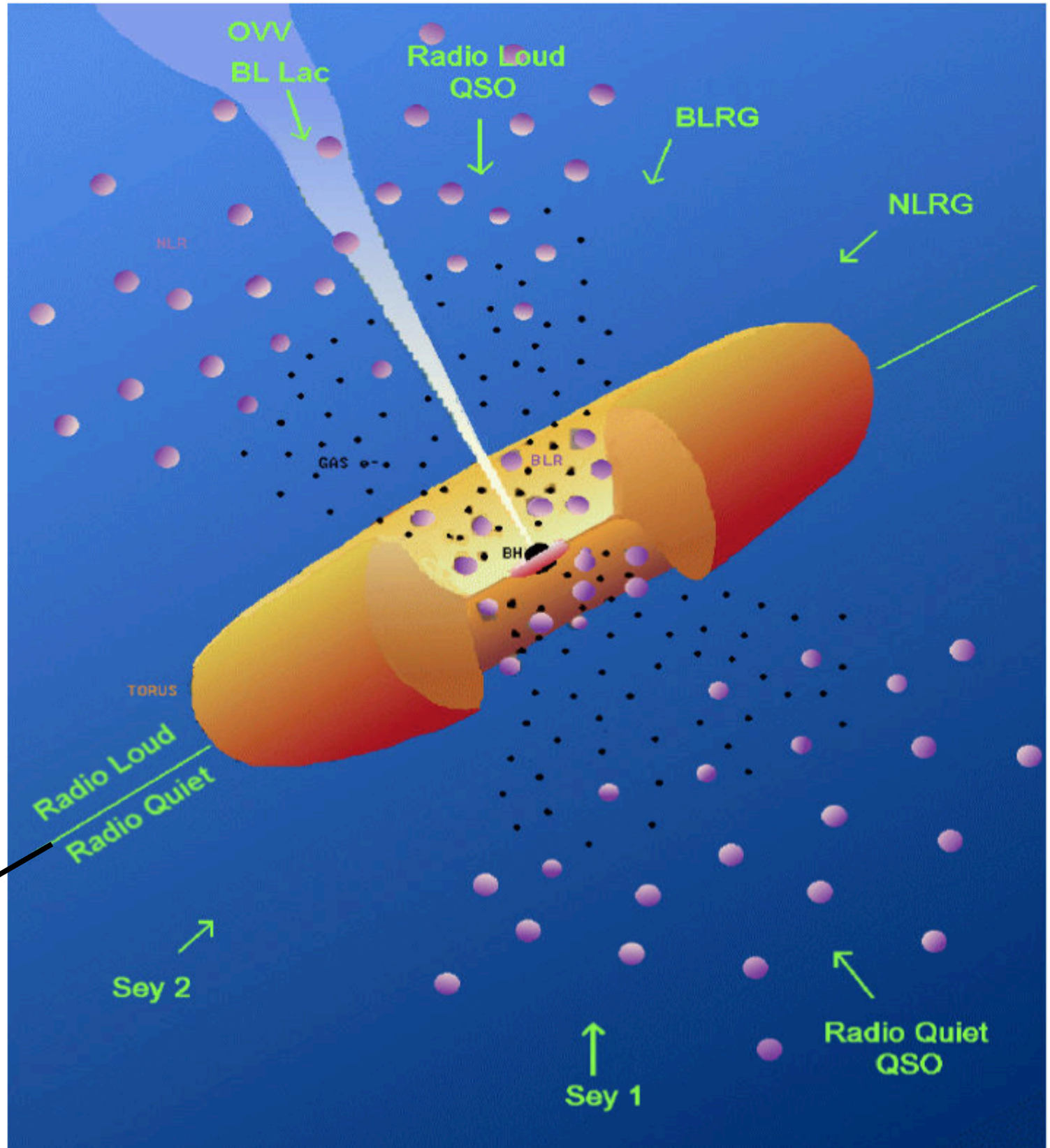
Blazars: what have we learned ? what now ?

