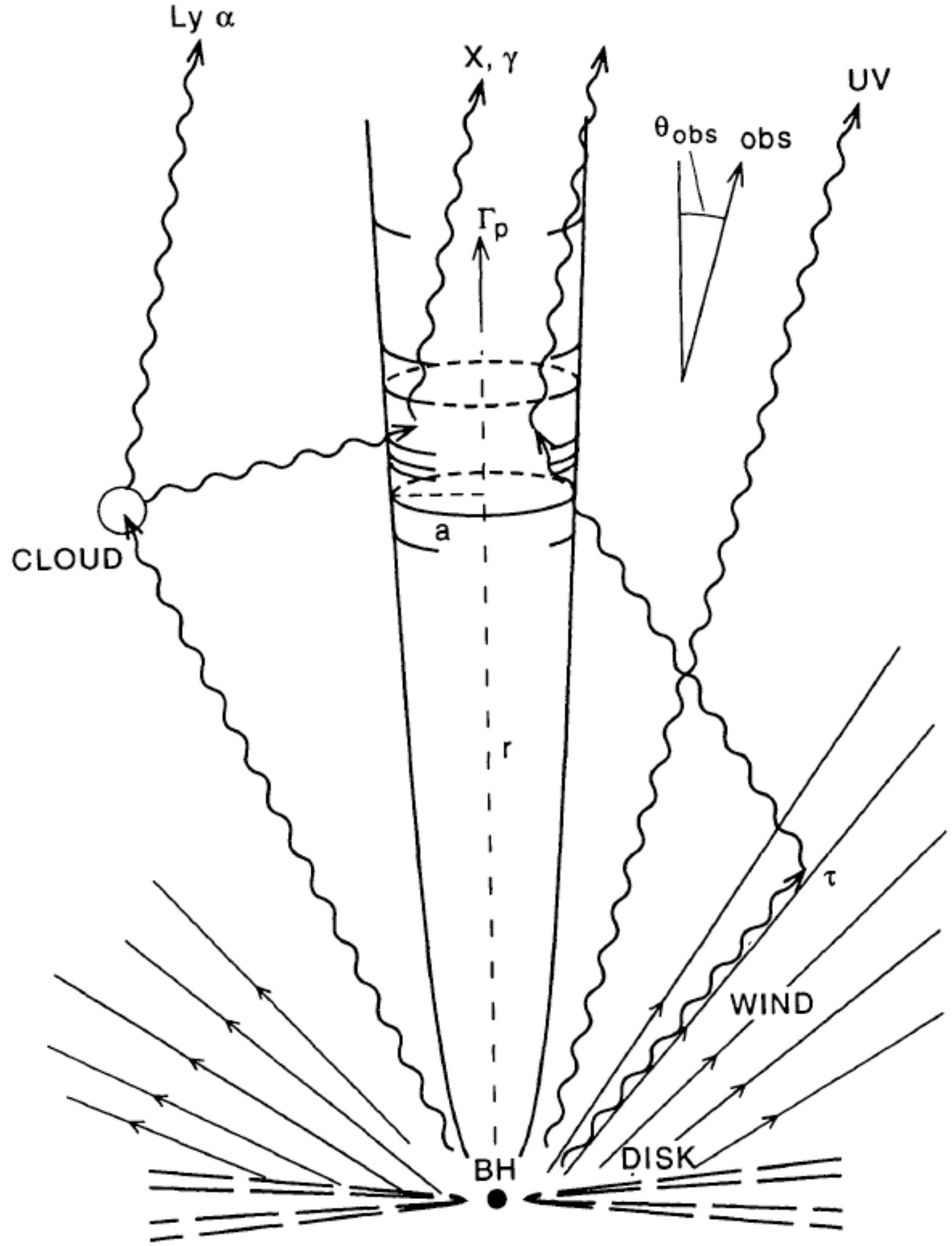
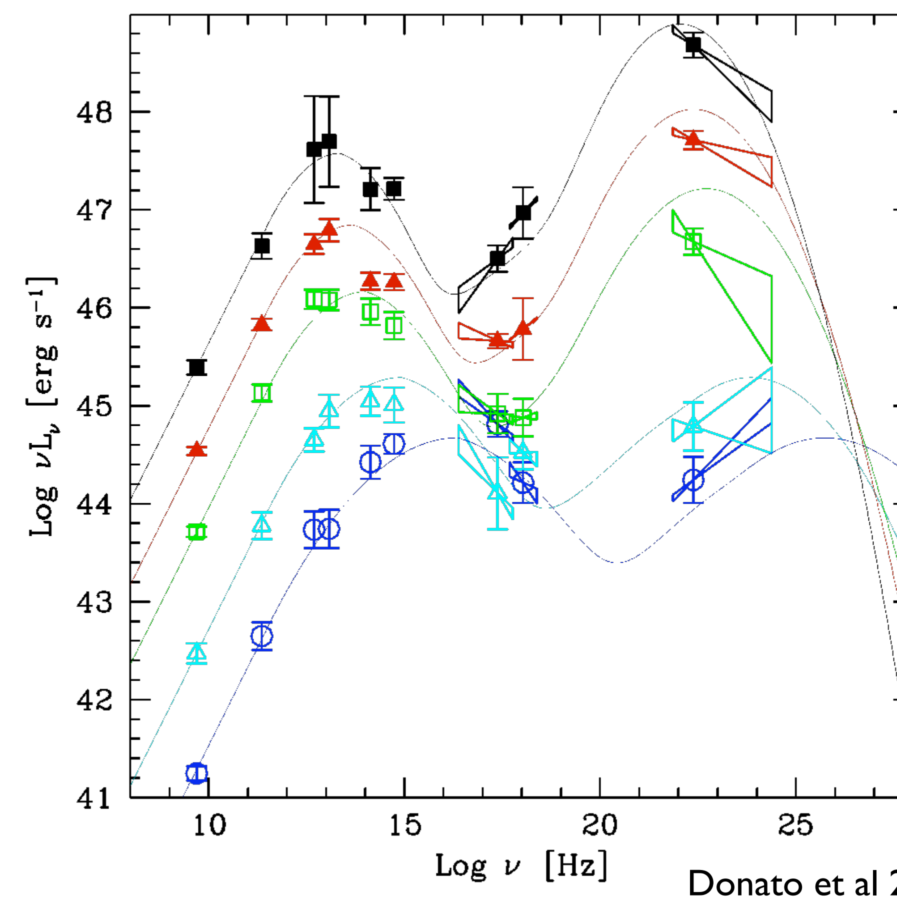


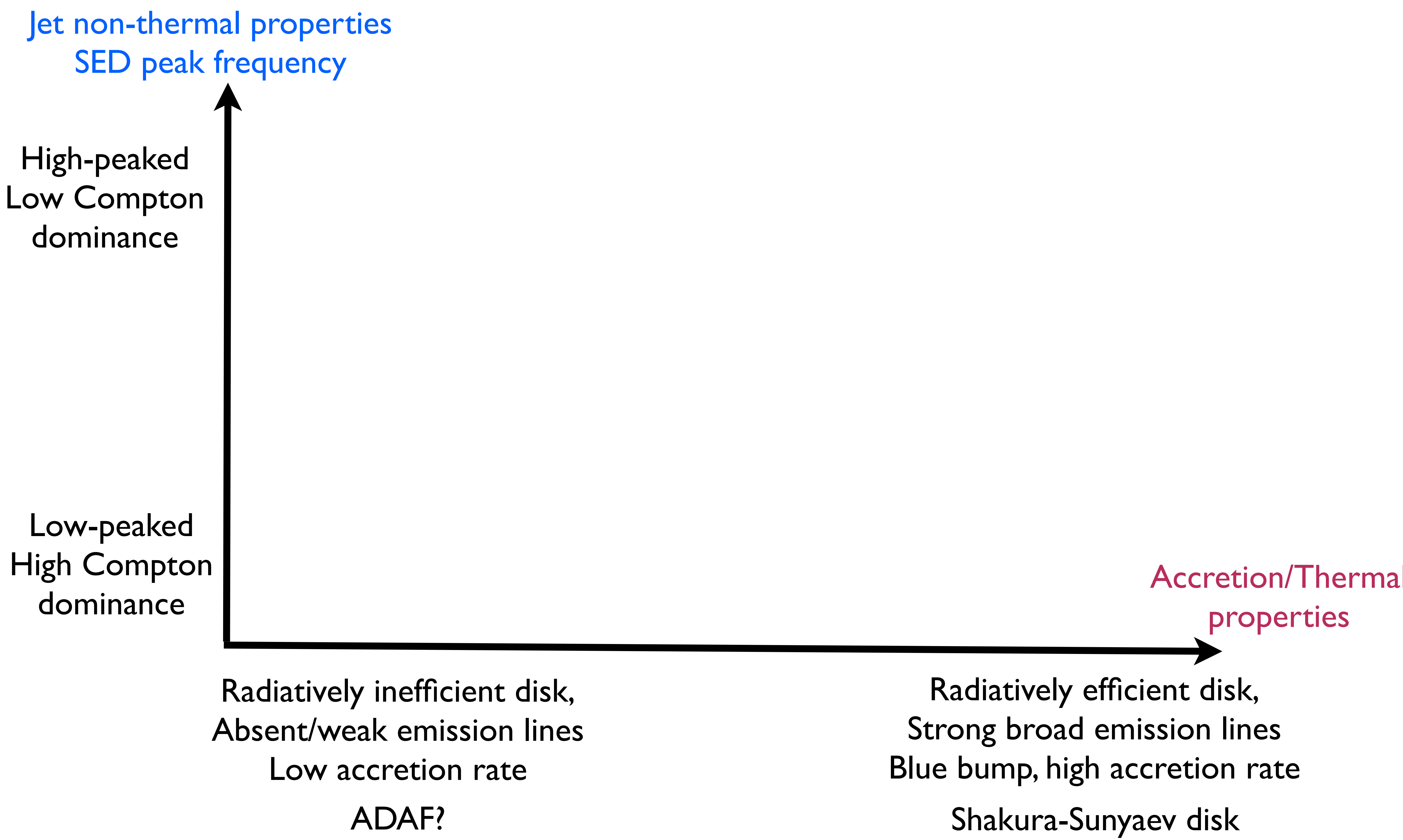
FIG. 2.—Geometry of the source. The radiating region, denoted by short cylinder of dimension a, moves along the jet with pattern Lorentz factor Γ_p. Underlying flow moves with Lorentz factor Γ, which may be different.

Sikora et al. 1994



Donato et al 2002

The Main Plane of Blazars



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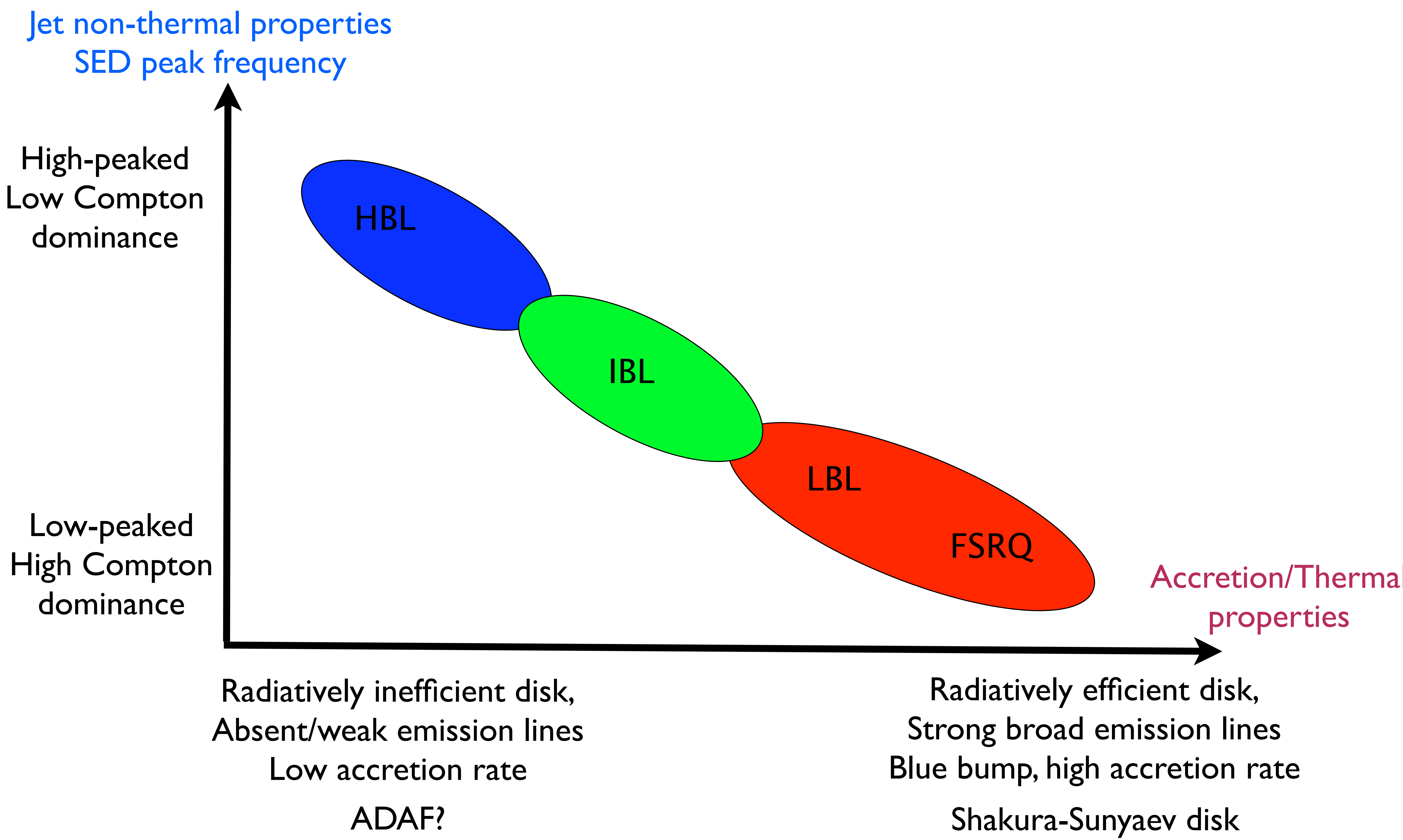
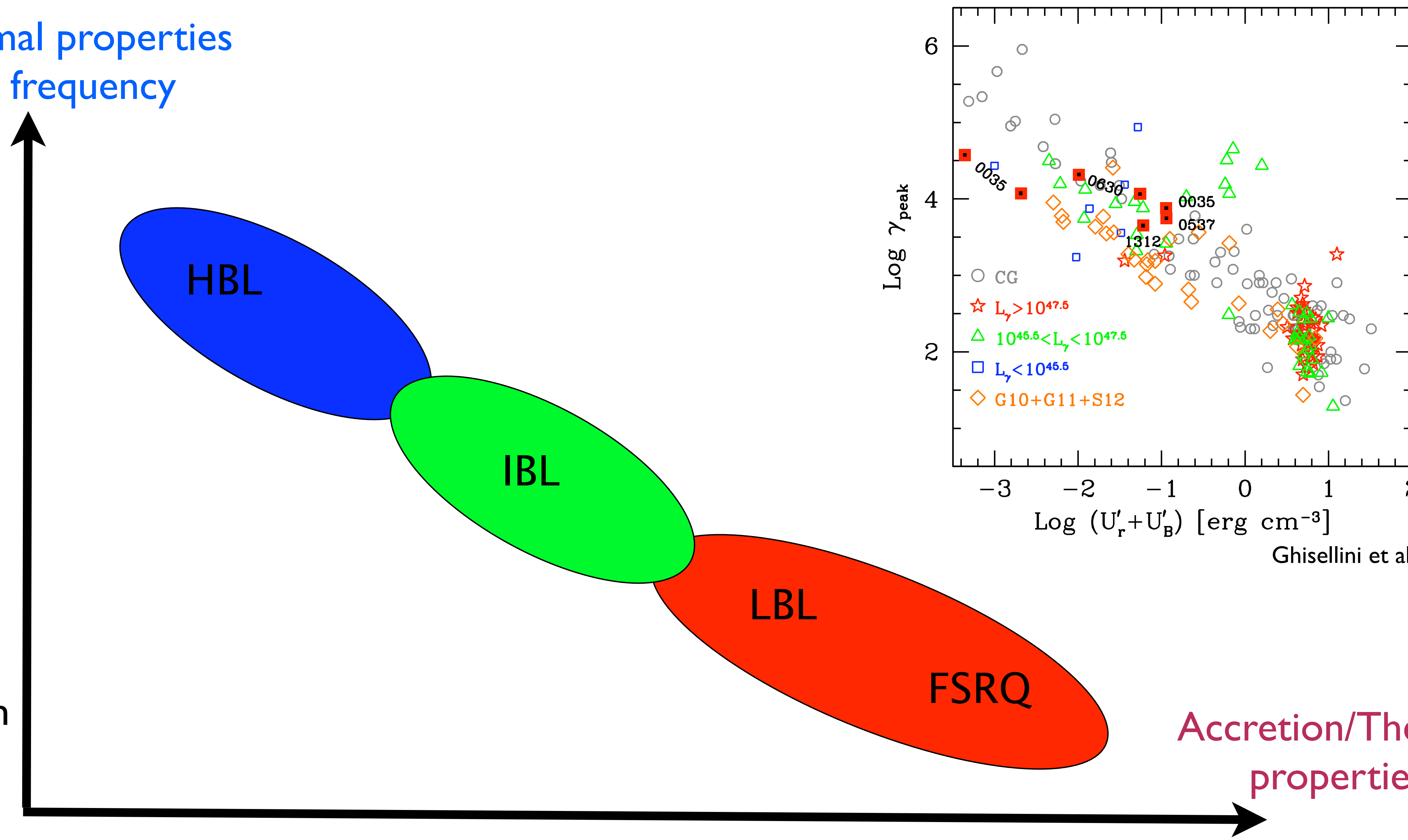


The Main Plane of Blazars

Jet non-thermal properties
SED peak frequency

High-peaked
Low Compton
dominance



Ghisellini et al. 98-12

Low-peaked
High Compton
dominance

Accretion/Thermal
properties

Radiatively inefficient disk,
Absent/weak emission lines
Low accretion rate

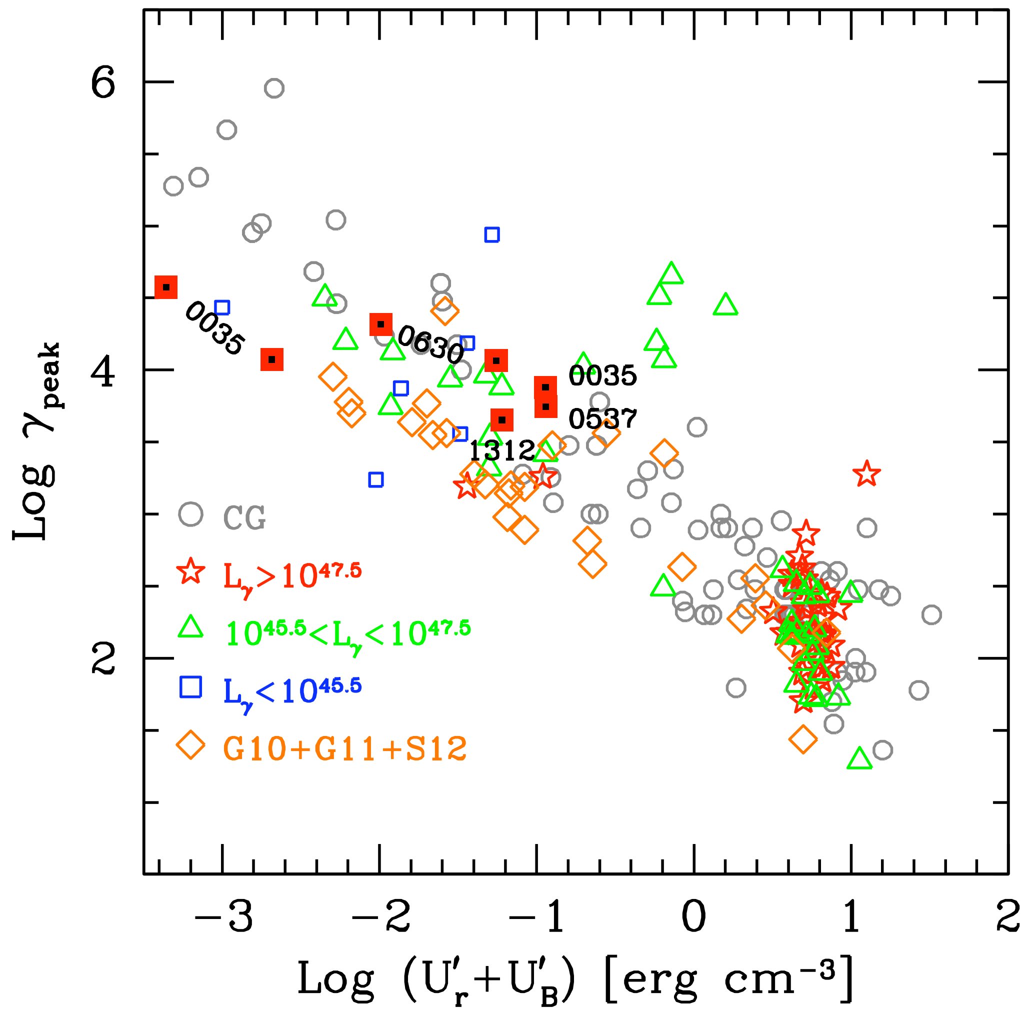
ADAF?

Radiatively efficient disk,
Strong broad emission lines
Blue bump, high accretion rate

Shakura-Sunyaev disk

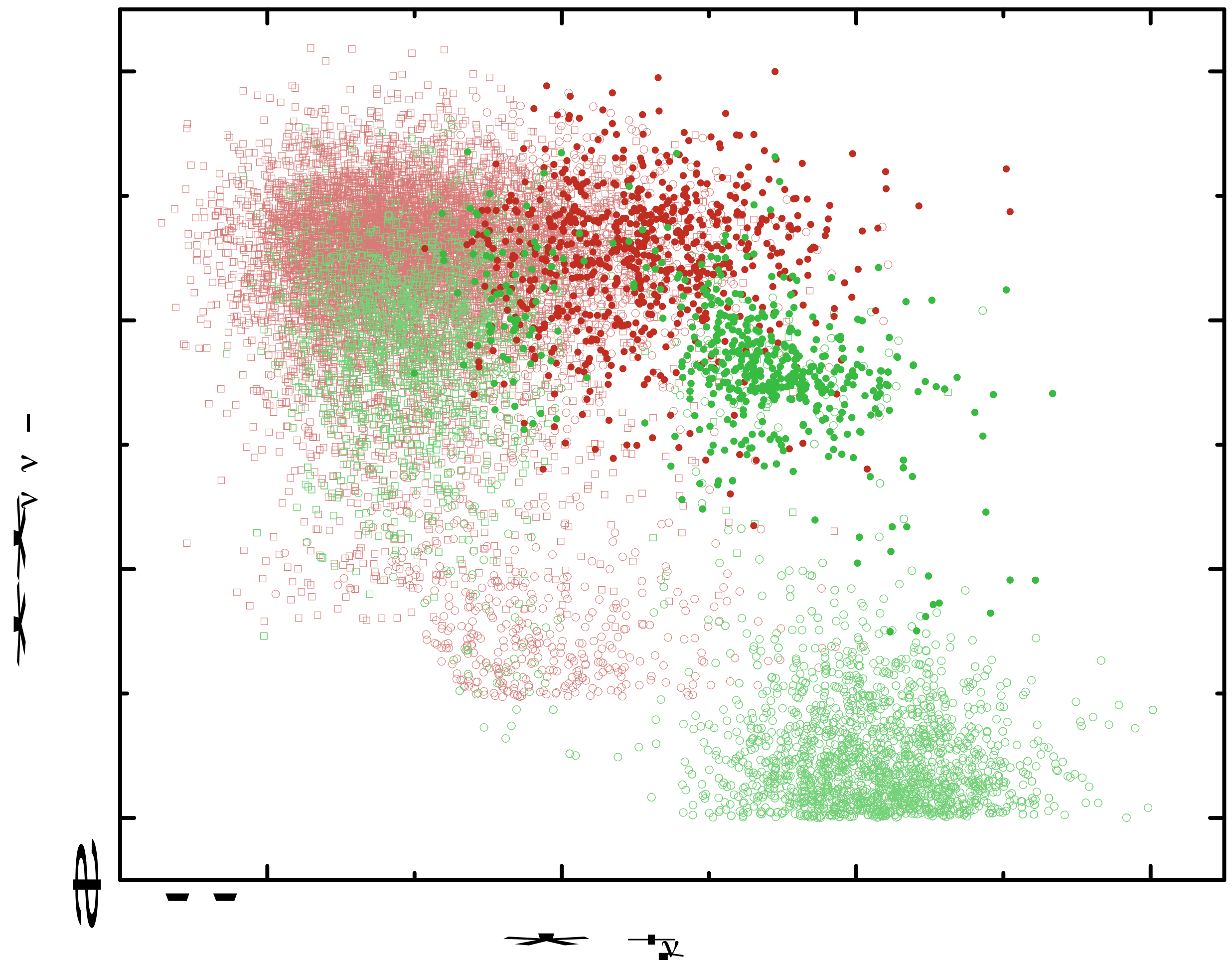
Origin of Blazar Sequence:
problem of many Fermi BL Lacs with no redshift

Physical ?