(a very personal view)

L. Costamante

Disentangle orientation from intrinsic properties

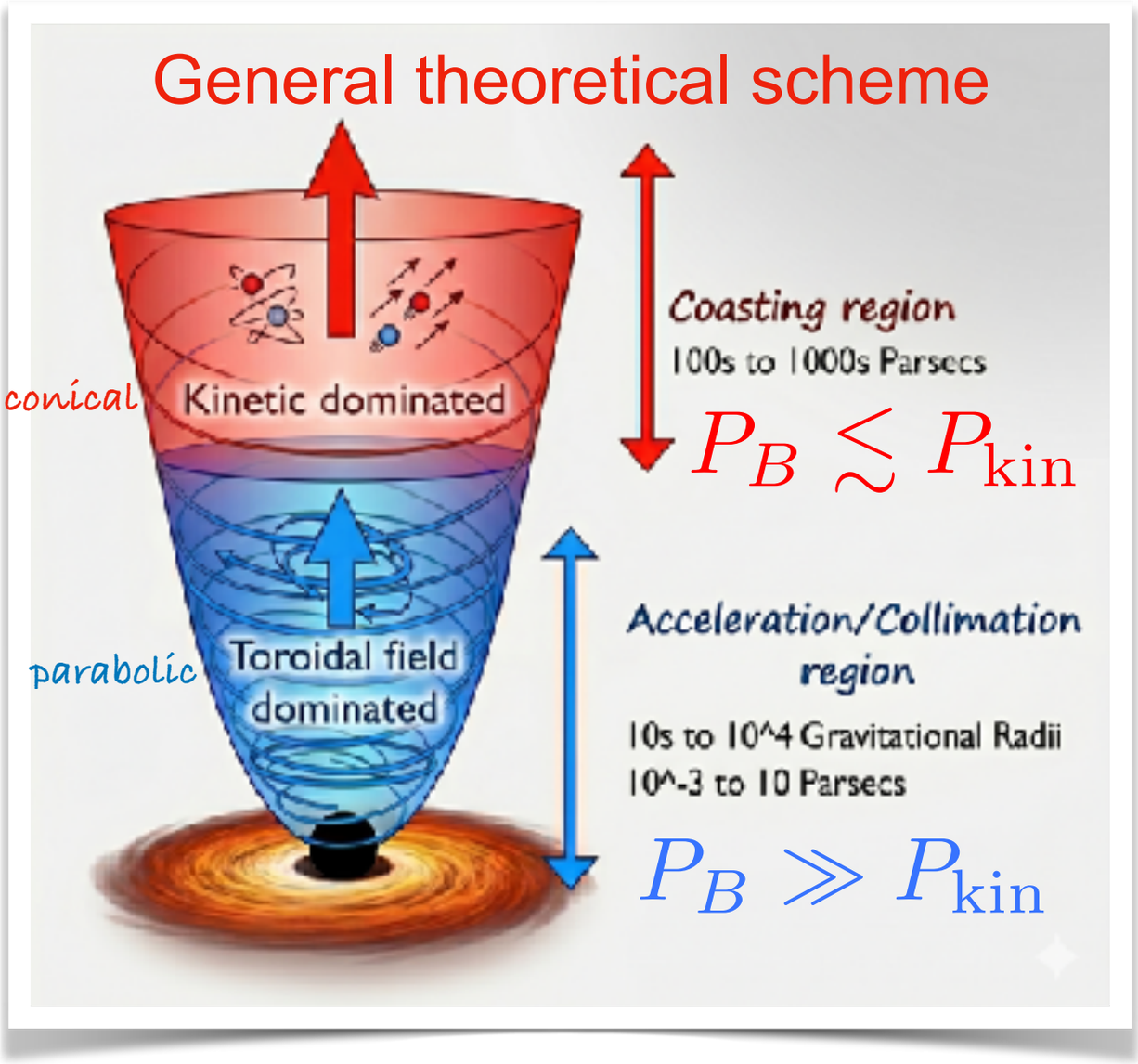
"Unification scenario"



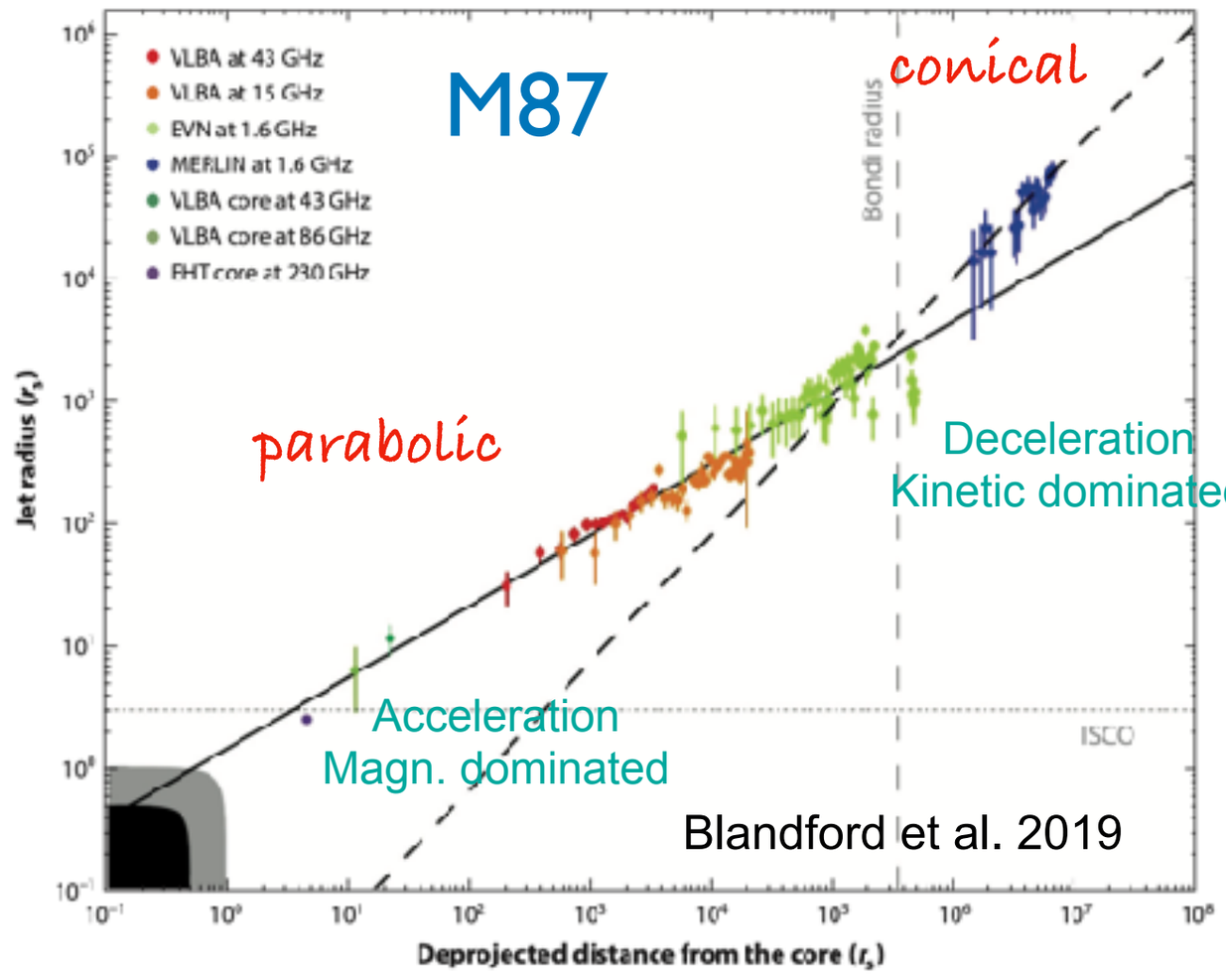
Gamma-ray Loudness

Urry & Padovani 1994

Jet structure, roughly…