Ghisellini et al. 1998-2012

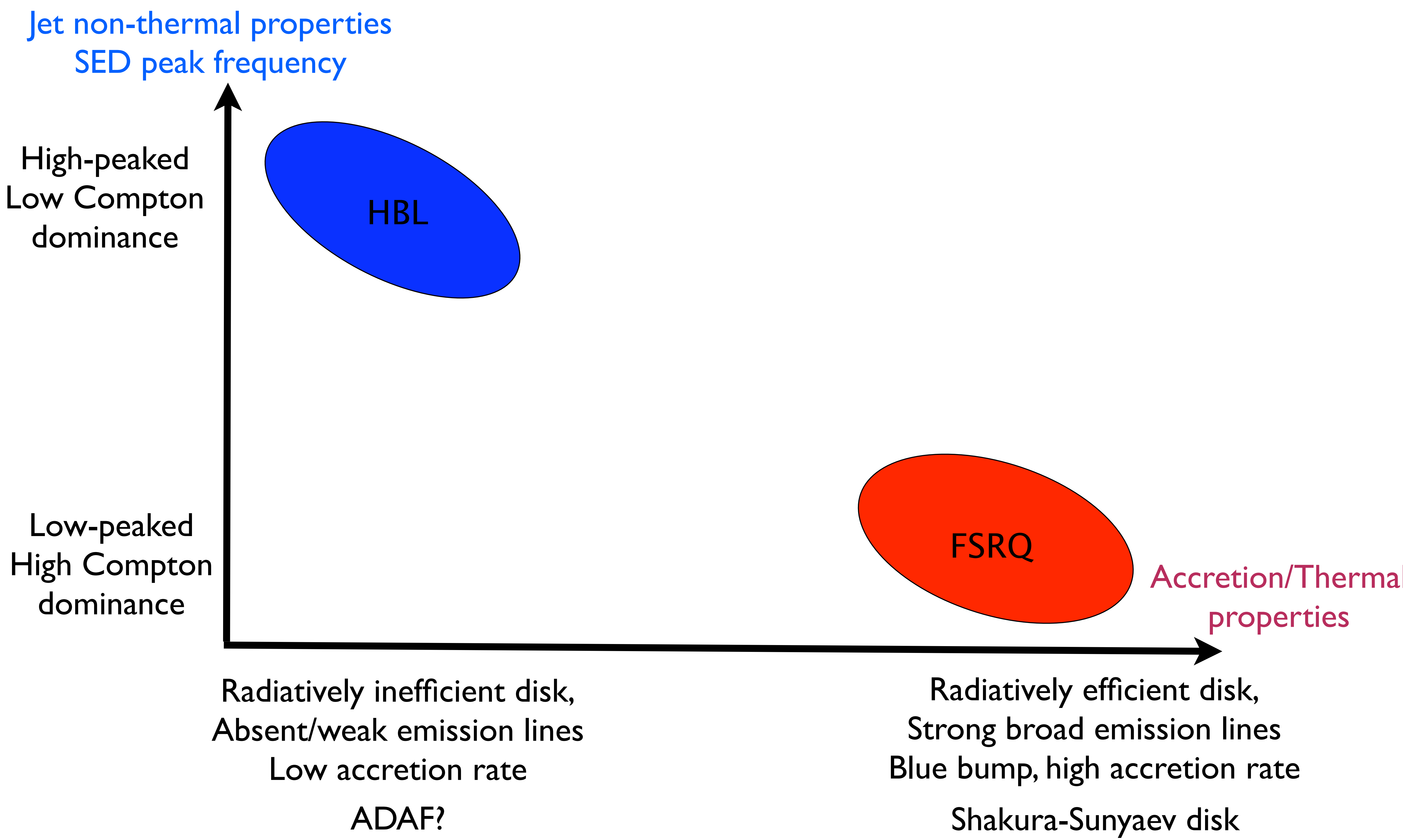
Selection bias ?



Simulations of observational biases

Giommi, Padovani et al. 2012

Focus of the talk:



Synchrotron peak frequencies

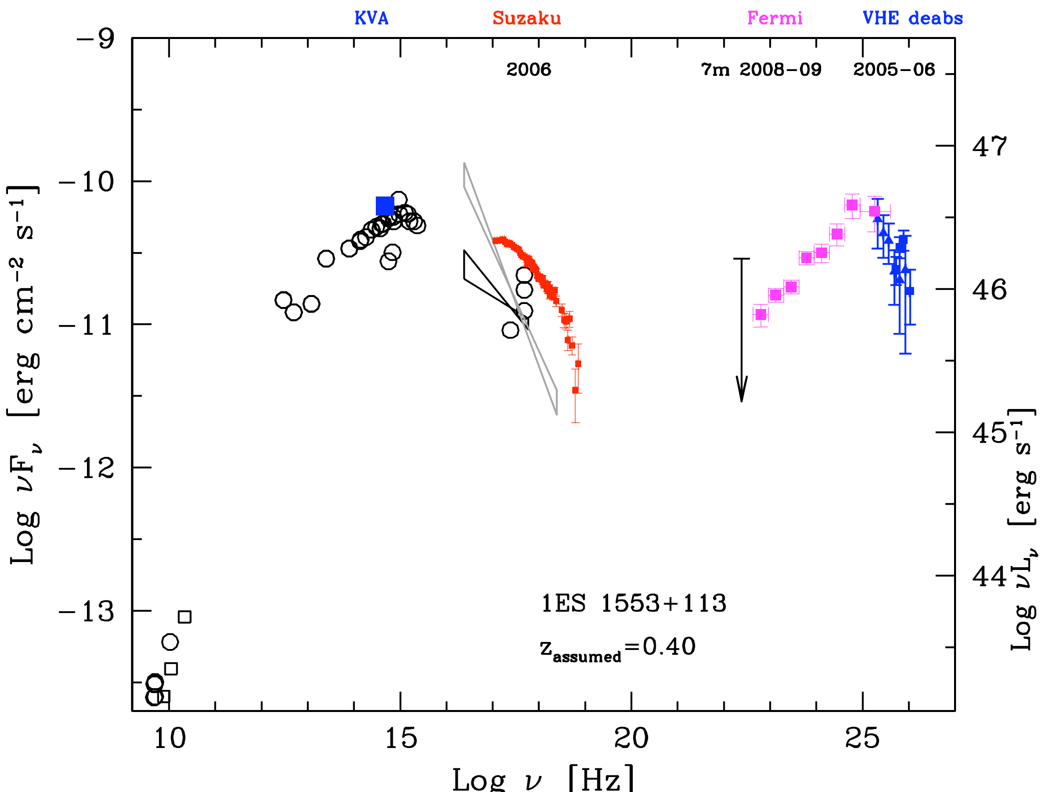
HBL = - standard HBL (peak UV-softX)
- Extreme BL (peak > few keV)

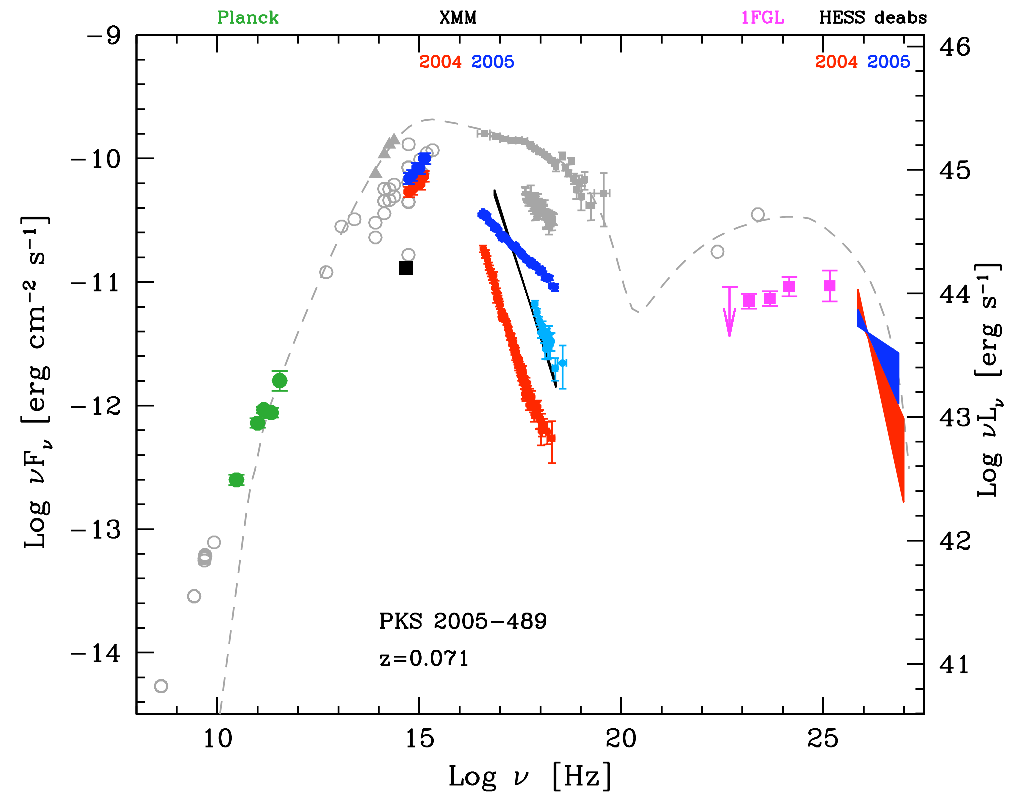
Compton peak frequencies

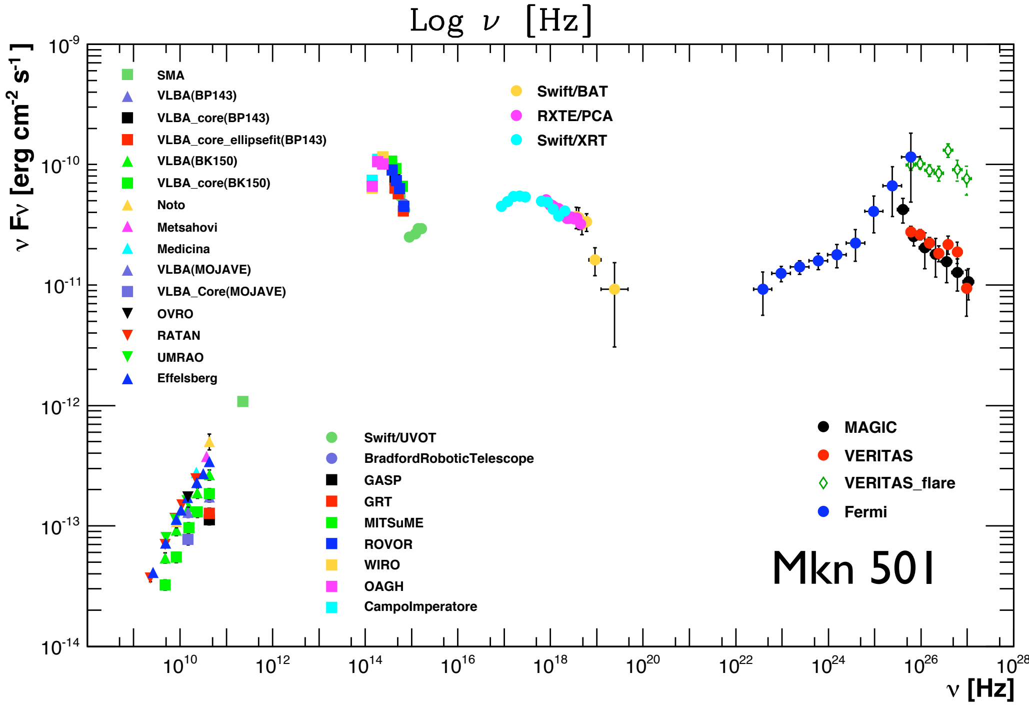
Two types of HBL as well !

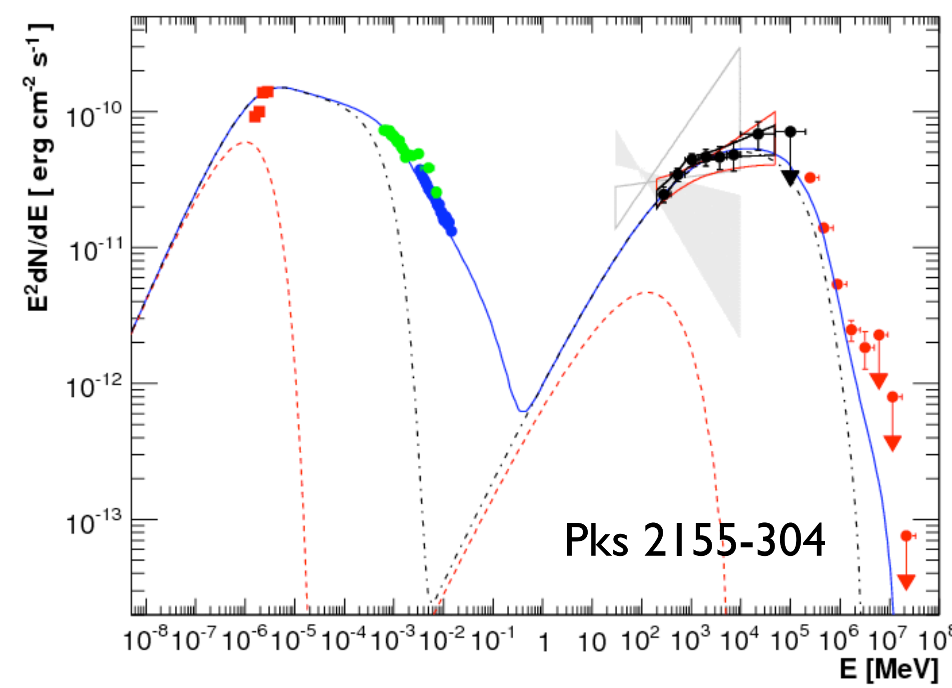
“GBL”

~100 GeV-peaked HBL objects (bright and easily detected in Fermi-LAT)





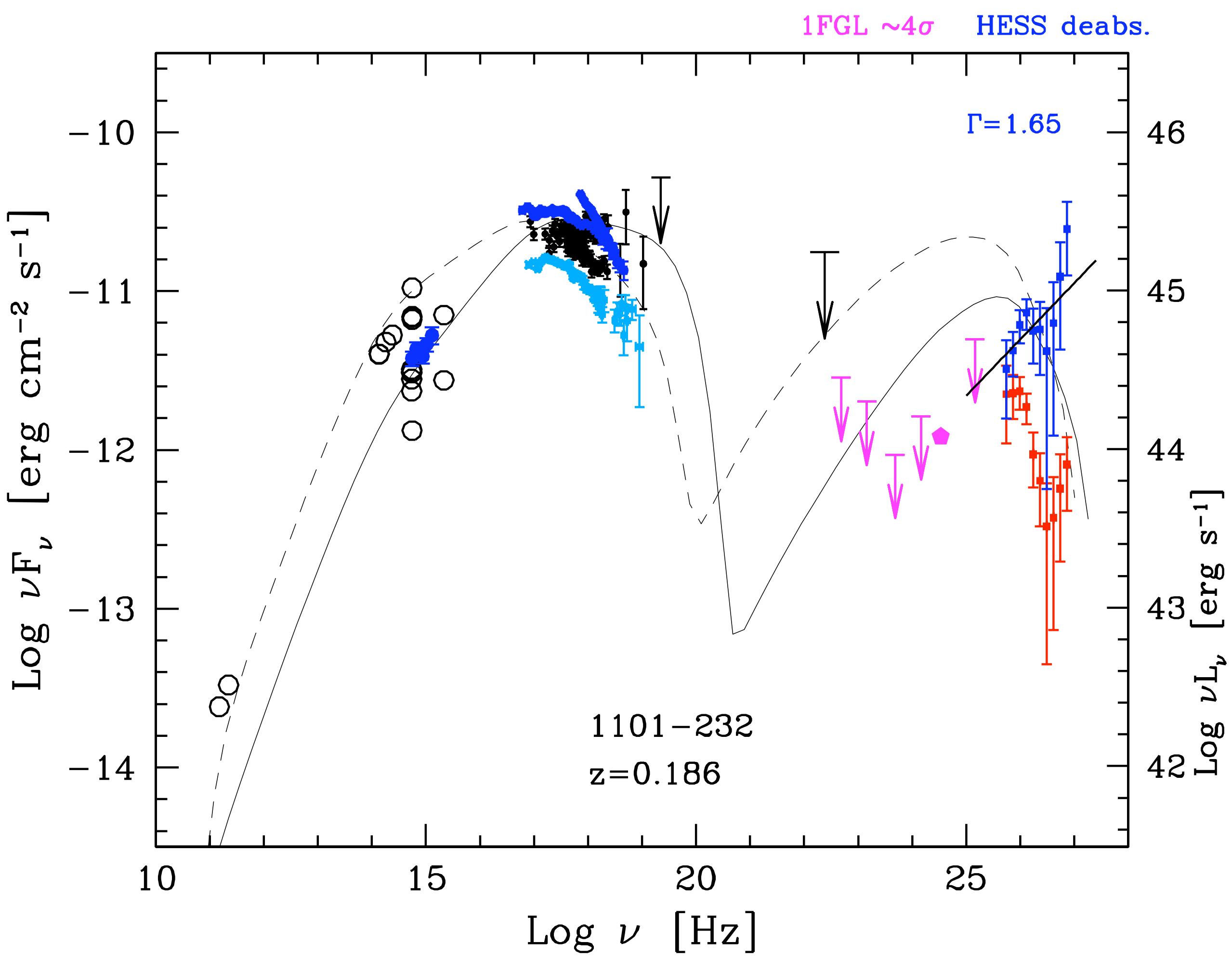


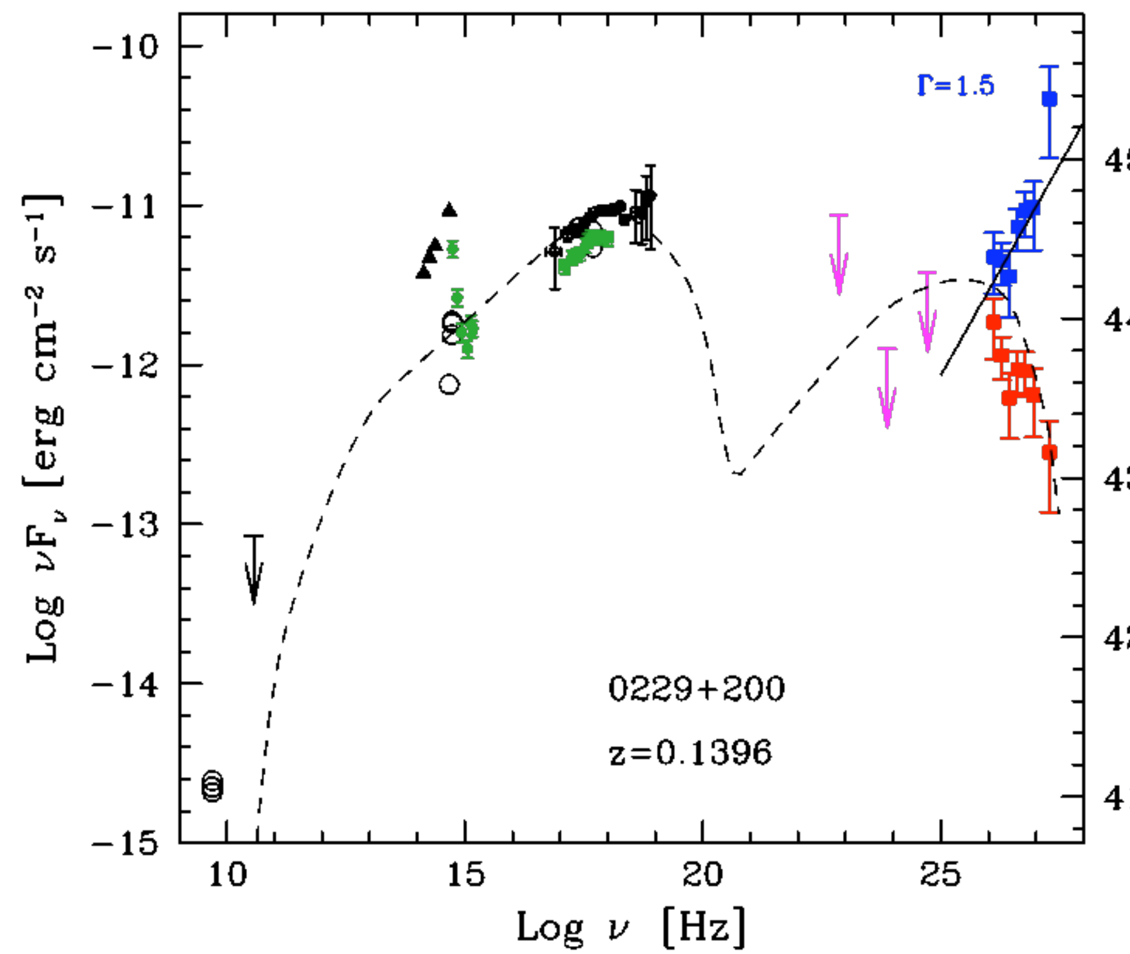


$\Gamma_{LAT} < 2$; $\Gamma_{VHE} > 2$

Abdo et al. (LAT coll)
2009, 2010a, 2010b, 2011

"TBL": TeV-peaked BL Lacs





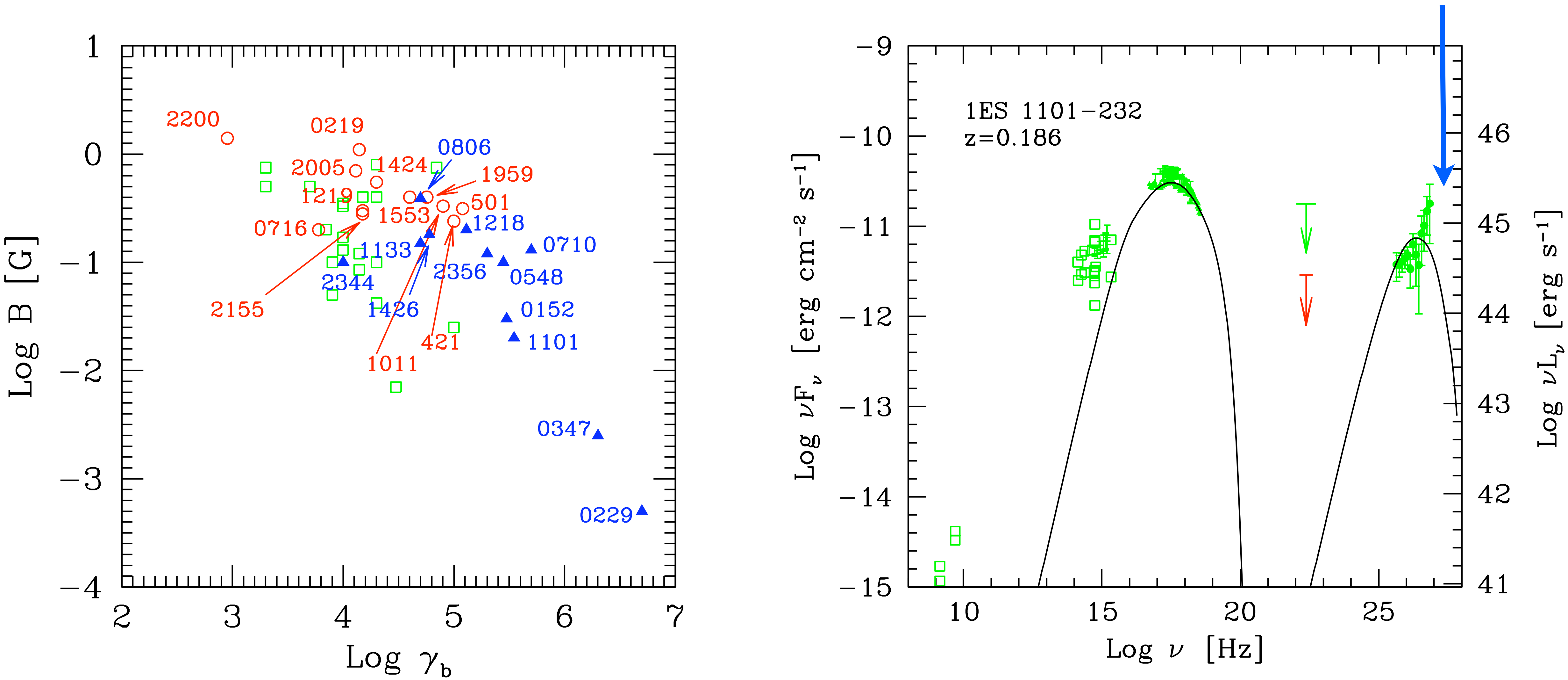
Intrinsic $\Gamma_{VHE} < 2$ (typically 1.5-1.7), with any EBL intensity (even lowest one).

⇒ Compton peak ≥ 3-20 TeV

Extremely difficult to model with one-zone SSC models, due to Klein-Nishina effects at high energies.

Not well fitted by standard SSC models, require extreme parameters and multi-zone (does not fit Opt-UV)

True peak



Tavecchio et al 2009

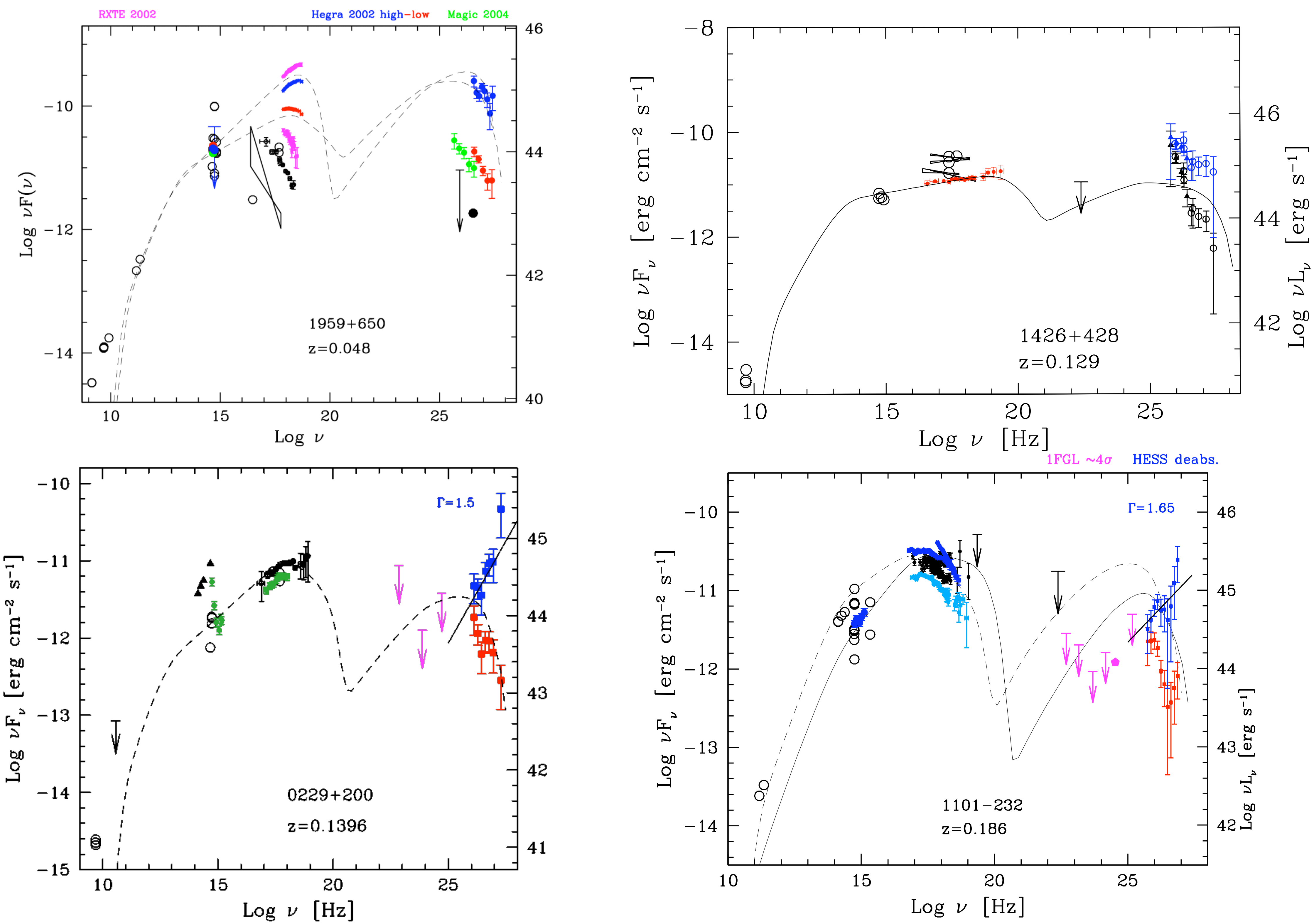
New type of BL Lac objects: TBL

How many ? 9/29: ~1/3 HBL

Relation Extreme-X — Extreme-TeV ? No...