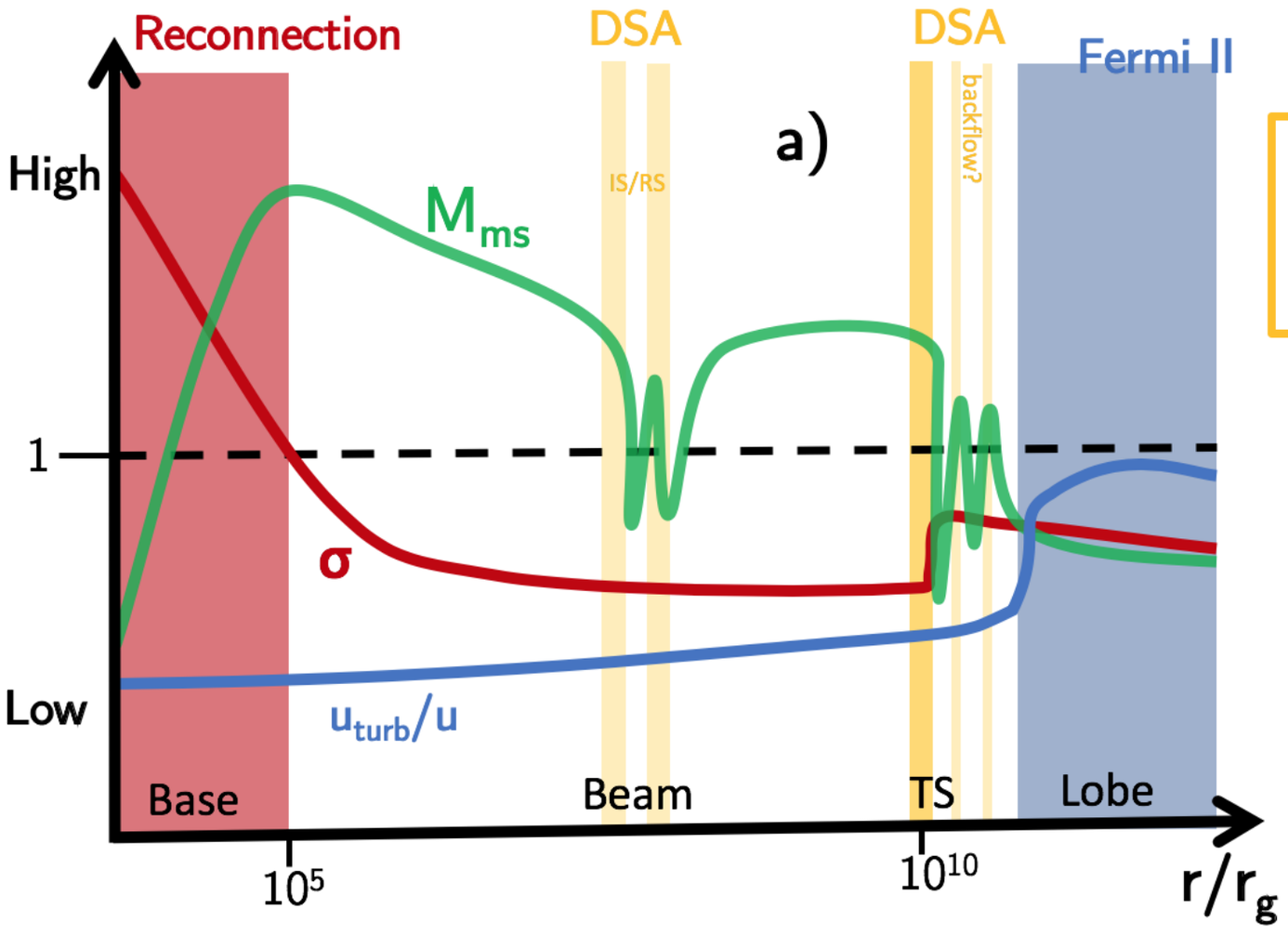


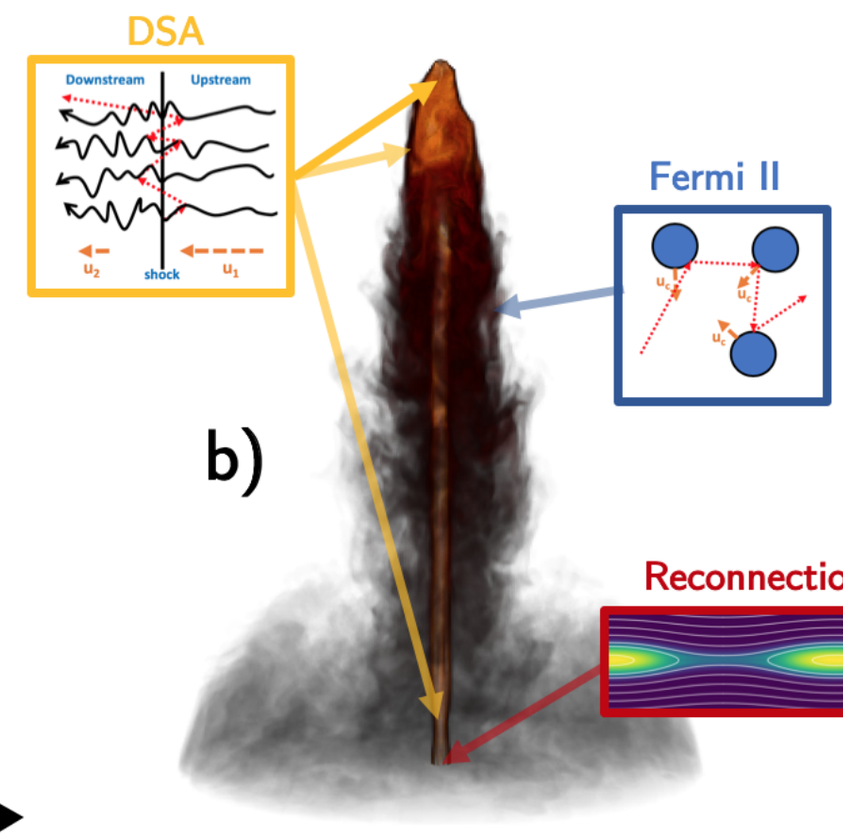
e.g. Contopoulos 1994, Komissarov et al. 2009
Tchekhovskoy et al. 2009



Blandford et al. 2019

What particle acceleration mechanisms ?
and where ?





σ = magnetisation

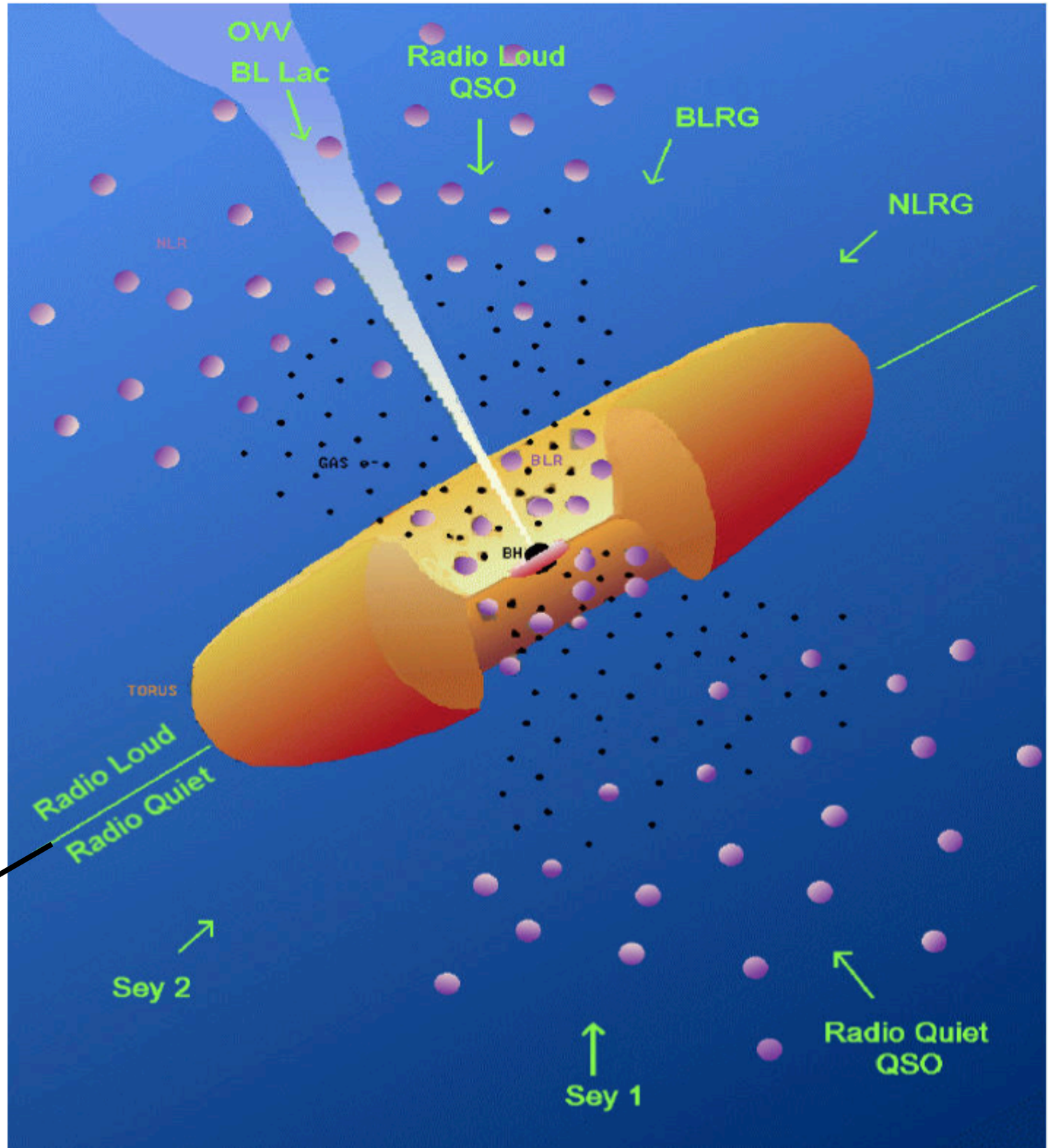
Ms = magnetosonic Mach number

u_{turb}/u = ratio of turbulent vs bulk velocities

From review by Matthews et al. 2020

Disentangle orientation from intrinsic properties

"Unification scenario"



Gamma-ray Loudness

Urry & Padovani 1994

1) Thermal Properties

FSRQ (FR II) **BL Lacs** (FR I)