How can be explained ?

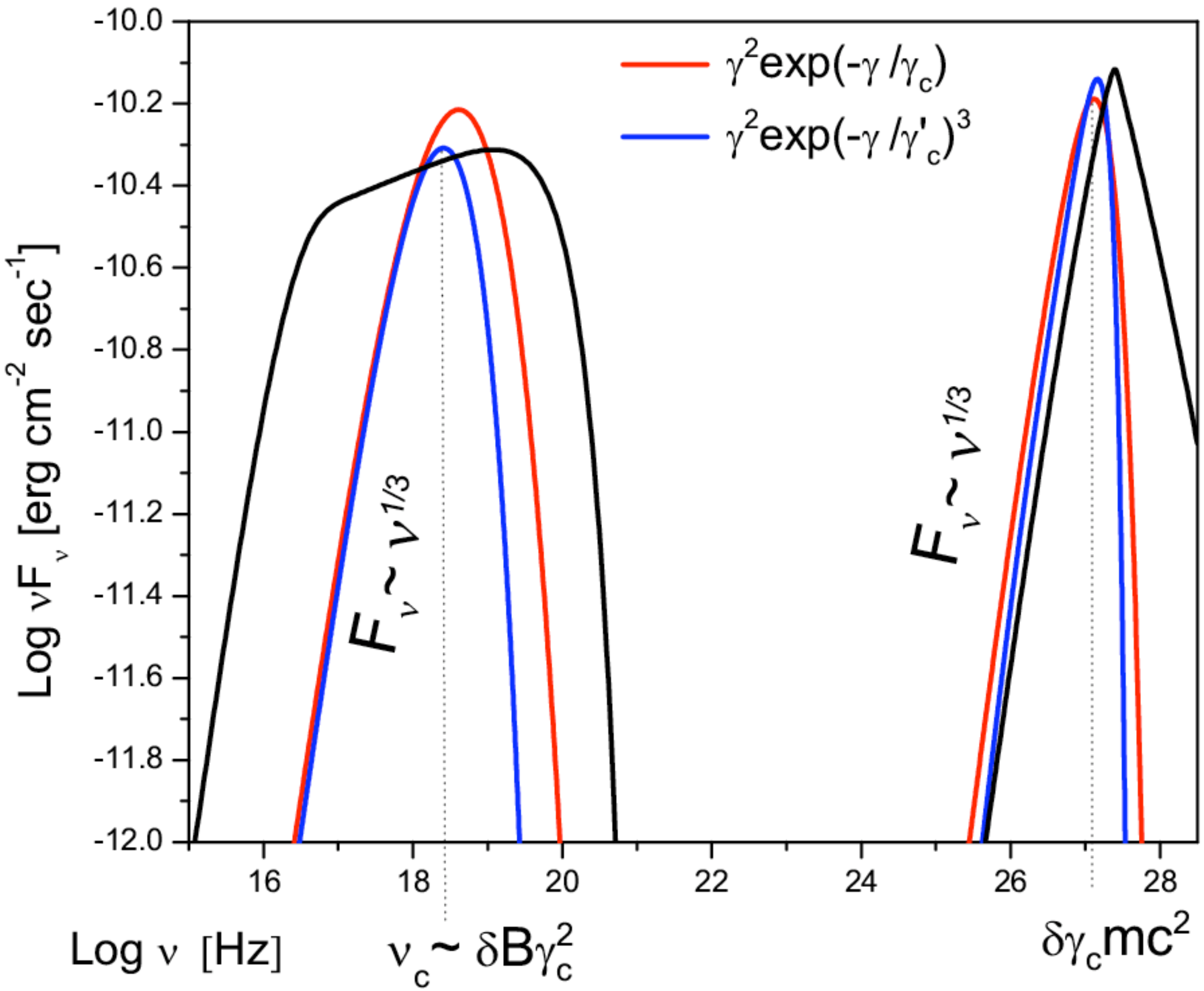
Relation X-TeV ? Not very clear:



We cannot predict GBL/TBL from SED or Fermi spectrum!

How to make very hard spectra (even <1.5) with one-zone SSC ?

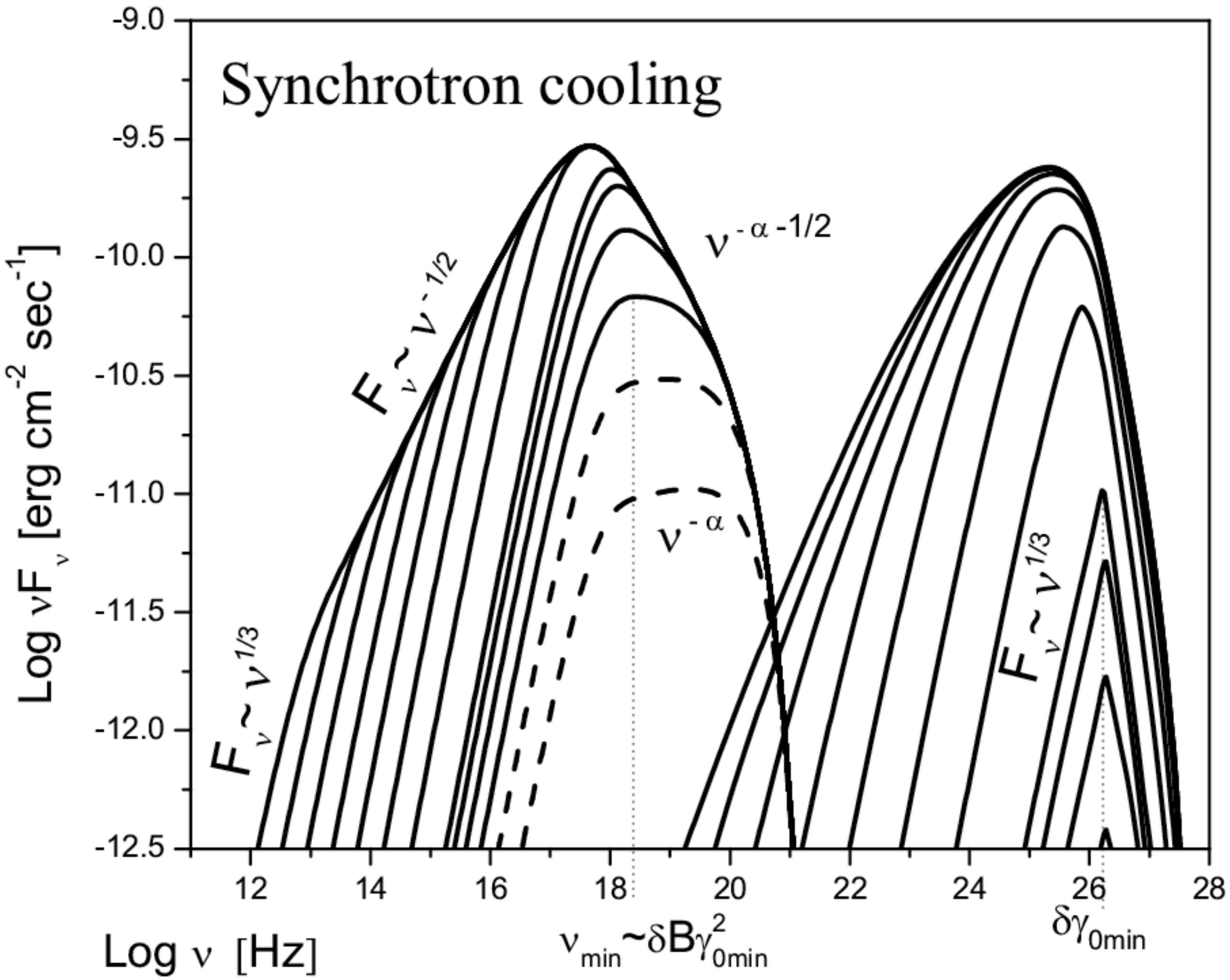
comprehensive discussion in recent paper: Lefa et al 2011



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

- Maxwellian distribution (Henri et al 2002)

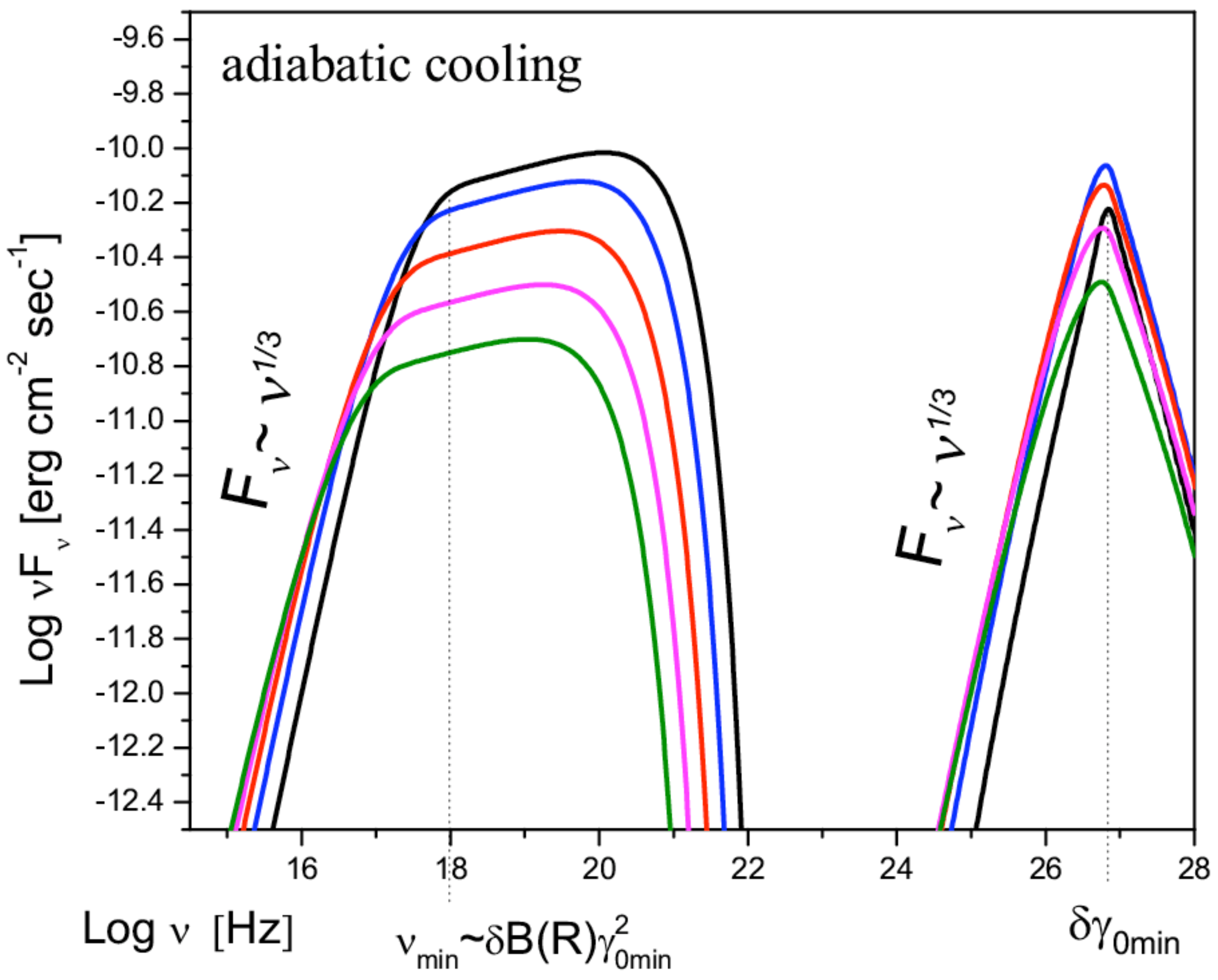
How to make very hard spectra with one-zone SSC ?



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

Lefa et al. 2011

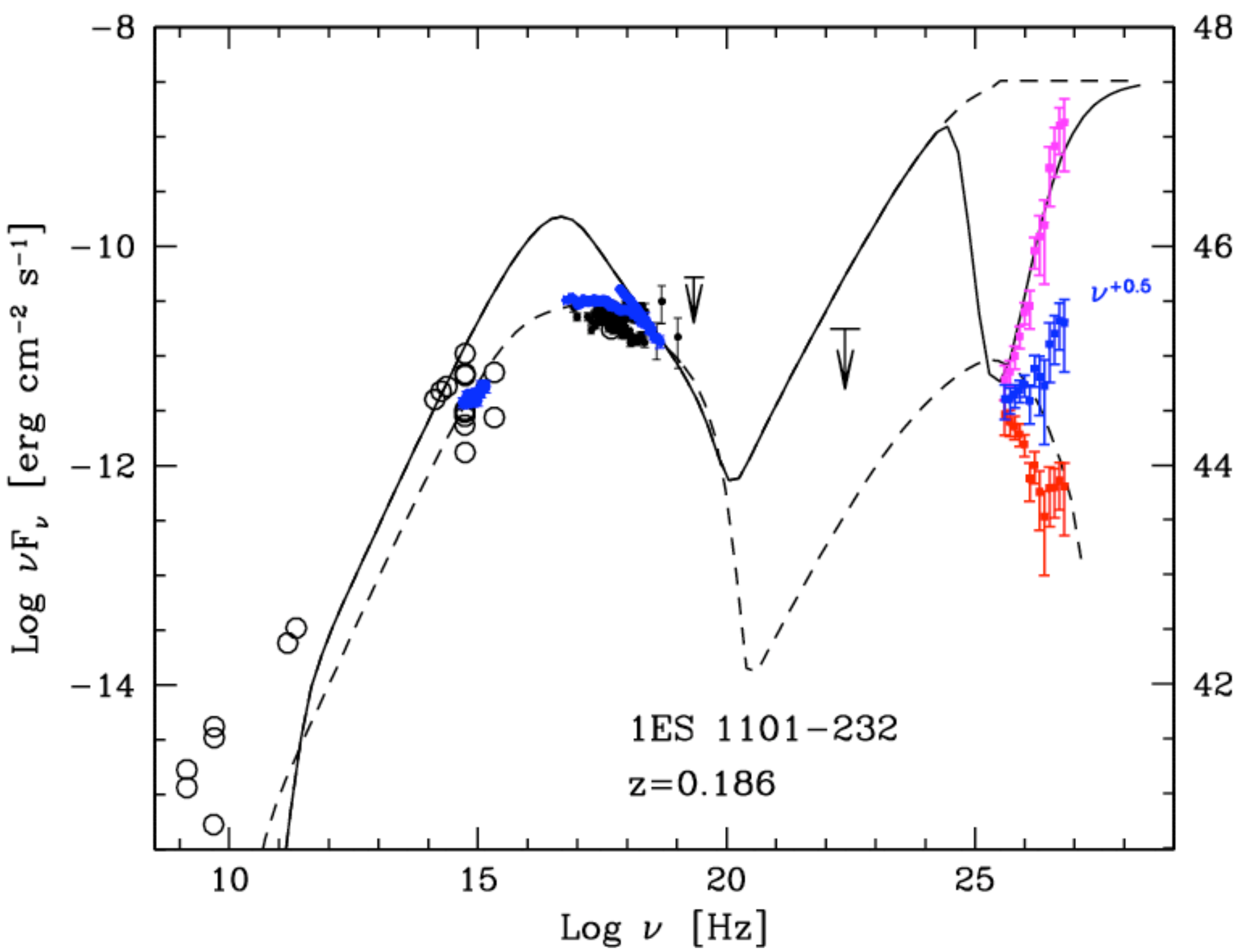
How to make very hard spectra with one-zone SSC ?



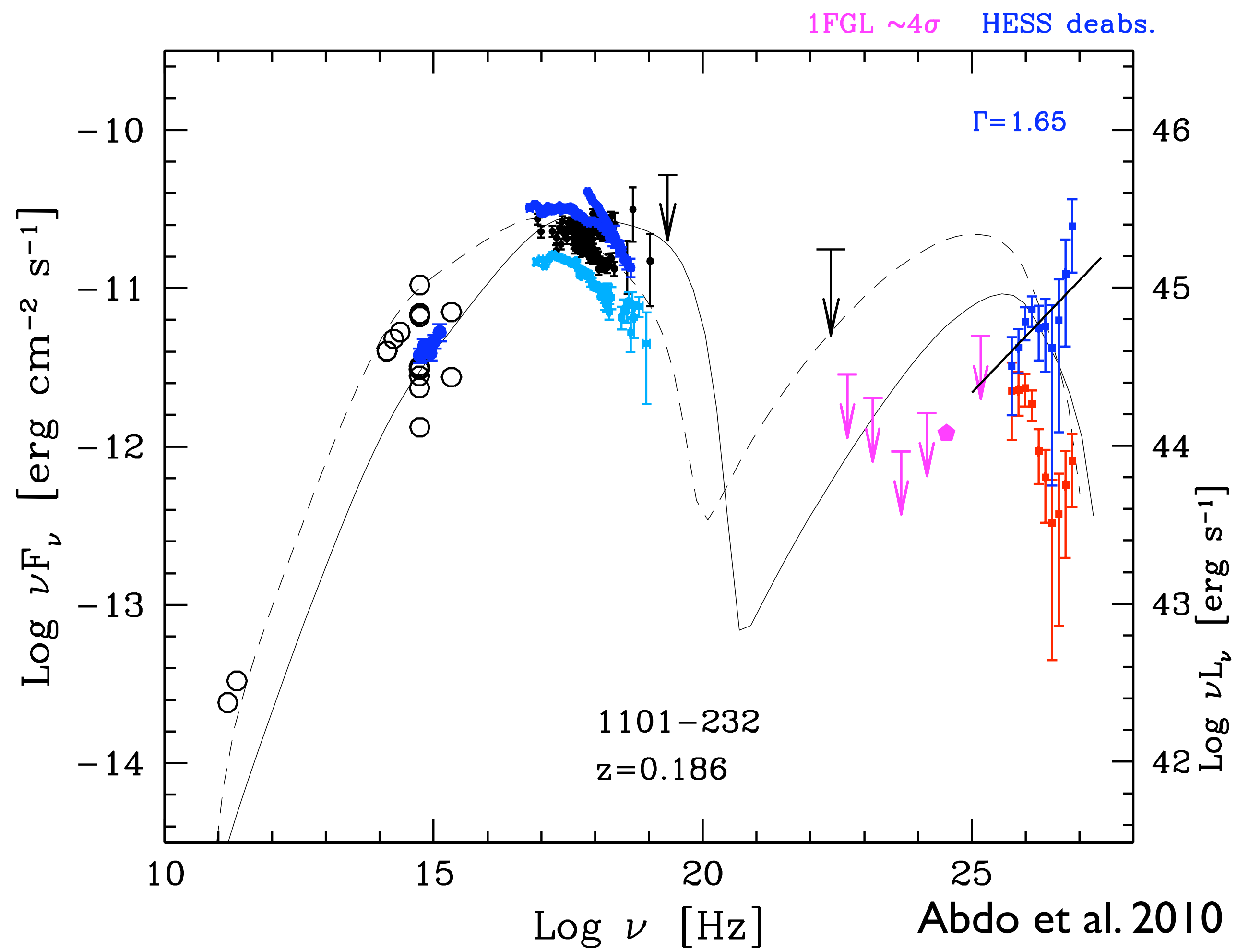
To keep the hard features.

Lefa et al. 2011

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



see e.g. Aharonian, Khangulyan, LC 2008

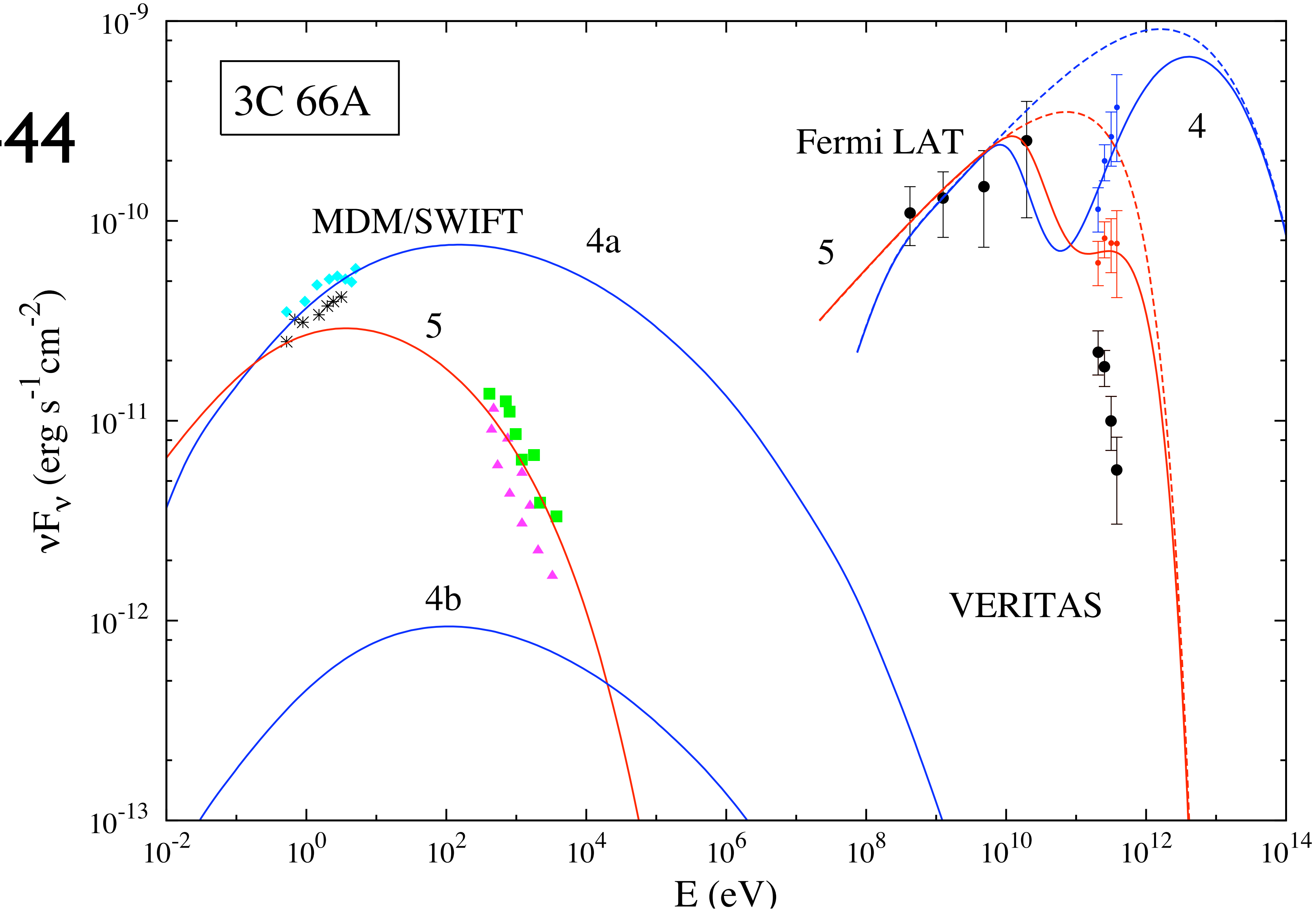


Abdo et al. 2010

But Fermi data seem now to exclude this...