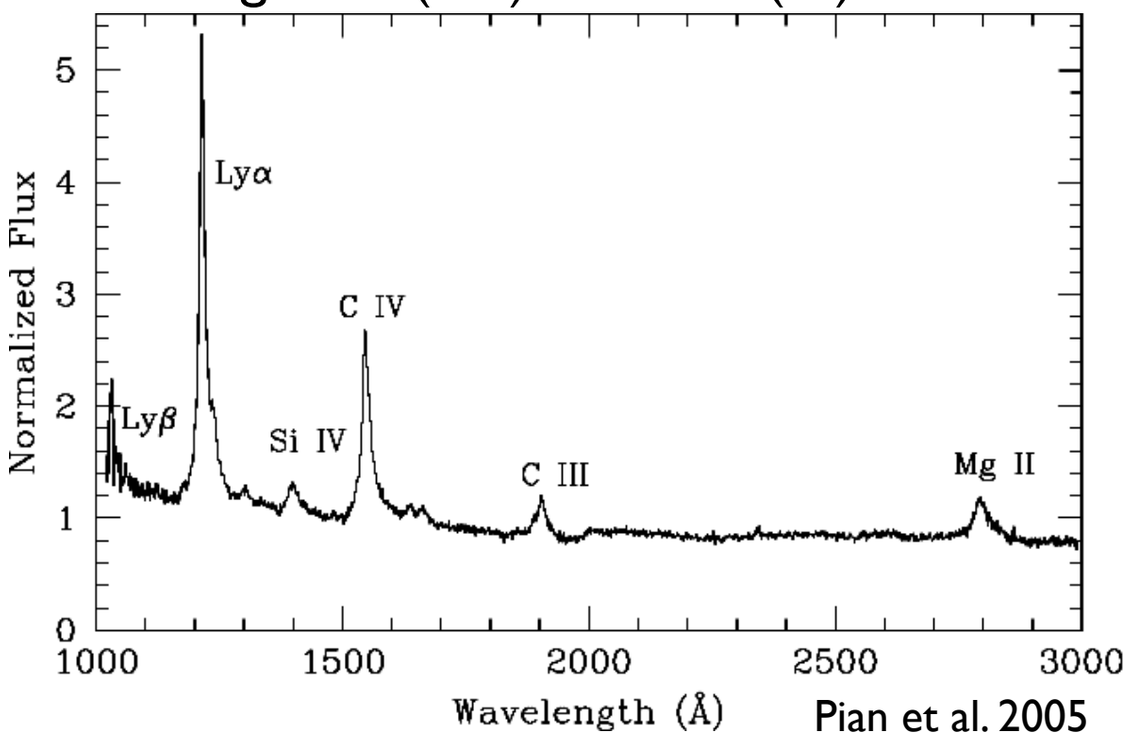
Broad Emission Lines:

EW>5 Å **EW<5 Å**

Continuum range of EW and line luminosities:

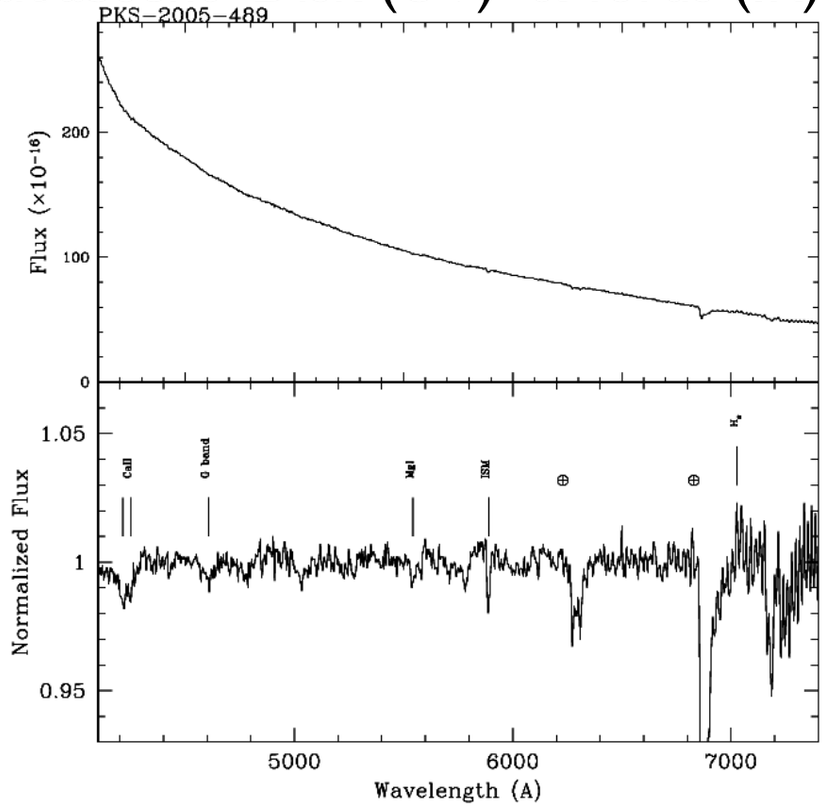
10^{46} erg/s ----------► $<10^{40}$ erg/s