But it might work in some Fermi-bright BL Lacs:

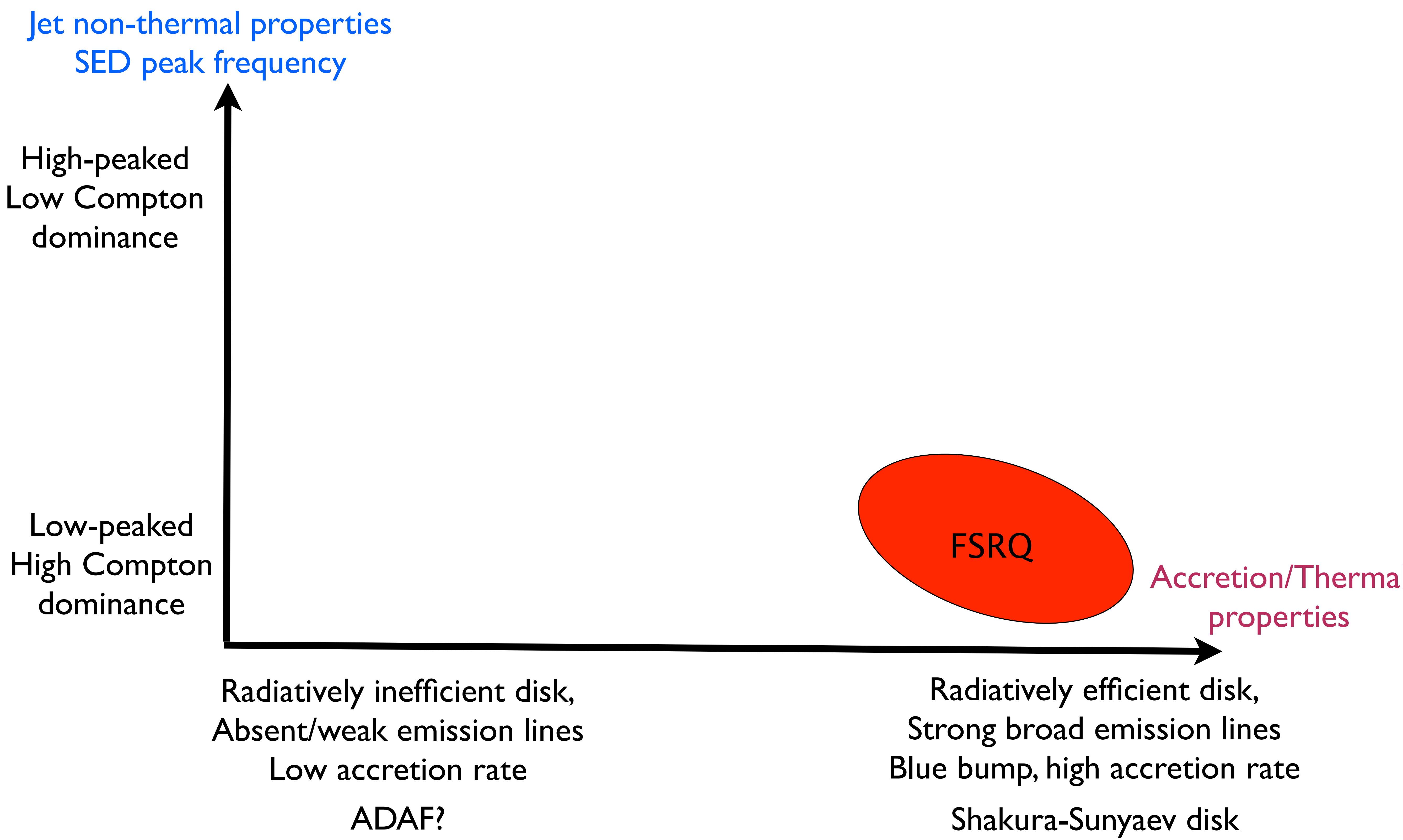
If z=0.444



Simultaneous Fermi-Veritas observations

e.g. Aharonian et al 2008, Zacharopoulou et al. 2011

Also example of proton-synchrotron model


Jet non-thermal properties
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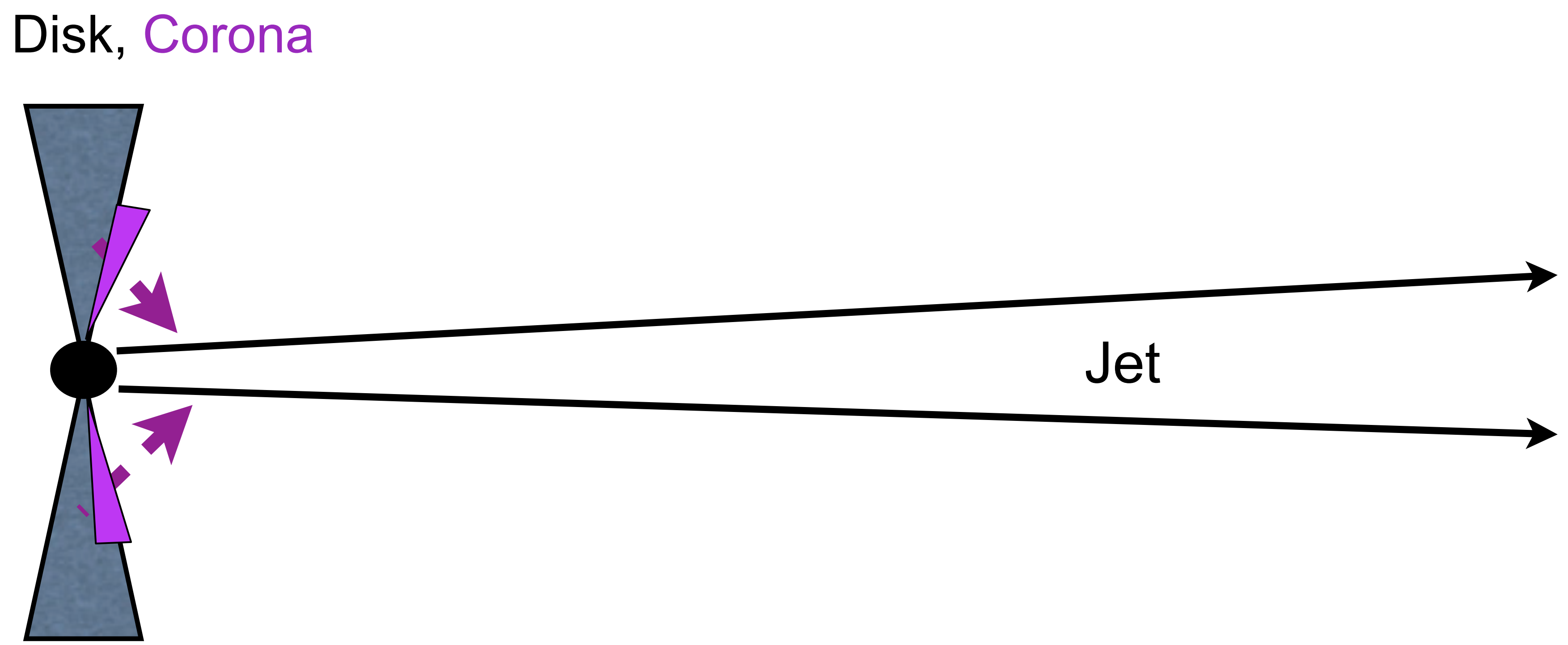
Location of the blazar emitting region(s)



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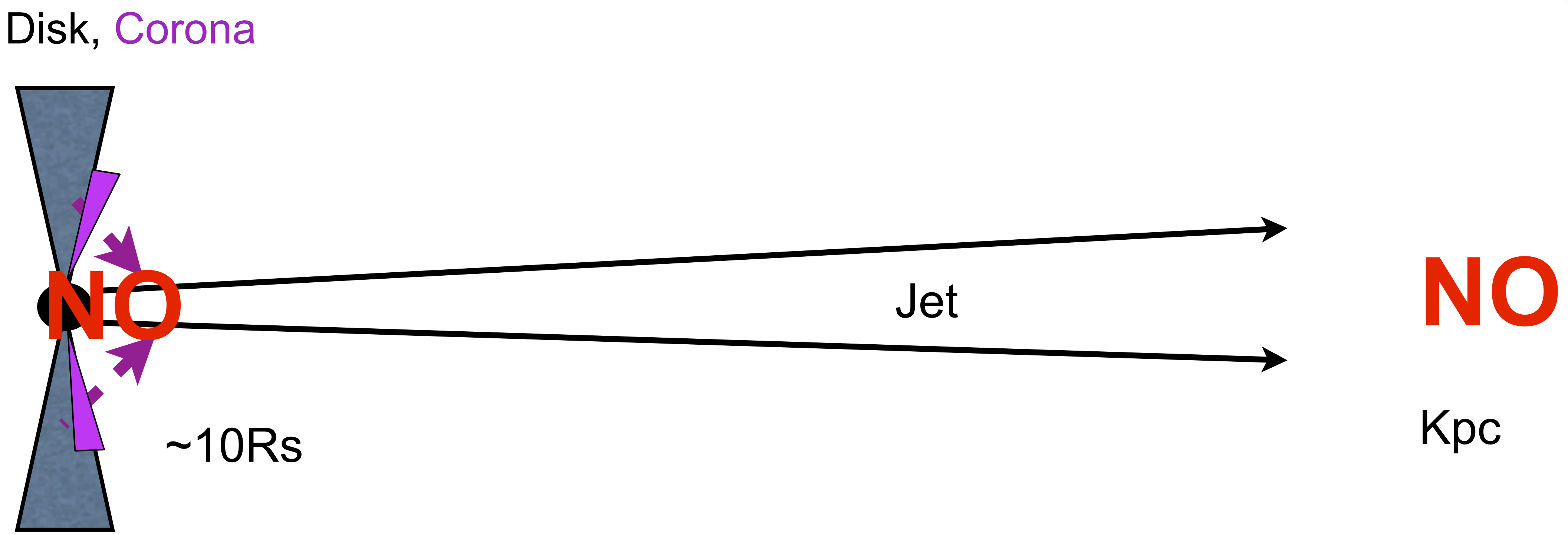

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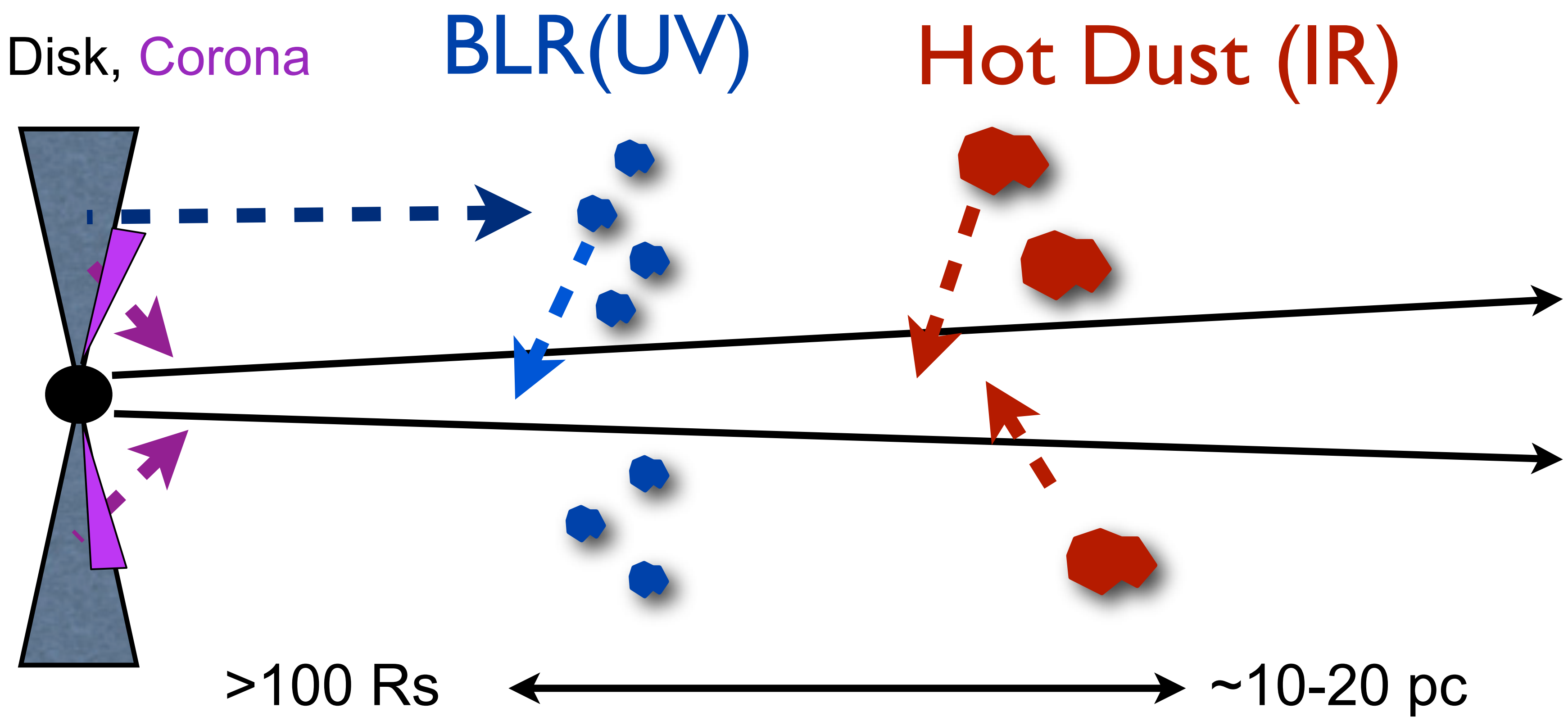

$$R_{\rm BLR} \simeq 0.1 \times {L_{46}}^{1/2}\ {\rm pc}$$ (Bentz et al. 2006 ; Kaspi et al. 2007)

$$R_{\rm HD} \simeq 2.5 \times {L_{46}}^{1/2}\ {\rm pc}$$ (Cleary et al. 2007 ; Nenkova et al. 2008)

$$\mathbf{R \propto L_{disk}^{1/2}}$$

$$\mathbf{U_{rad} \propto L/R^2 \sim const. \sim 10^{-2} erg/cm^3}$$

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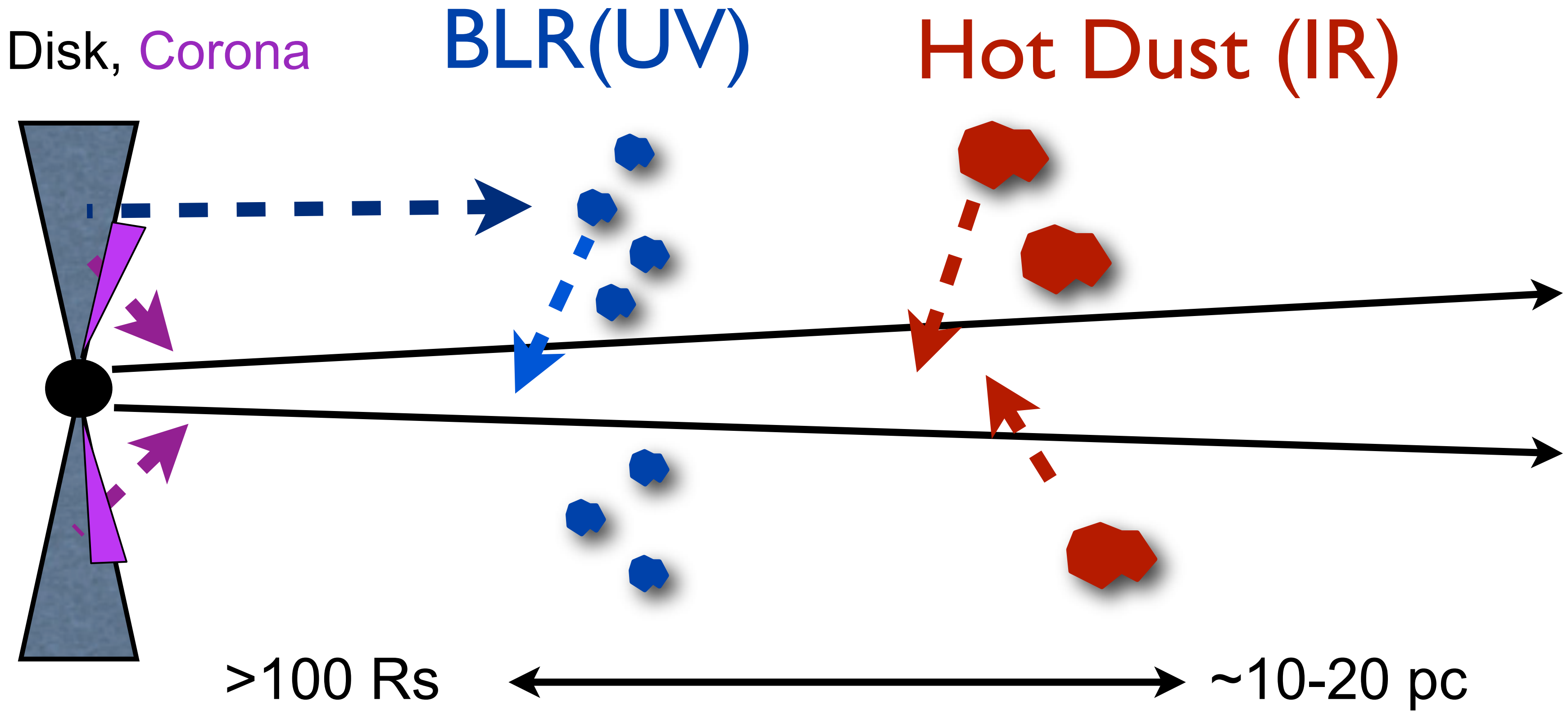

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$$\mathbf{R \propto L_{disk}^{1/2}} \qquad \mathbf{U_{rad} \propto L/R^2 \sim const. \sim 10^{-2} erg/cm^3}$$

Basic 0th-order assumptions/approximations:

a) R ~ as above

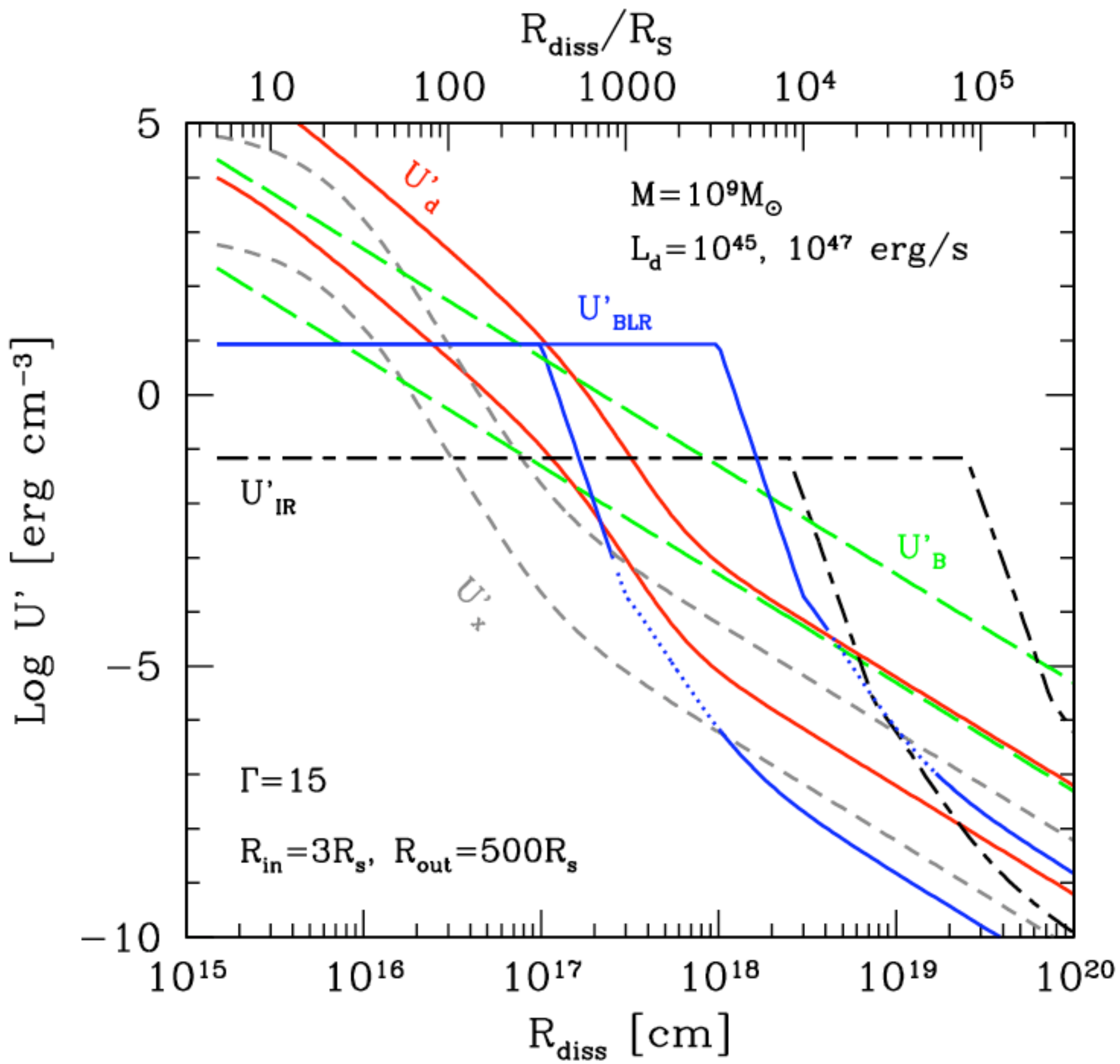
b) isotropic field (shell)

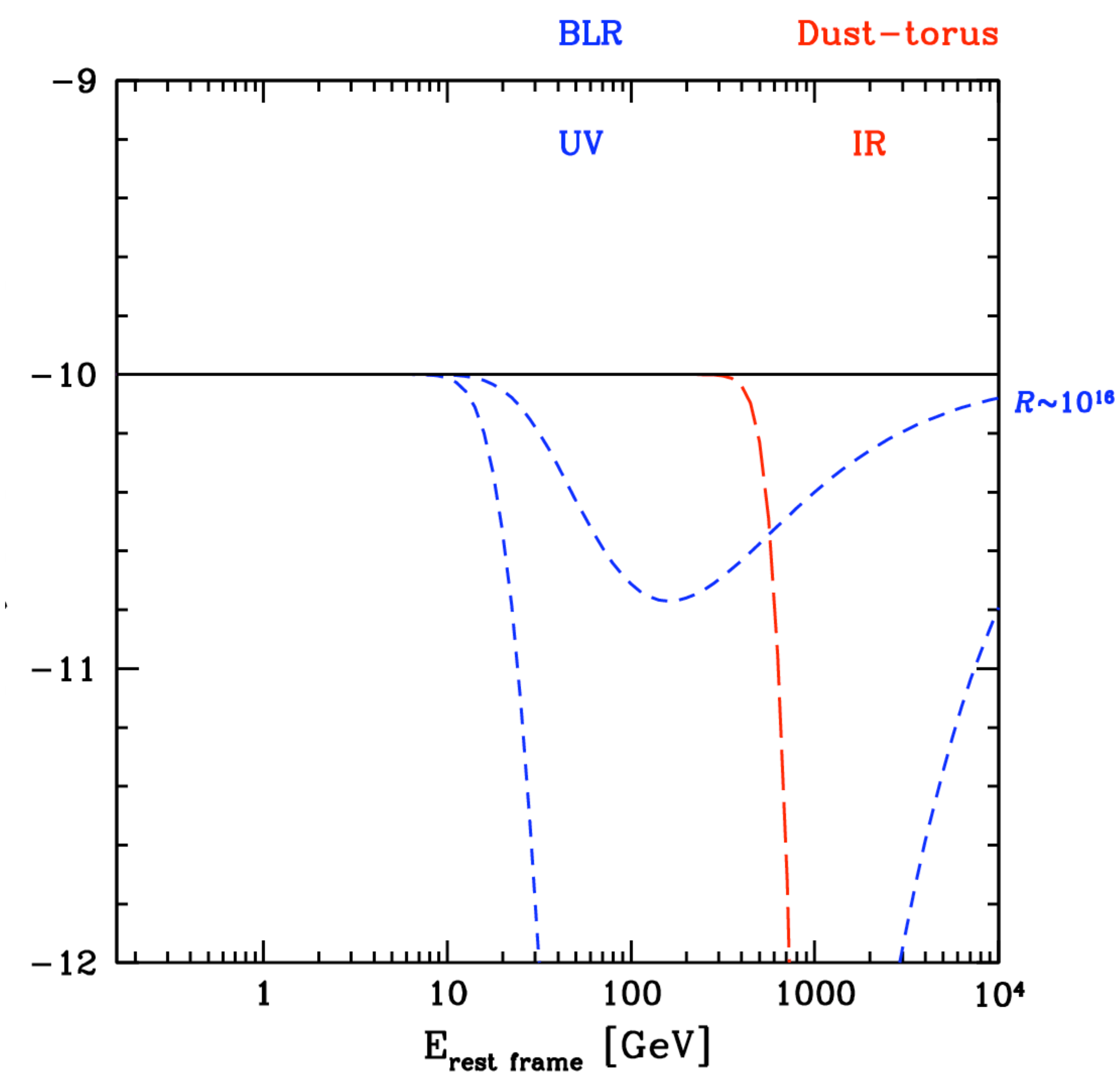
c) BlackBody spectrum @9eV (0.2 eV)

d) reprocessing factor η~ 10% (20-30%)

(e.g. Ghisellini et al. 2009
Sikora et al. 2009)

Broad Line Region (UV, Ly α, CIV, Mg II) or **Hot Dust (IR)** photons are used as target for External Compton mechanism. These same photons cause huge internal γ - γ absorption !





(Ghisellini et al 2009, Sikora et al 2009)

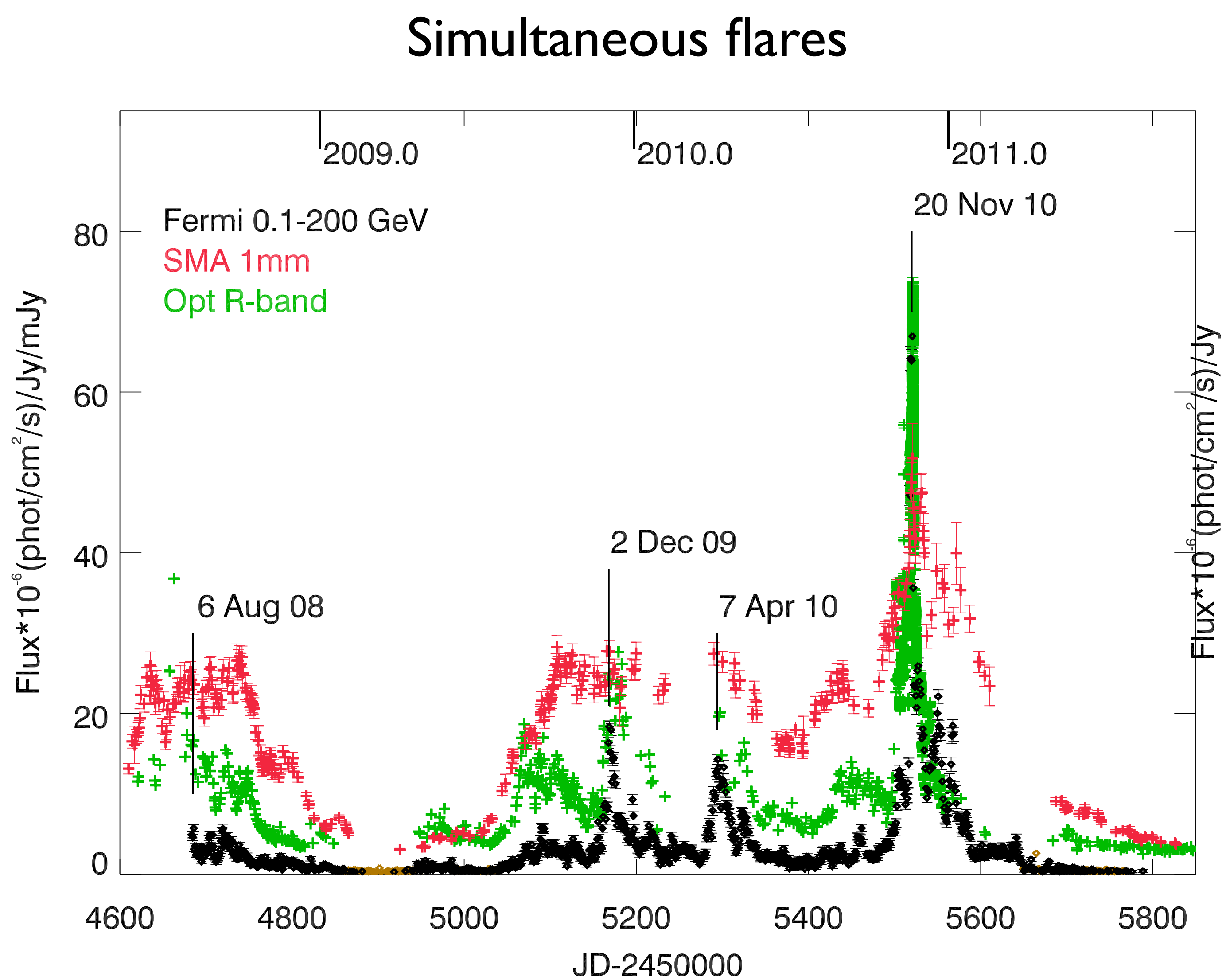
Two (opposite) lines of interpretation
(on same data...)

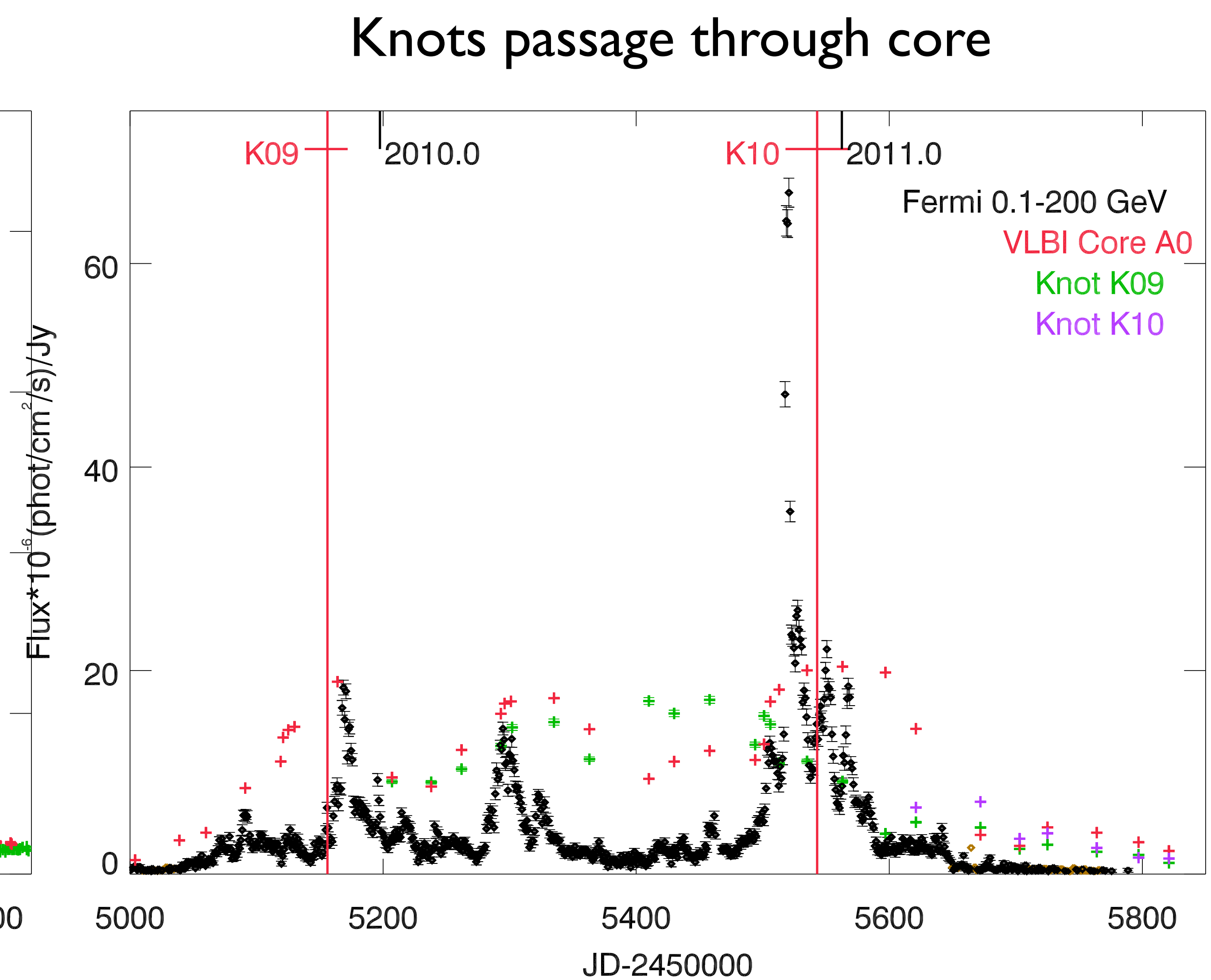
1) Marscher et al. : dissipation > 10-20 pc

2) Tavecchio, Poutanen et al: dissipation < 0.1 pc

example: 3C 454.3

Radio-Gamma Correlation:





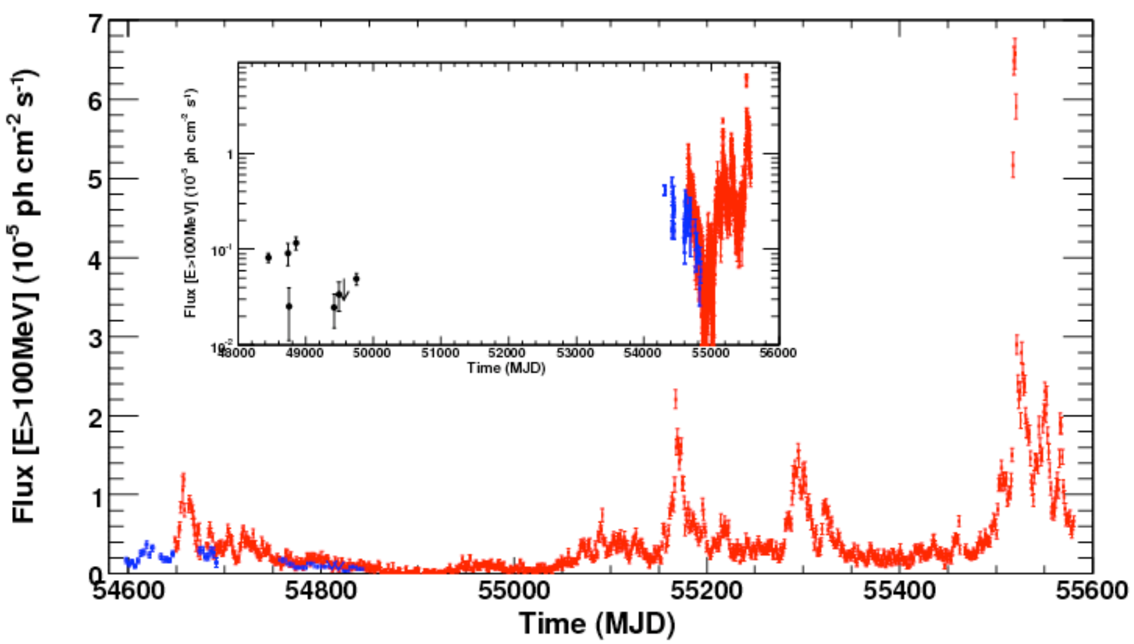
Jorstad 2011, Marscher et al 2011-2012

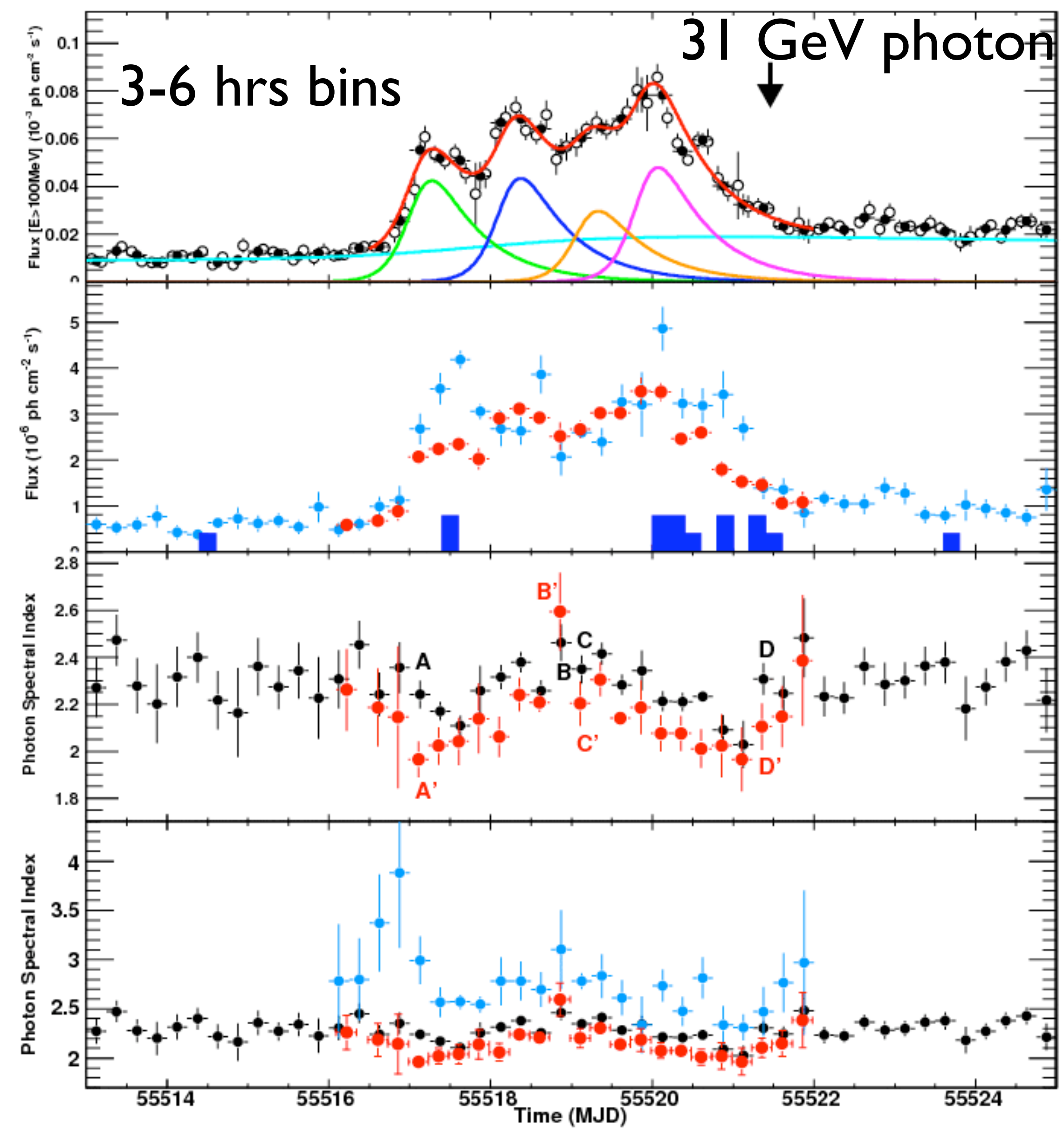
Radio/Gamma Co-spatial, transparent to radio

Flares: 43 positives, 13 negatives (34 Fermi blazars)

But Gamma region compact !

varability seen down to the shortest timescales allowed by statistics (0.1-1 GeV)





$r_{diss} \approx$ few 10^{15} $(\delta/10)$ cm

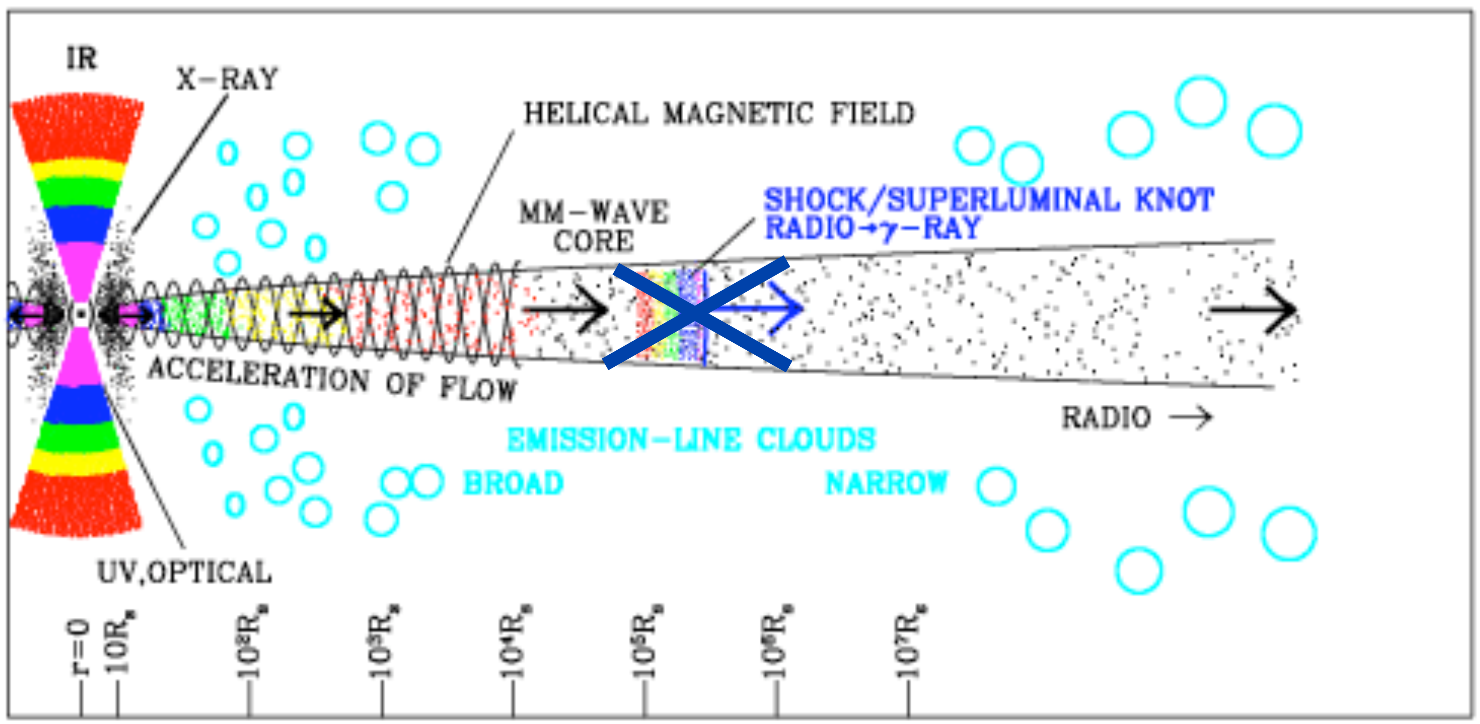
Not transparent to radio

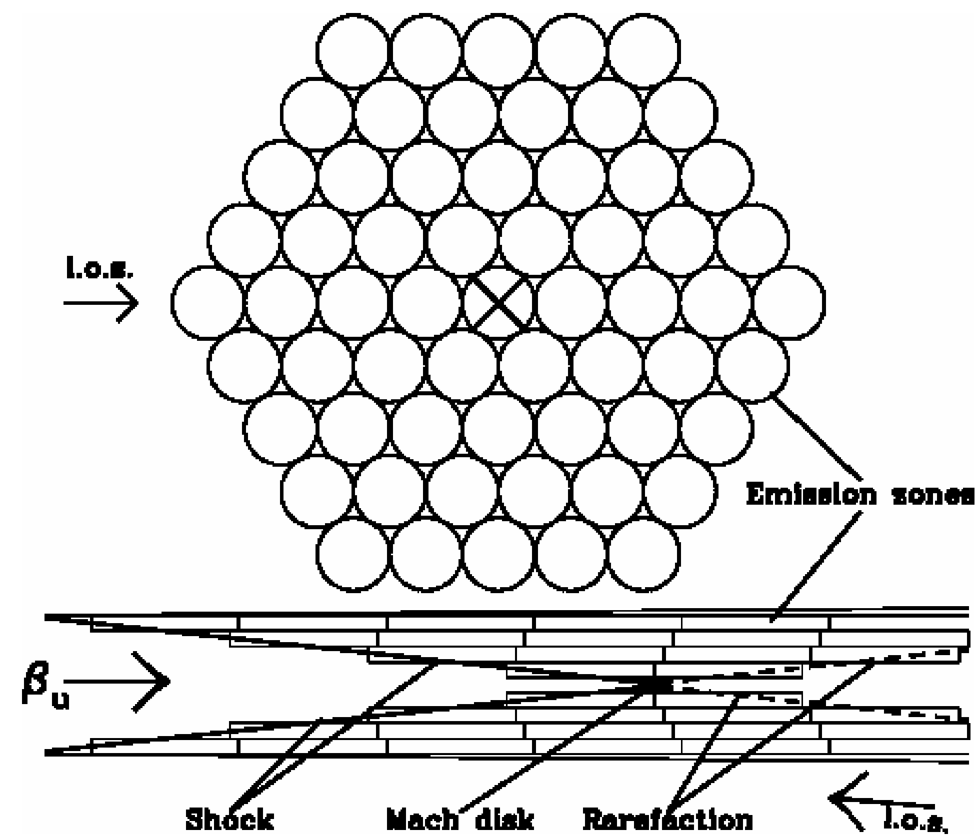
Abdo et al (LAT coll) 2010, 2011

Compact but large ? different filling volumes

cell-in-jet, recollimation shock

Komissarov & Falle 97
Nalewajko & Sikora 08
Bromberg & Levinson 09





Marscher et al 2011-12

For 2010 flare of 3C 454.3: 1/60 jet cross-section

Two (opposite) lines of interpretation

1) Marscher et al. : dissipation > 10-20 pc

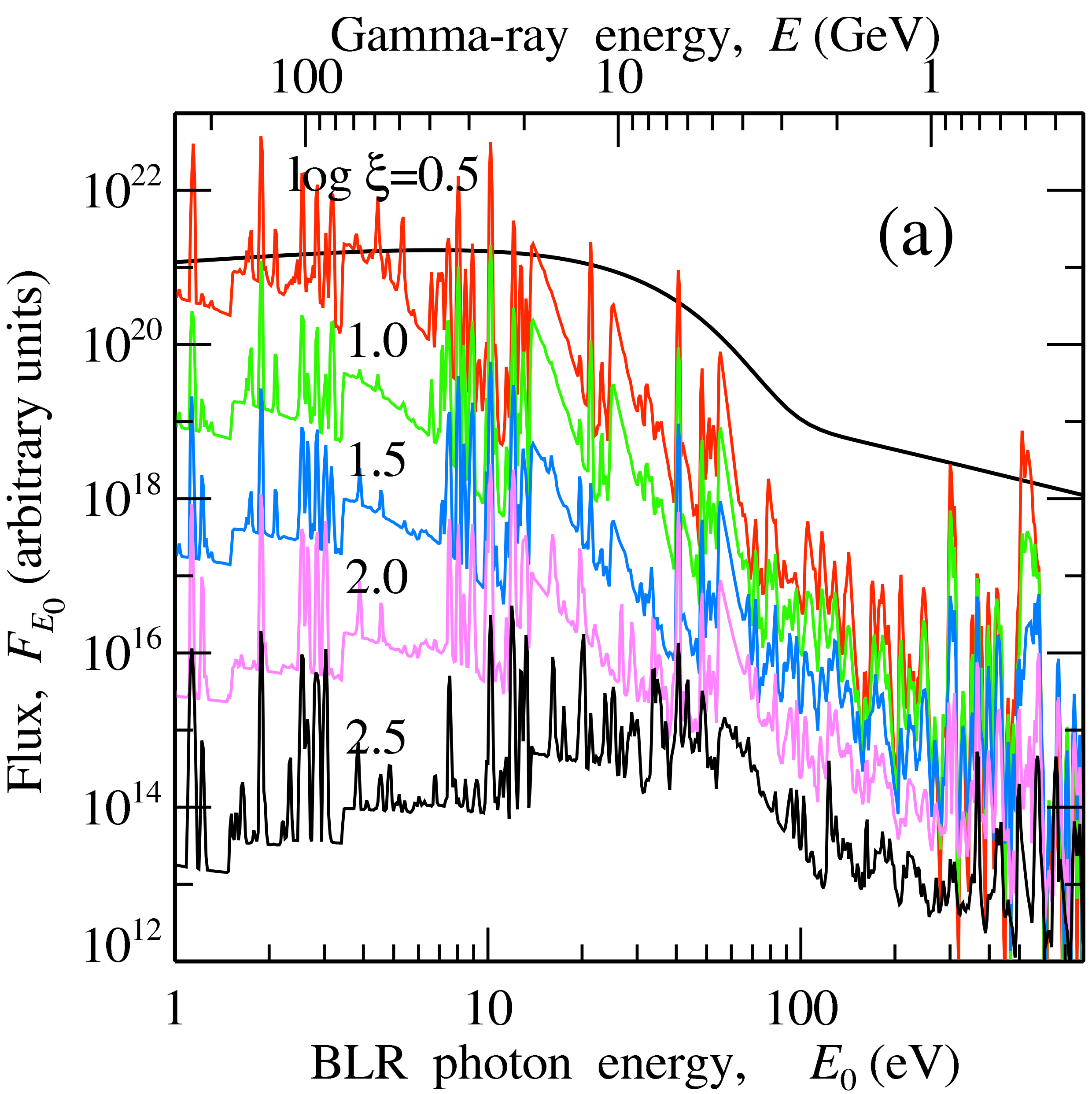
2) Tavecchio, Poutanen et al: dissipation < 0.1 pc

Compactness = closer to the BH
(where jet cross-section is small)

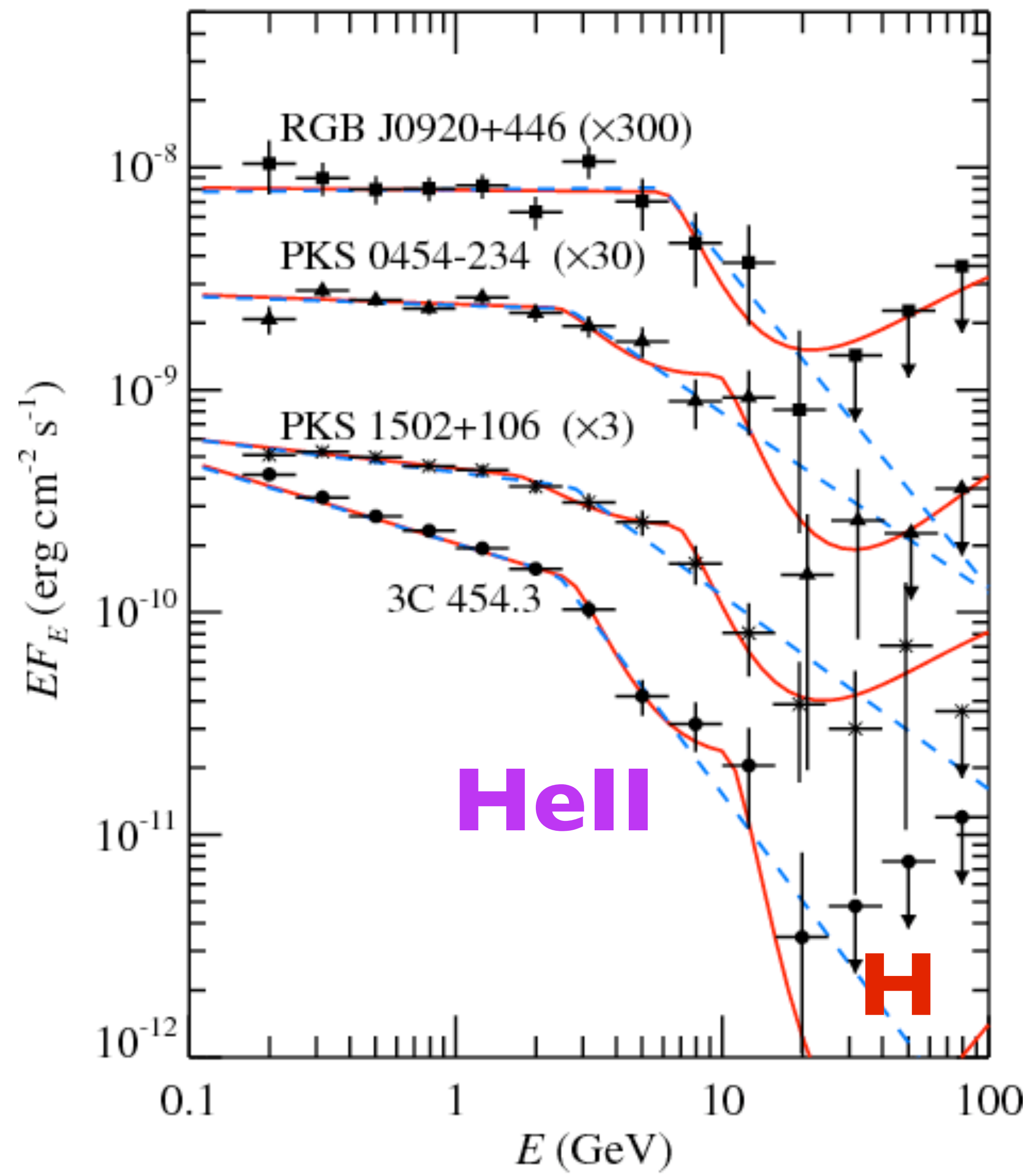
Stratified BLR:
High and Low excitation lines

$R_H \sim 0.2\text{-}0.3\ R_0$ $R_L \sim 3\text{-}5\ R_0$

BLR at different ionization parameter

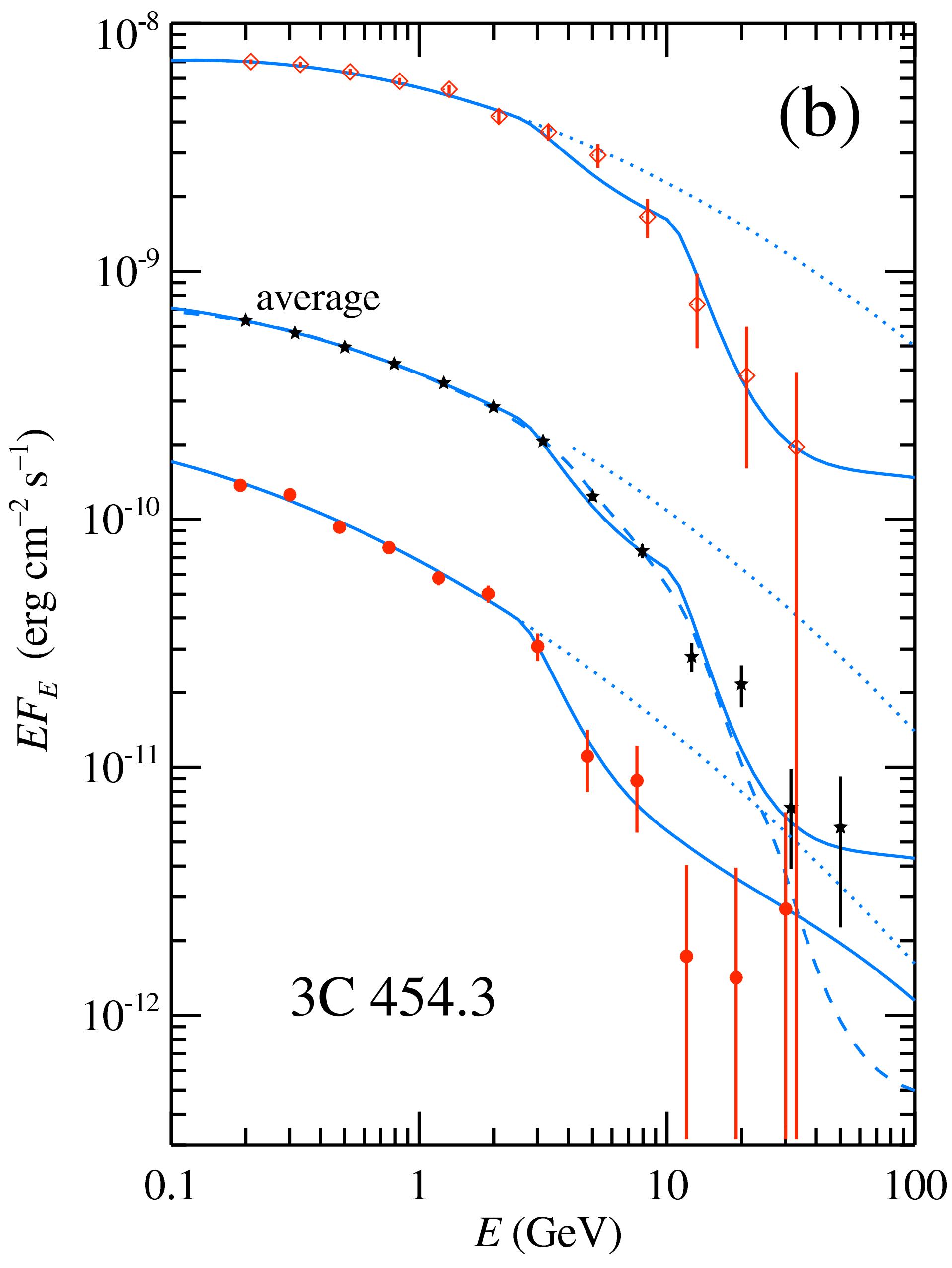


Double absorption:



Poutanen and Stern 2010-2012

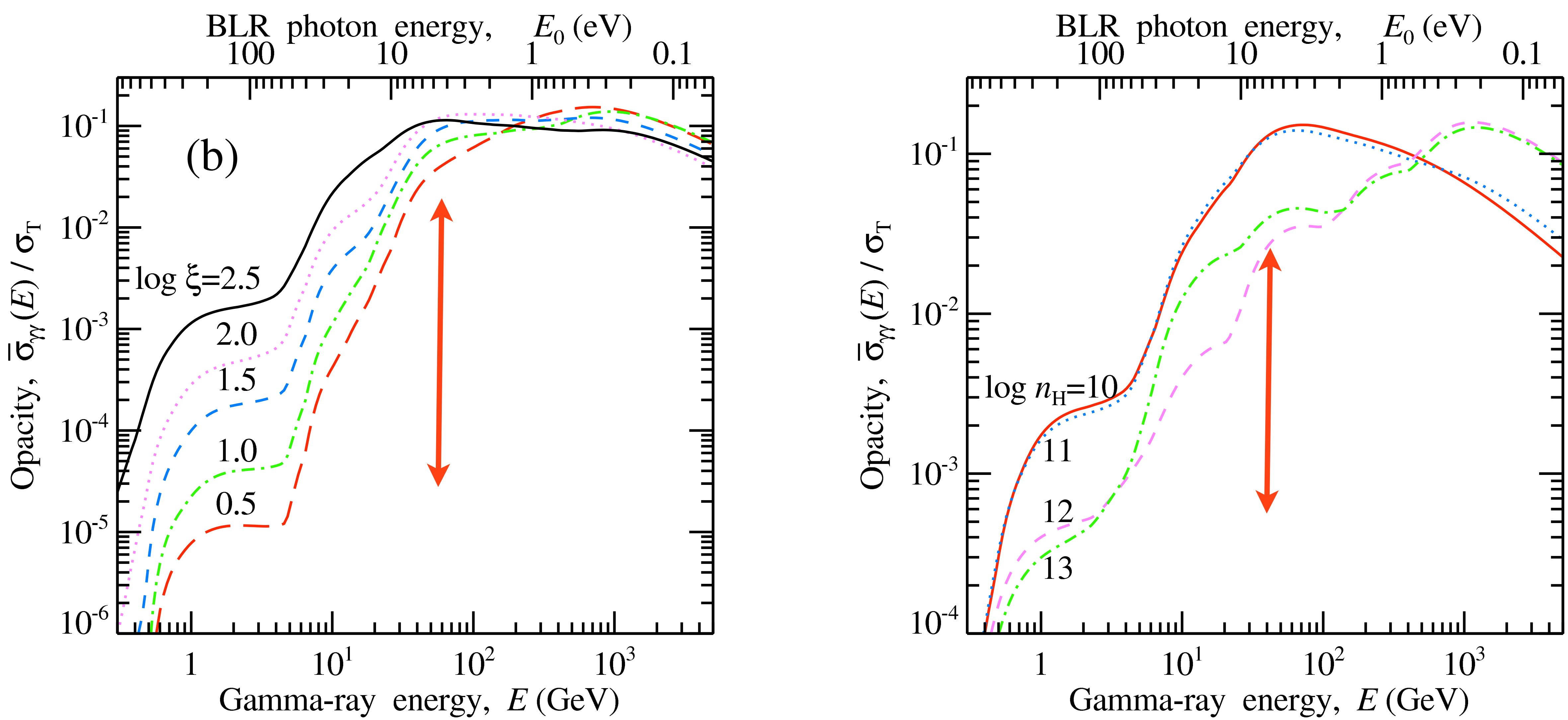
τ_{He} and τ_H fitted independently



Fast gamma-ray variability
+
Breaks ~3-4 GeV
=
$R_{diss} < R_{[high\ ionization\ BLR]}$

Poutanen and Stern 2011

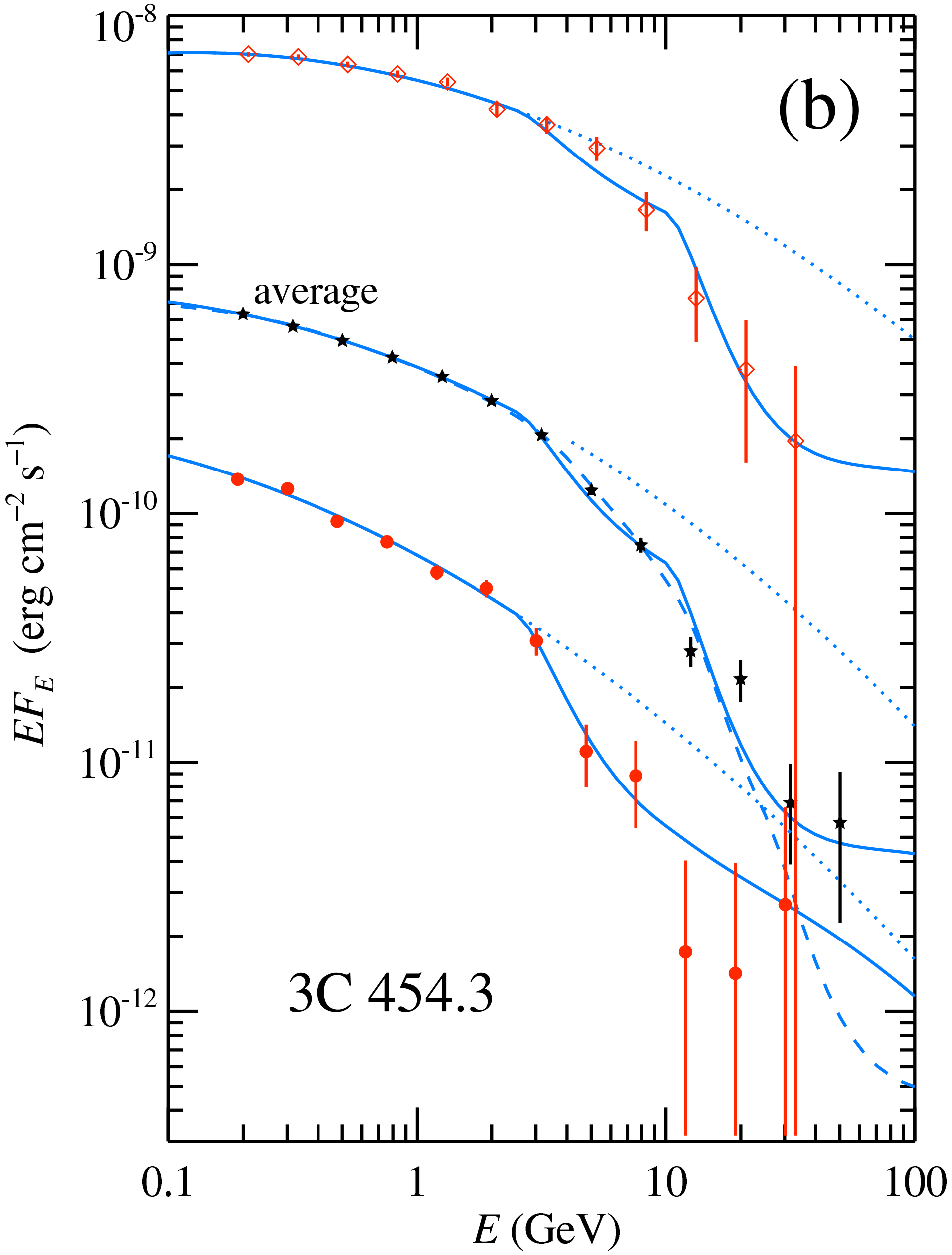
Problem with BLR-absorption interpretation:

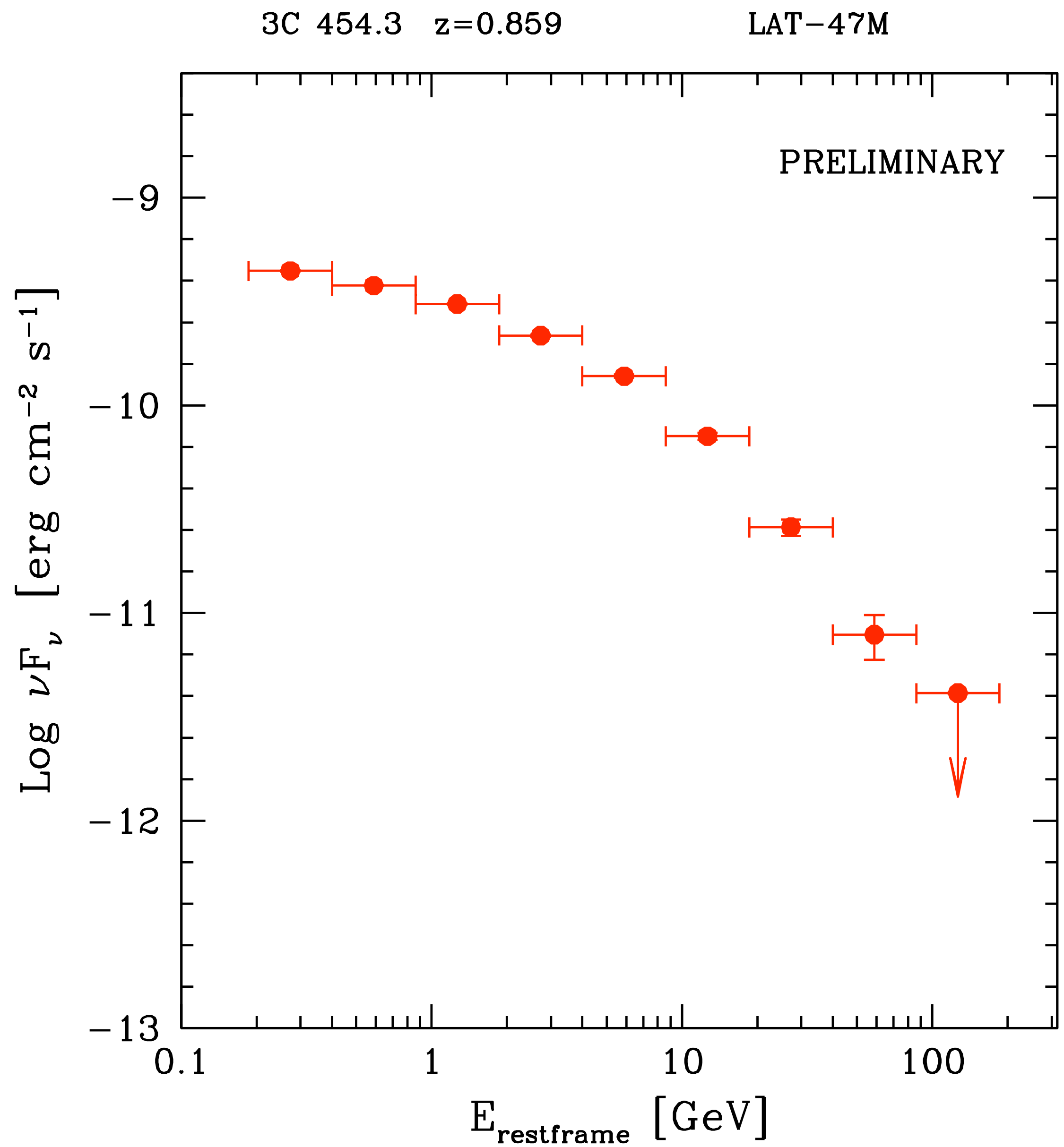


Data from Poutanen 2011

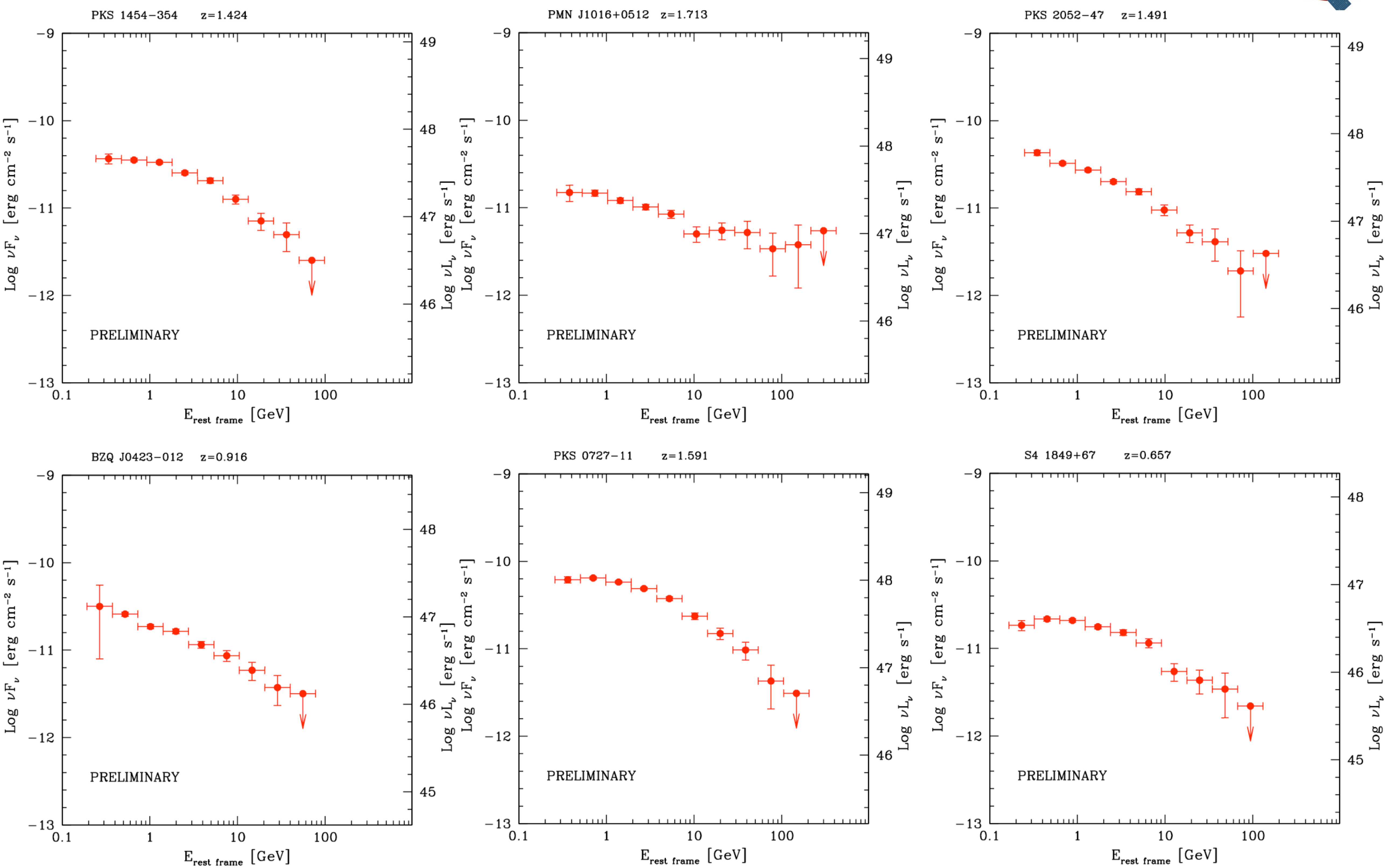
$$\text{If } \tau_{He} > 1 \quad \Rightarrow \quad \tau_H > 100\text{x } \tau_{He}$$

We do not see such strong cutoffs





Fermi-LAT results on several FSRQ: NO evidence of strong BLR cut-offs !

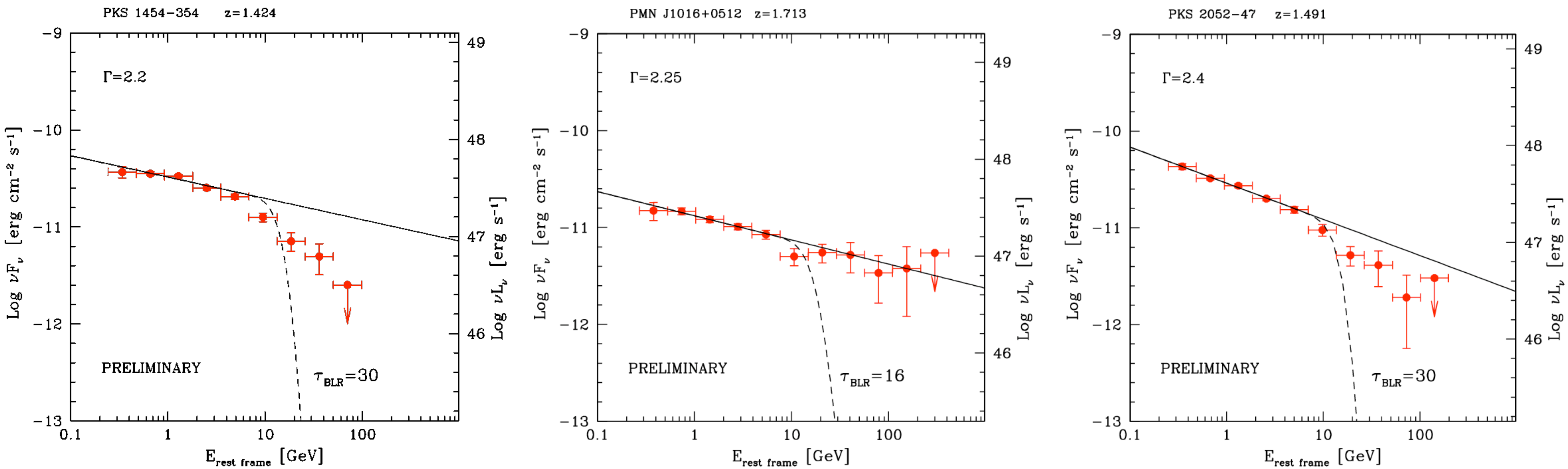


LC, Tramacere, Tosti (LAT coll) 2011, Fermi Symp.

Even among the most powerful objects !

Characterized by strong Disk emission and large BLRs

Examples assuming no intrinsic steepening (case most favorable to absorption):
power-law fits up to ~4 GeV extrapolated at higher energies, with (dashed lines) or without BLR absorption.



PKS 1454-354:	PMN J1016+0512:	BZQ J2056-471:
L_{disk} ~ 5×10^{46} erg/s , R_{blr} ~7×10^{17} cm	**L_{disk} ~ 9×10^{45} erg/s , R_{blr} ~3×10^{17} cm**	**L_{disk} ~ 4×10^{46} erg/s , R_{blr} ~6×10^{17} cm**
if R_{diss} ~2×10^{17} ⇒ **τ_{BLR} > 30 !**	if R_{diss} ~2.5×10^{17} ⇒ **τ_{BLR} > 16 !**	if R_{diss} ~2×10^{17} ⇒ **τ_{BLR} > 30 !**

Values of R_{diss} L_{disk} R_{blr} used in
Ghisellini et al 2009

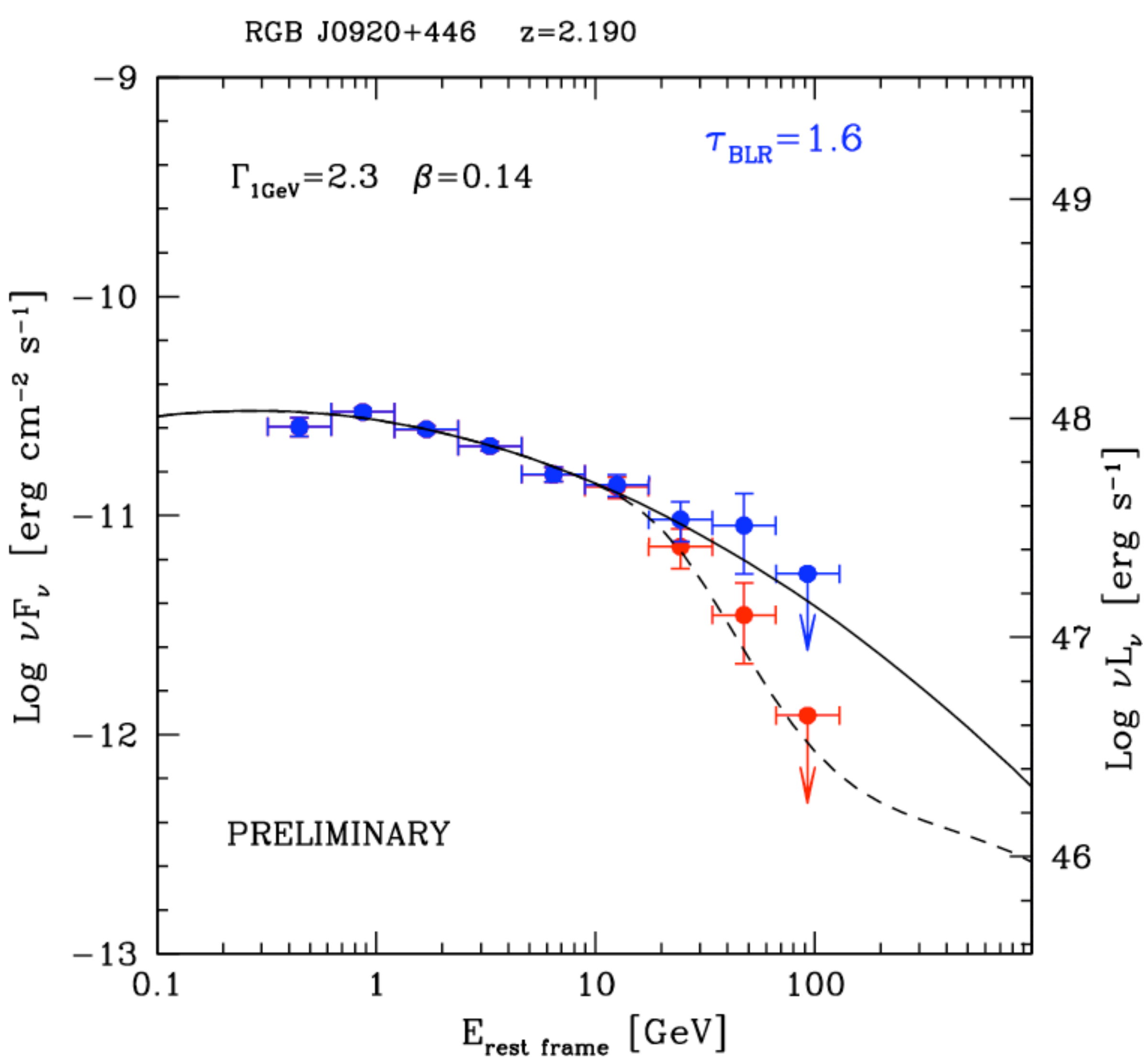
$R_{diss} \geq R_{BLR}$

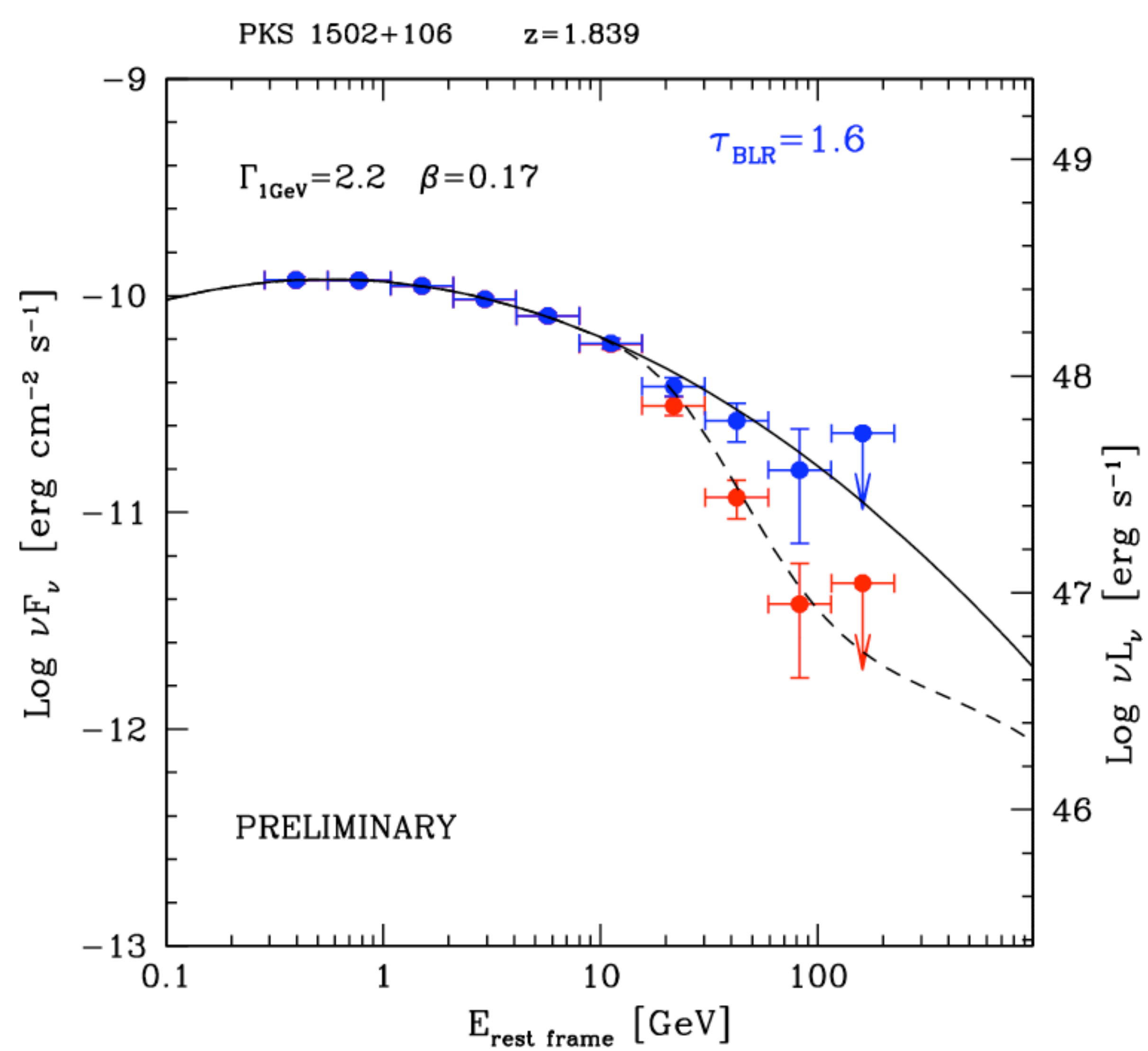
LC, Tramacere, Tosti (LAT coll) 2011, Fermi Symp.
Abdo et al. 2012 (in prep.)

Some objects compatible with mild BLR absorption

Log-parabolic fits to the data only up to ~3-4 GeV, and extrapolated at higher energies

LAT spectra: original, observed ; BLR de-absorbed





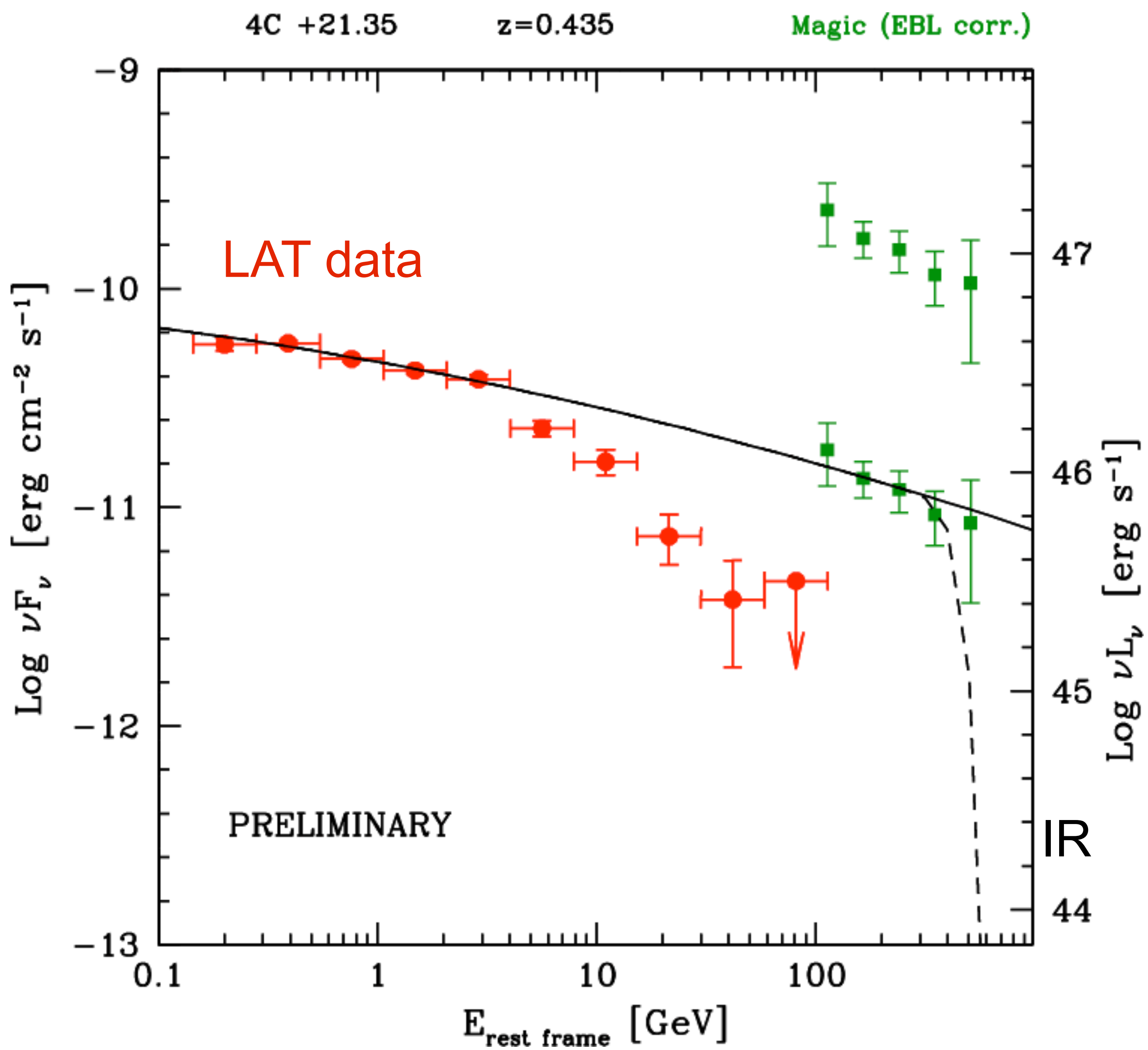
Only moderate (τ~1-2), corresponding to **$R_{diss} \cong R_{BLR}$**

...But could be also intrinsic cut-offs (end of particle distribution).

LC, Tramacere, Tosti (LAT coll) 2011, Fermi Symp.

Further evidence:
VHE detections of 4C 21.35 and PKS 1510-08

$R_{diss} > R_{BLR}$



Aleksic et al. 2011 (MAGIC coll)

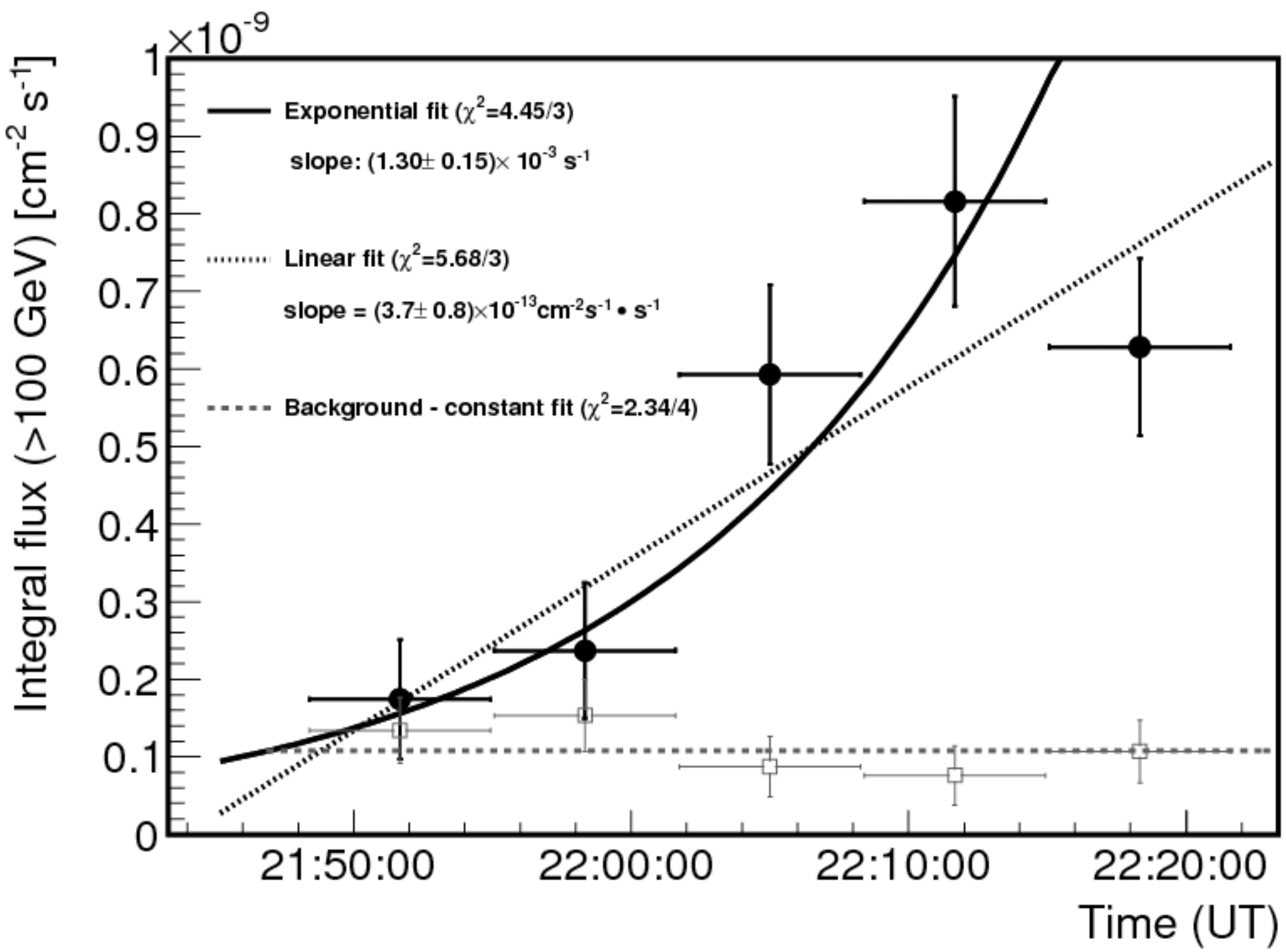
Problem? again, IR photons absorb VHE gamma-rays.

4C 21.35 has strong IR emission from Hot Dust, T~1200K:
L_{IR} ~ 8×10^{45} erg/s , R ~2-4 pc (Malmrose et al. 2011)

MAGIC fundamental discovery on 4C 21.35: fast variability !

2) R_{diss} > 1-10 pc ⇒ a) larger region, mm-transparent

b) variability ~days-week



Aleksic et al. 2011 (MAGIC coll)

Instead, 10-min variability !

$$R \sim 2.5 \times 10^{14}\ \delta_{10}\ t_{\mathrm{var,10min}}\ \mathrm{cm}$$

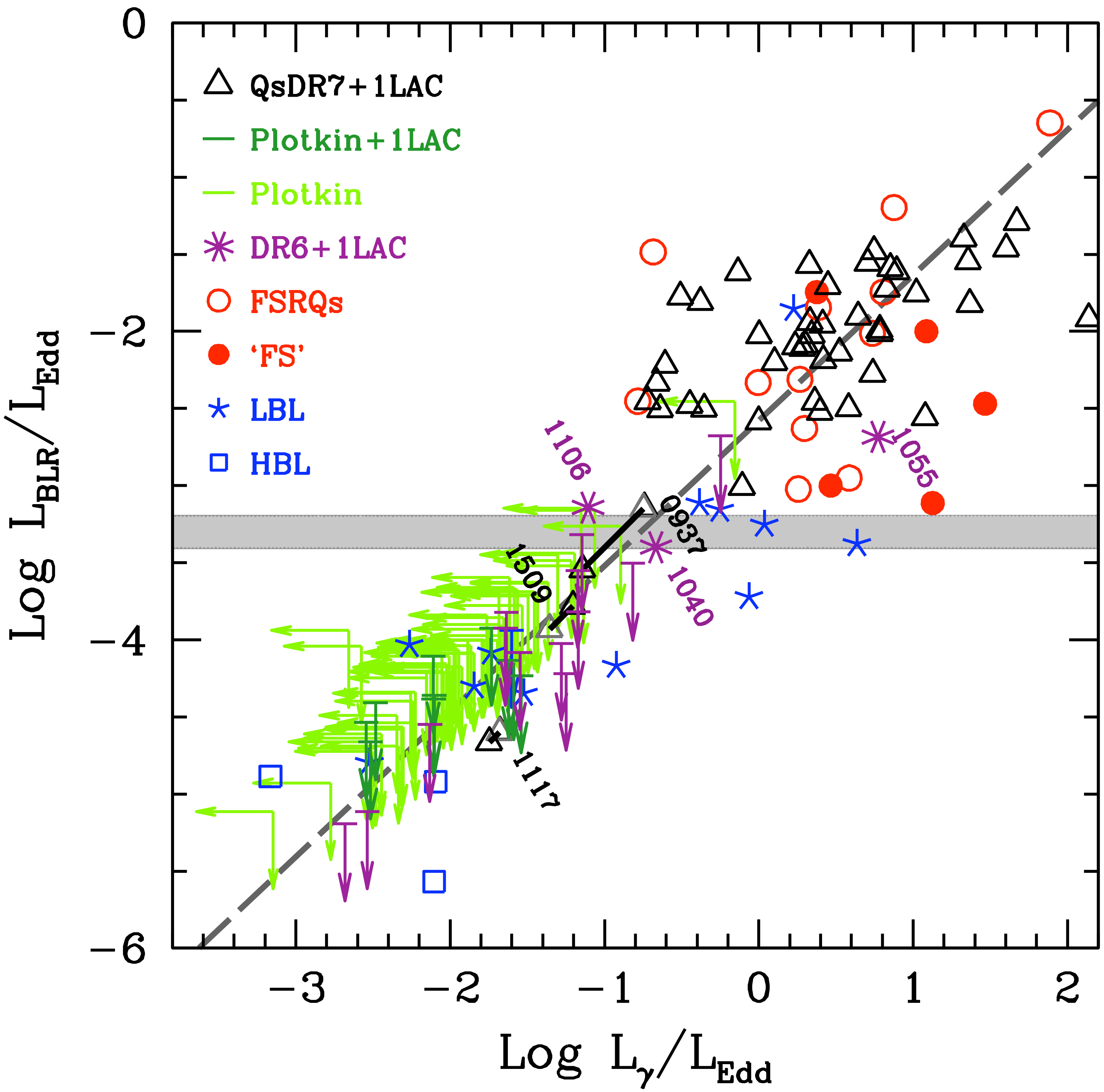
at several pc from Black Hole

Fermi-LAT + Cherenkov Tel data so far:

There seems to be no evidence of radiative interaction of Jet with BLR !

- No External Compton on BLR
- BLR does not determine the color of the SED

Jet - disk/BLR connection



T. Sbarrato et al 2011

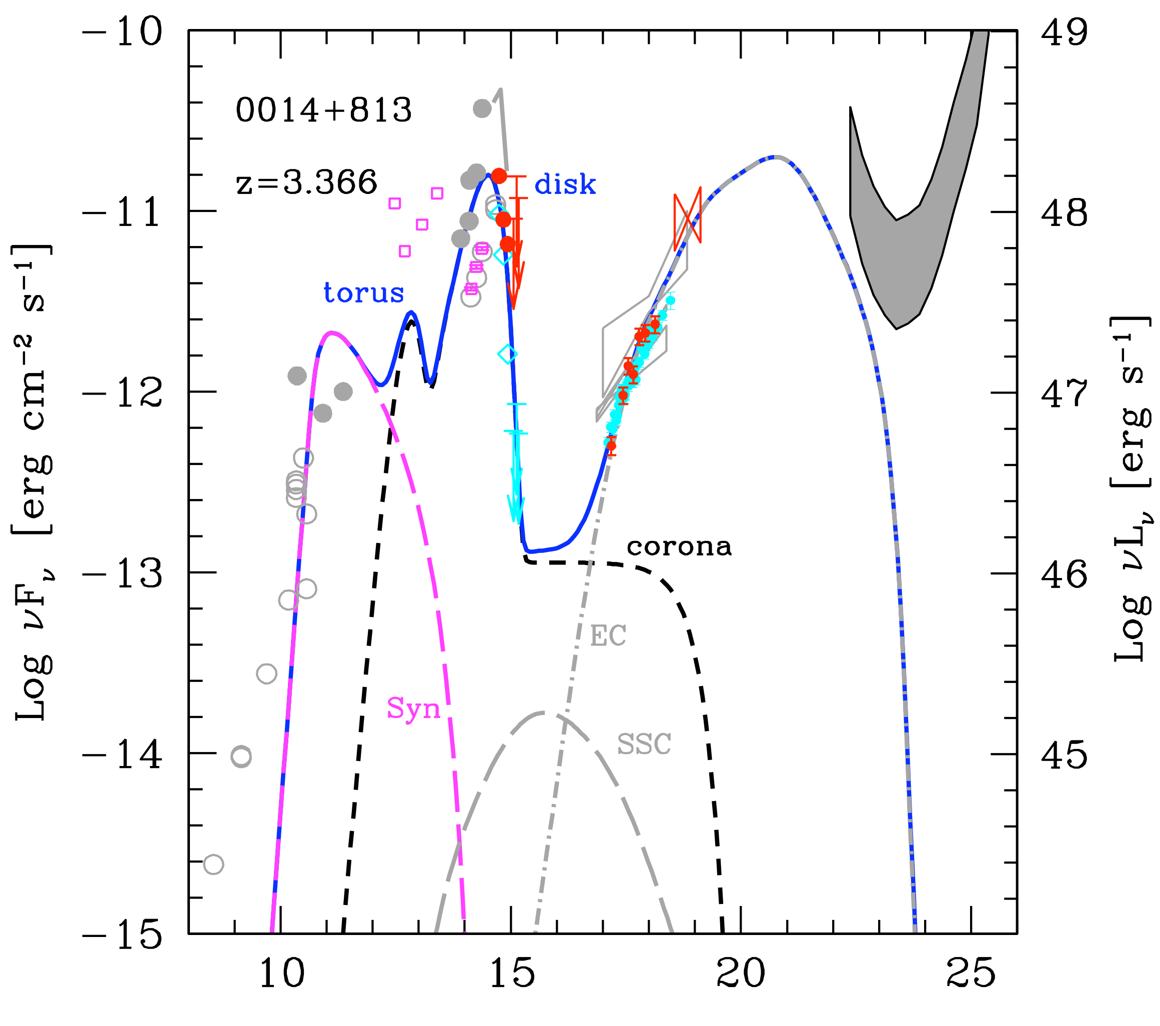
Conclusions

- We do not understand/explain TBL.
  (extreme/different particle acceleration? emission mechanism?)

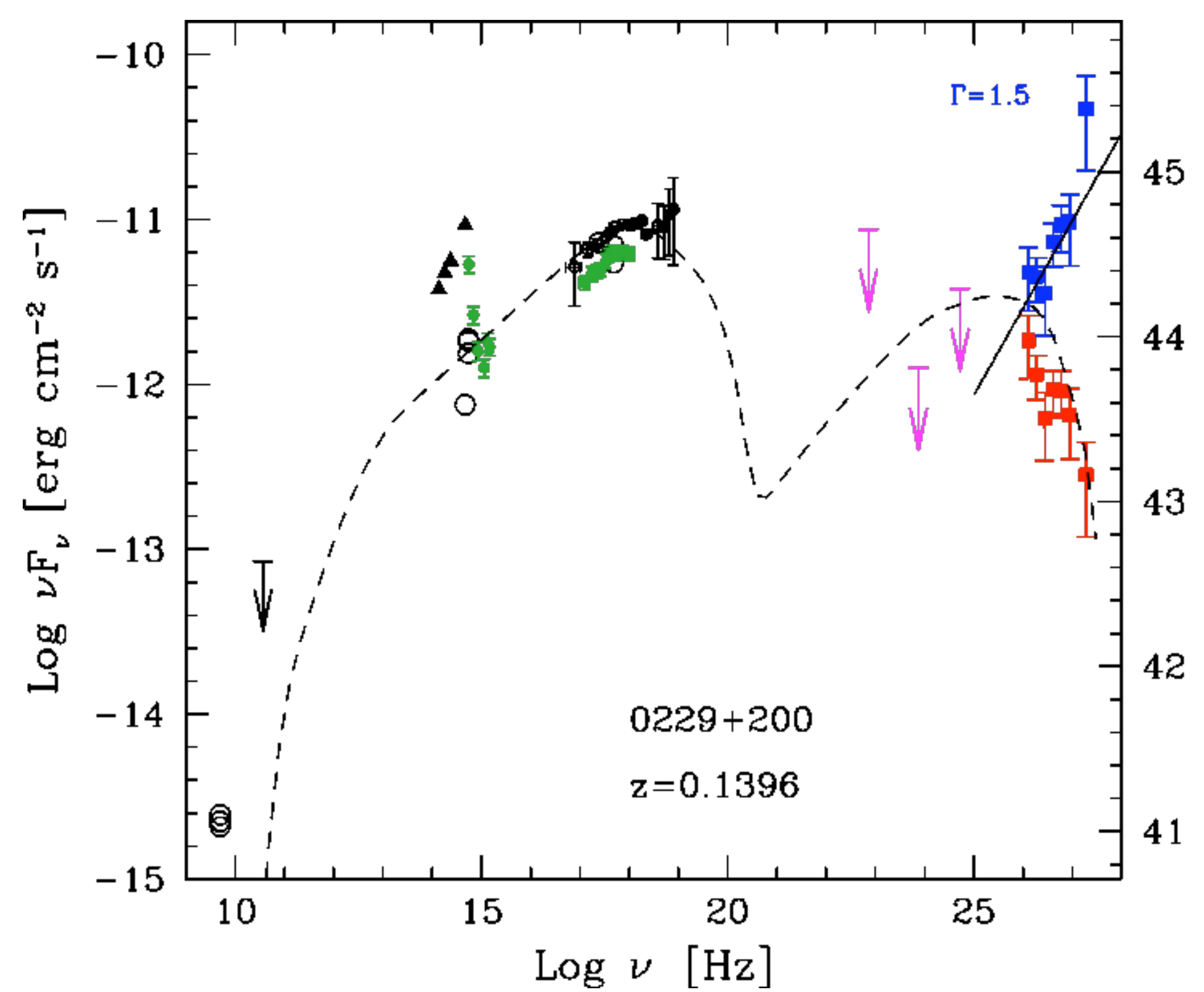
- BLR does not influence the jet directly (it's a proxy of the disk).
  (rethink EC on BLR, and all parameters derived from SED fitting)

Back-up slides

Fermi does *NOT* detect all type of blazars: misses at the two ends of SED sequence



MeV-blazar



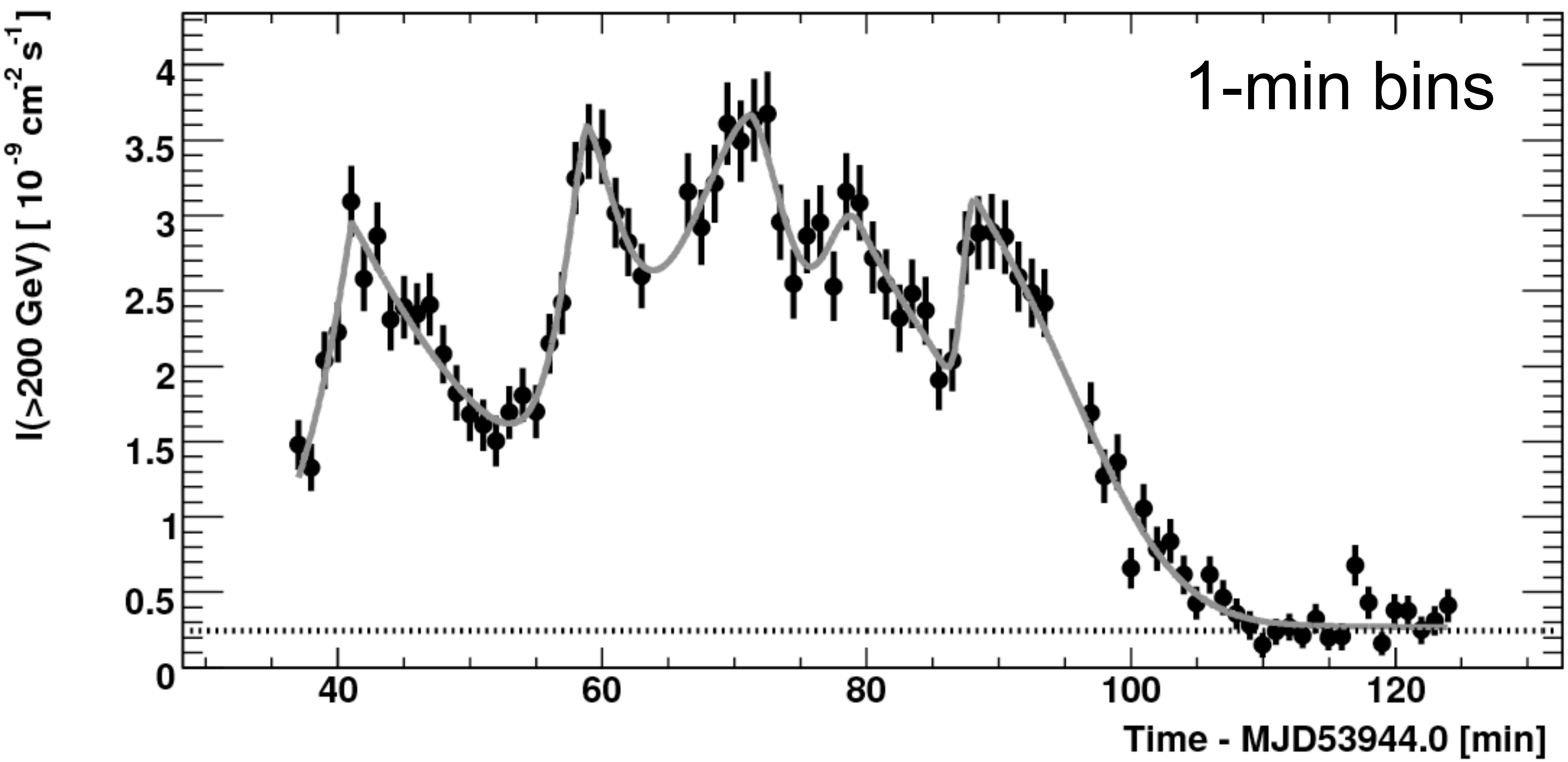
Hard TeV BL Lac

Ultra-fast variability in HBL !

2x flux in ~2-3 min.

10x in less than 1 hr

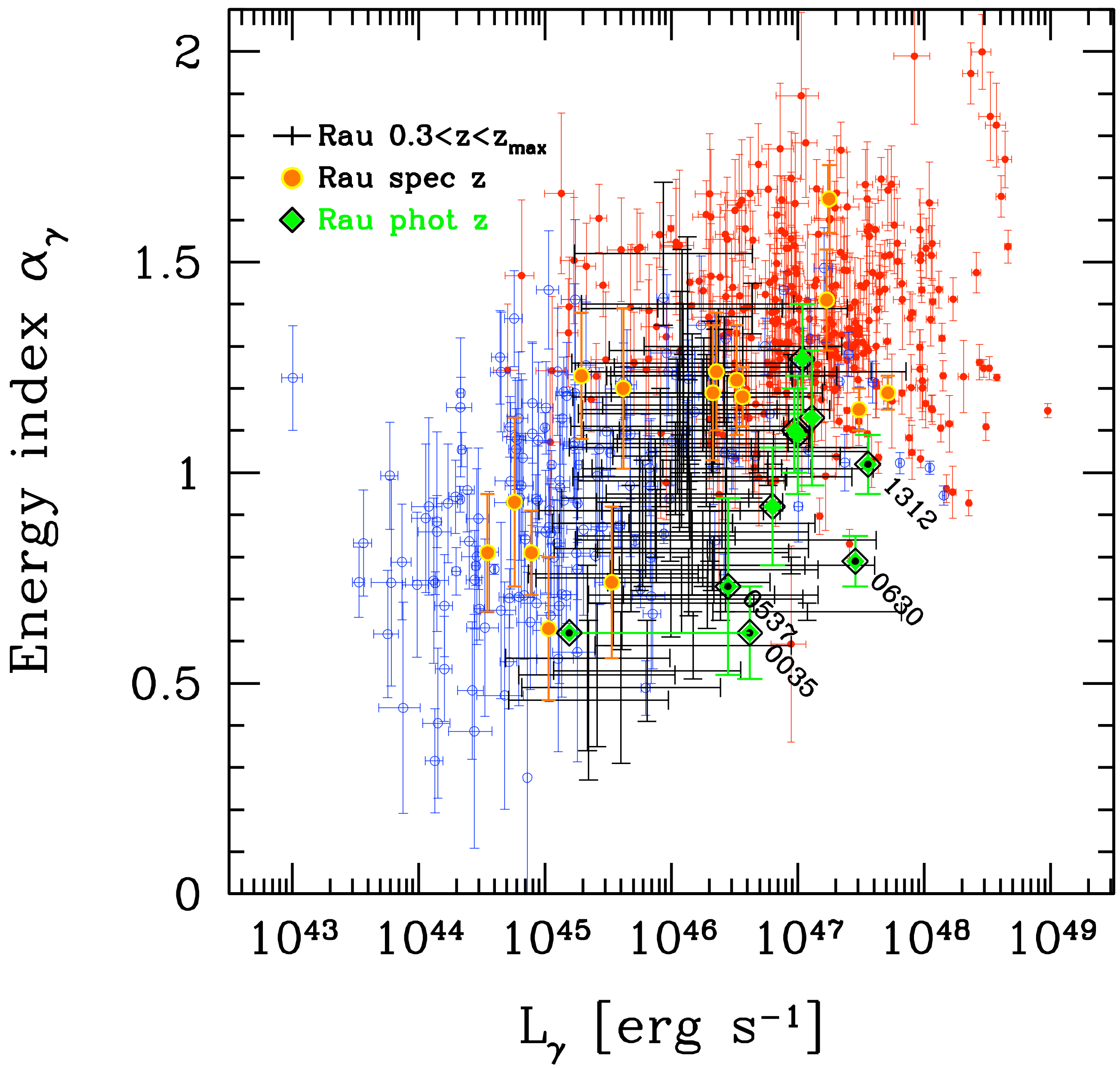
A



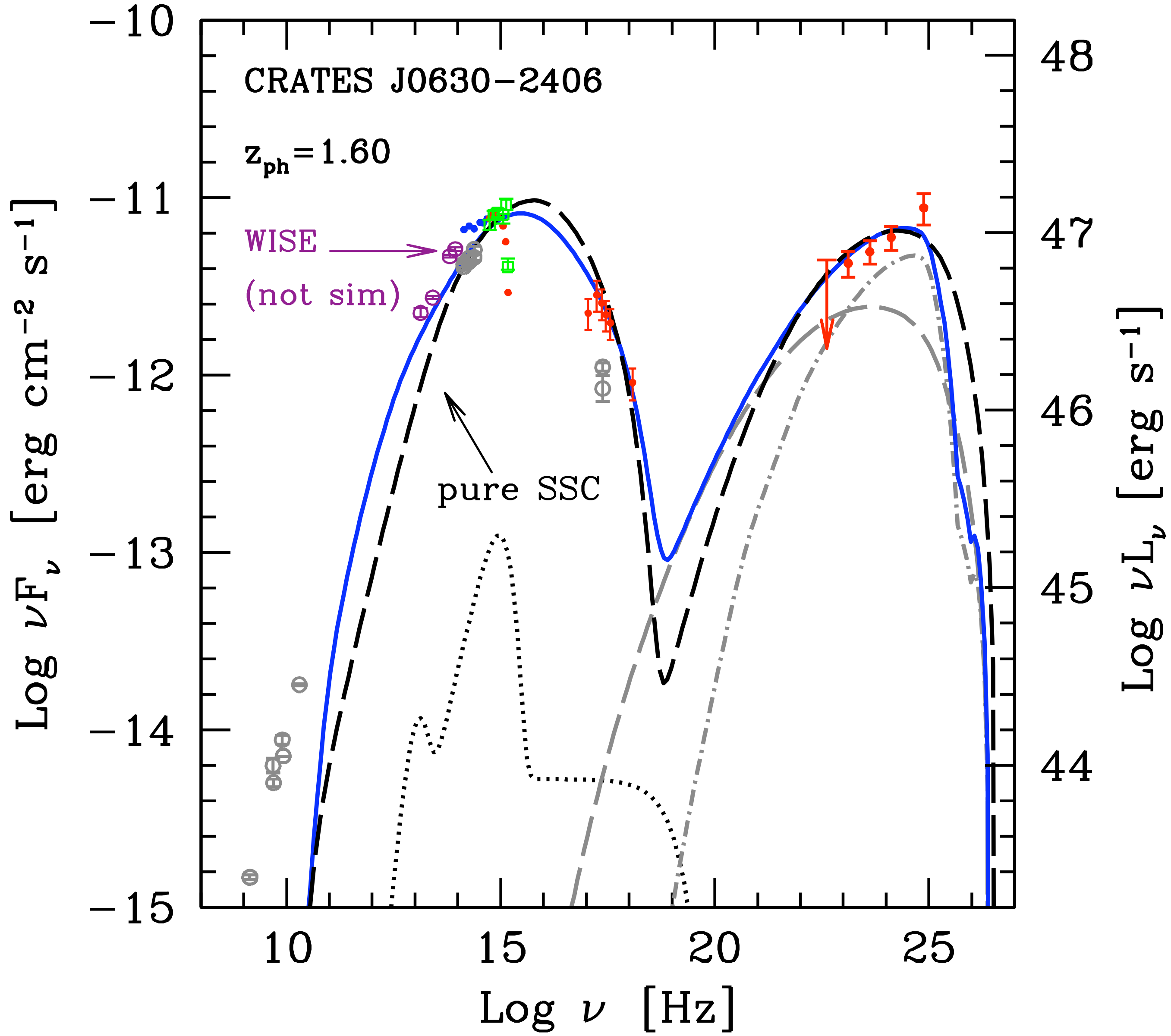
R ~$5\times10^{12}\ \delta$ cm ≈ 0.01 $\delta\ R_S$

Aharonian et al. (HESS coll) 2007

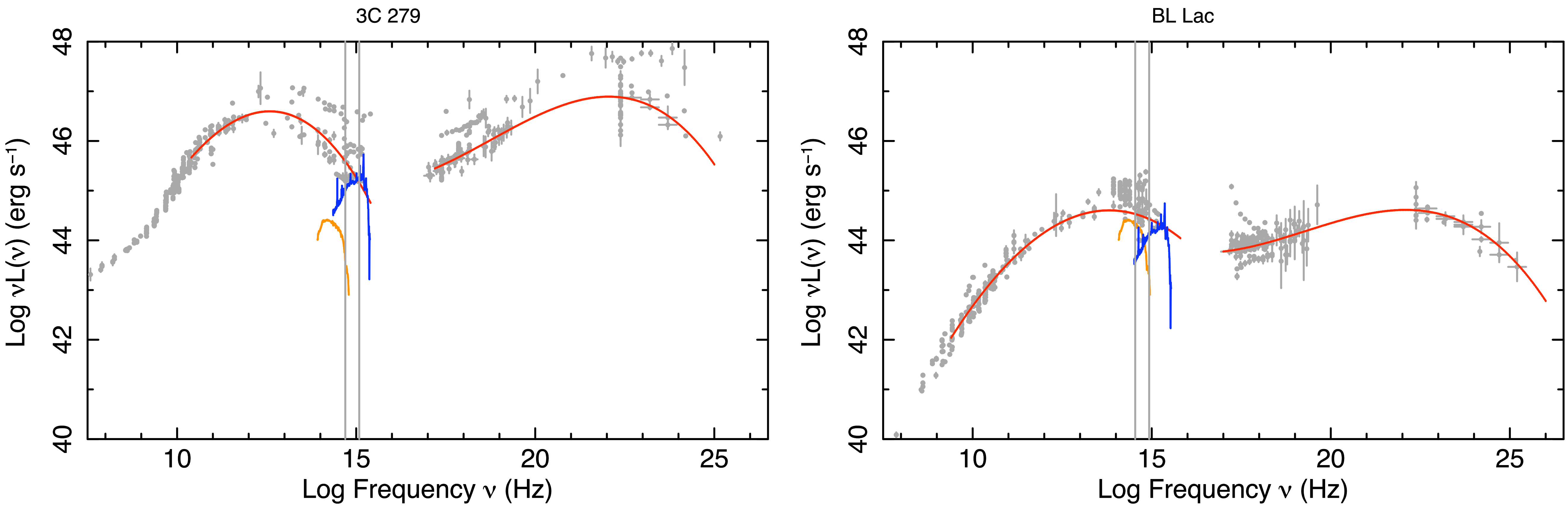
$\Gamma \geq$50-100 — Needle in jet ? (Ghisellini & Tavecchio 2008) — Jets in a jet ? (Giannios et al 2009) — magneto-centrifugal accel ? (Ghisellini et al 2008) — Jet-Star interaction ? (Barkov et al. 2010, 2011)



Energy index α_γ
Rau 0.3<z<z_{max}
Rau spec z
Rau phot z
1312
0630
0537
0035
L_γ [erg s^{-1}]

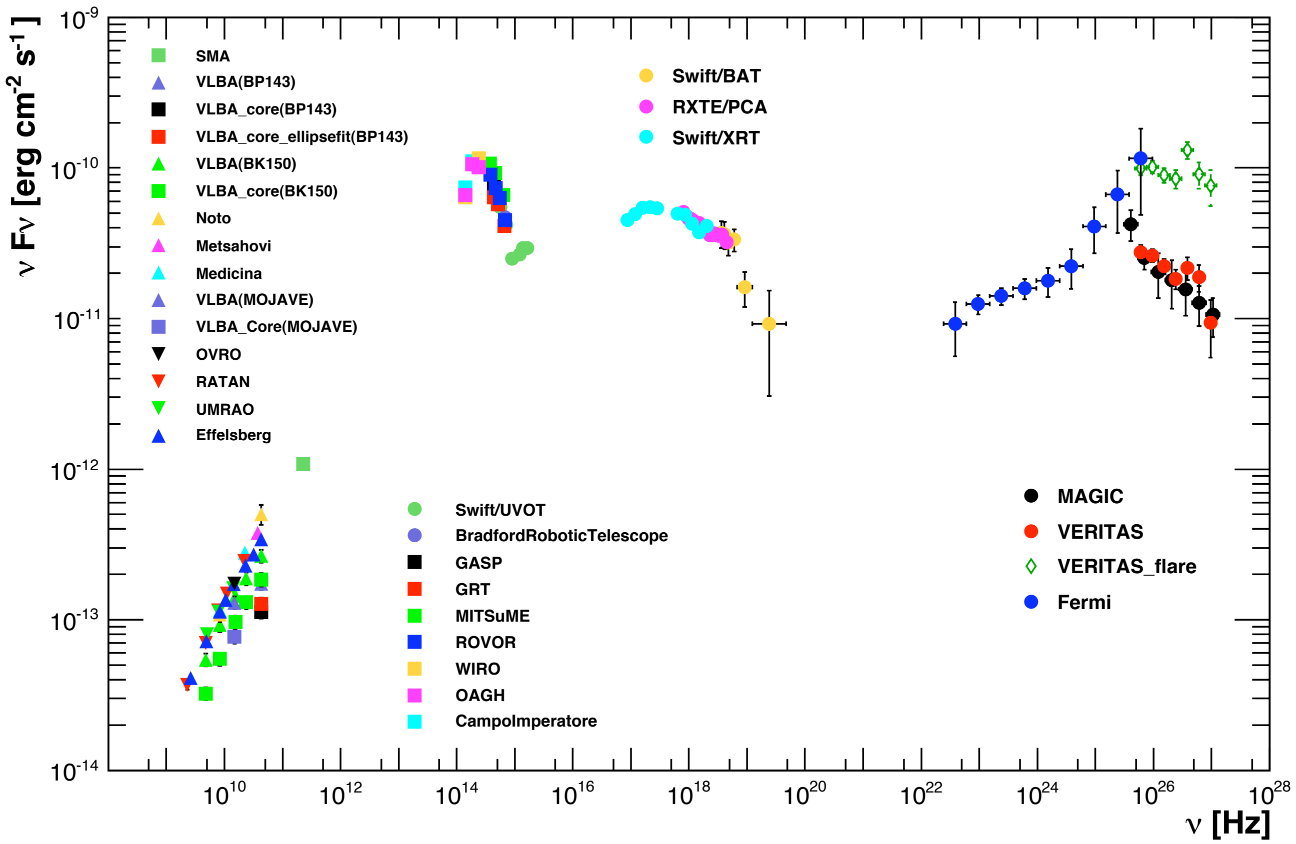


CRATES J0630−2406
z_{ph}=1.60
WISE
(not sim)
pure SSC
Log νF_ν [erg cm^{-2} s^{-1}]
Log νL_ν [erg s^{-1}]
Log ν [Hz]

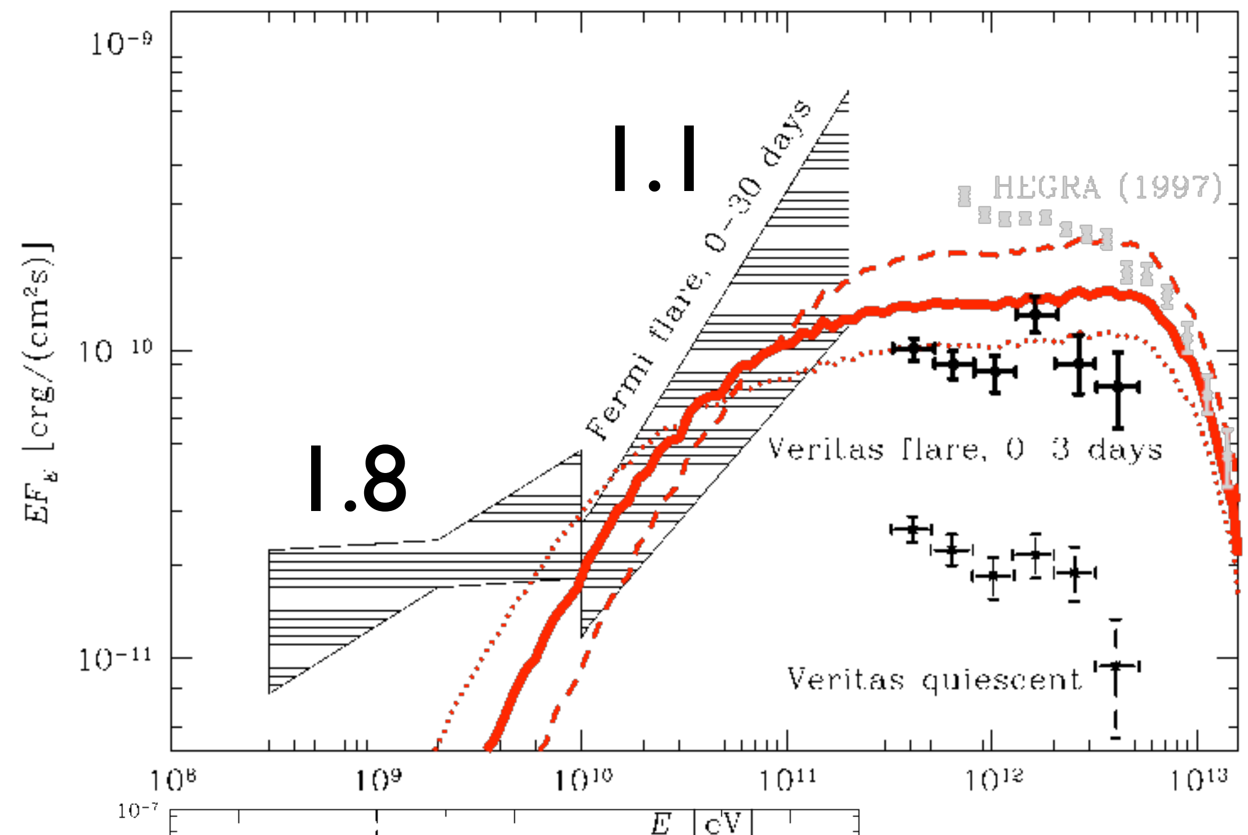

3C 279
BL Lac
Log νL(ν) (erg s⁻¹)
Log Frequency ν (Hz)
40
42
44
46
48
10
15
20
25

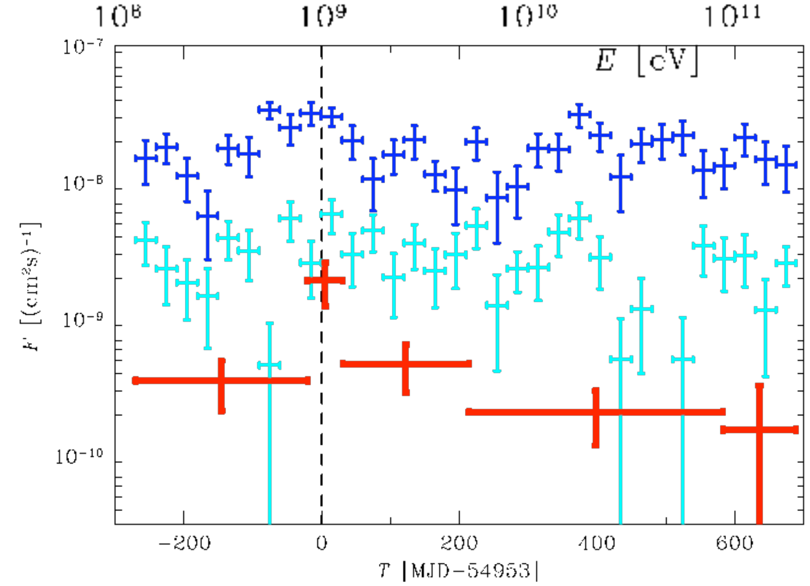
New, hard, transient components emerging at high energies ??

Mkn 501 (only a hint..)



Abdo et al. (LAT Coll) 2010

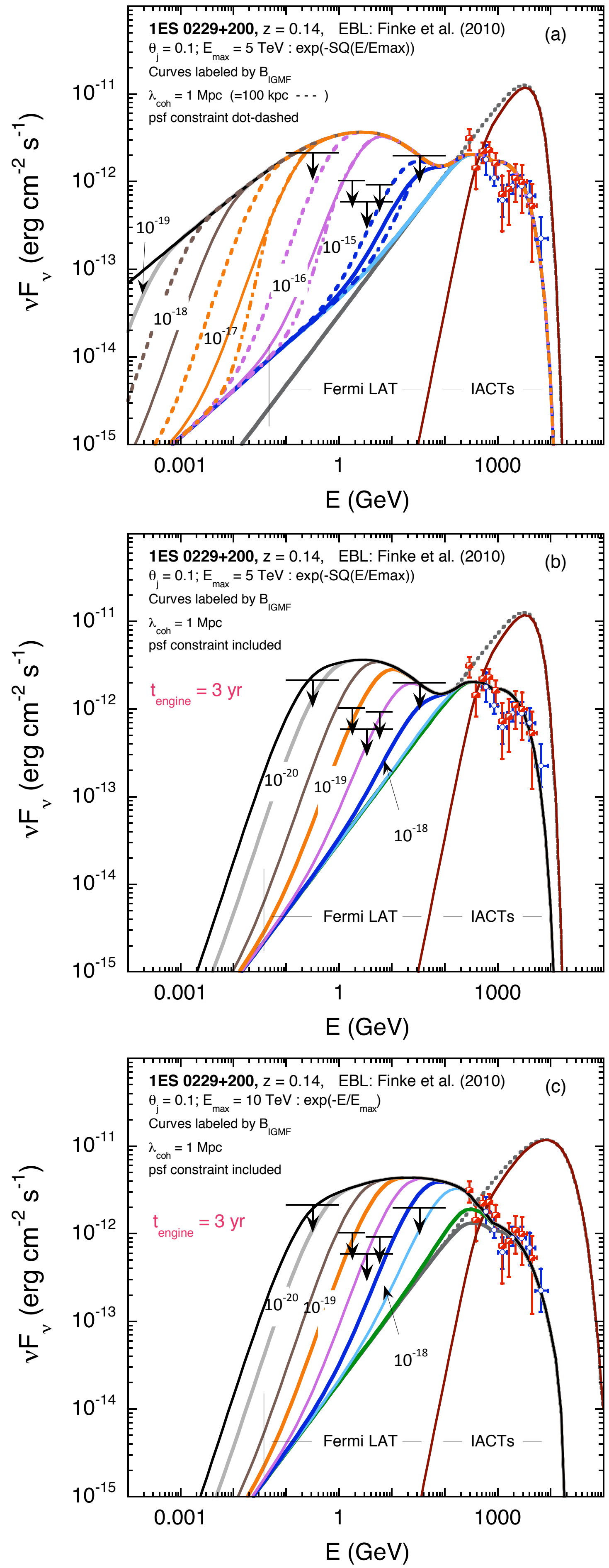




Neronov et al 2011

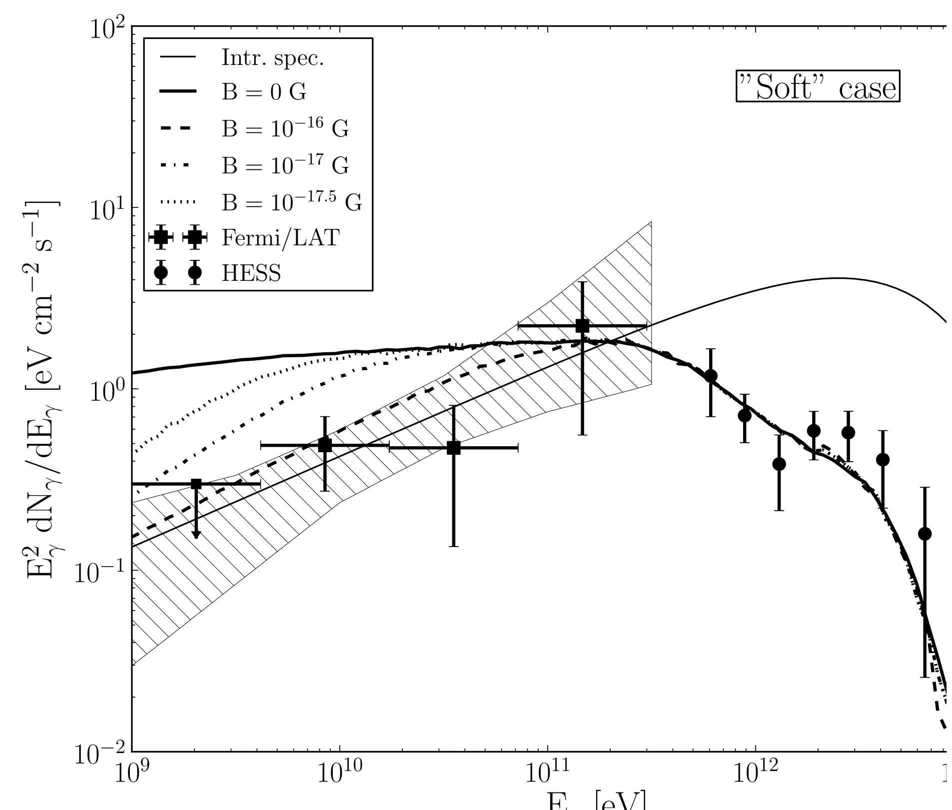
>10 GeV

But only a bunch of photons, very uncertain results...



Constraints on the Intergalactic Magnetic field

Lower limit from absence of γ-γ cascade emission



Neronov et al. 2010, Dermer et al 2011, Vovk et al. 2011