Strong Disk (UV) & Torus (IR) emission



Pian et al. 2005

Weak/absent Disk (UV) & Torus (IR) emission

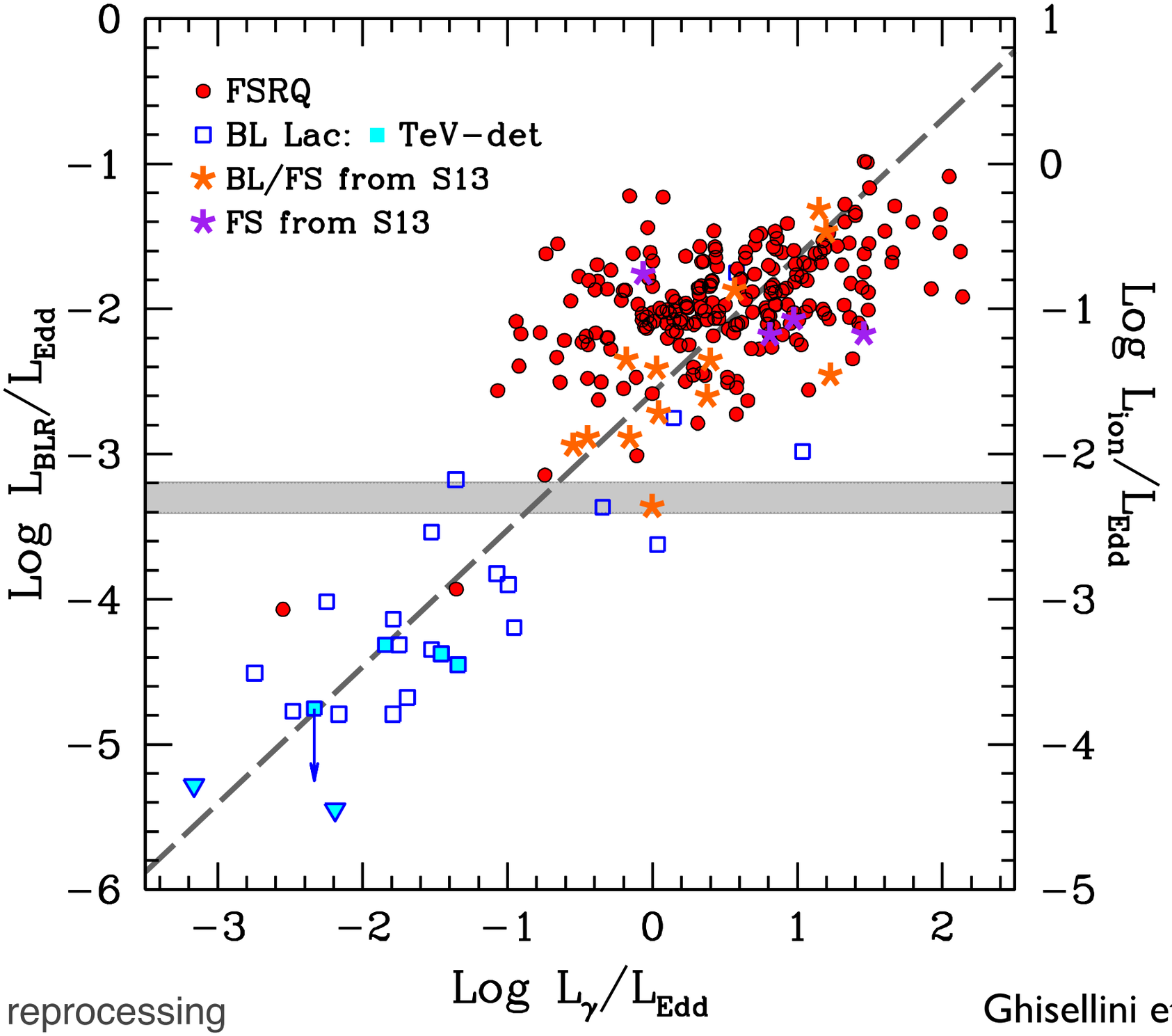


Introducing BH mass

(Virial or M_{BH} - M_R relation)

real FSRQ

real BLLacs



radiatively efficient

radiatively inefficient

with 10-20% reprocessing

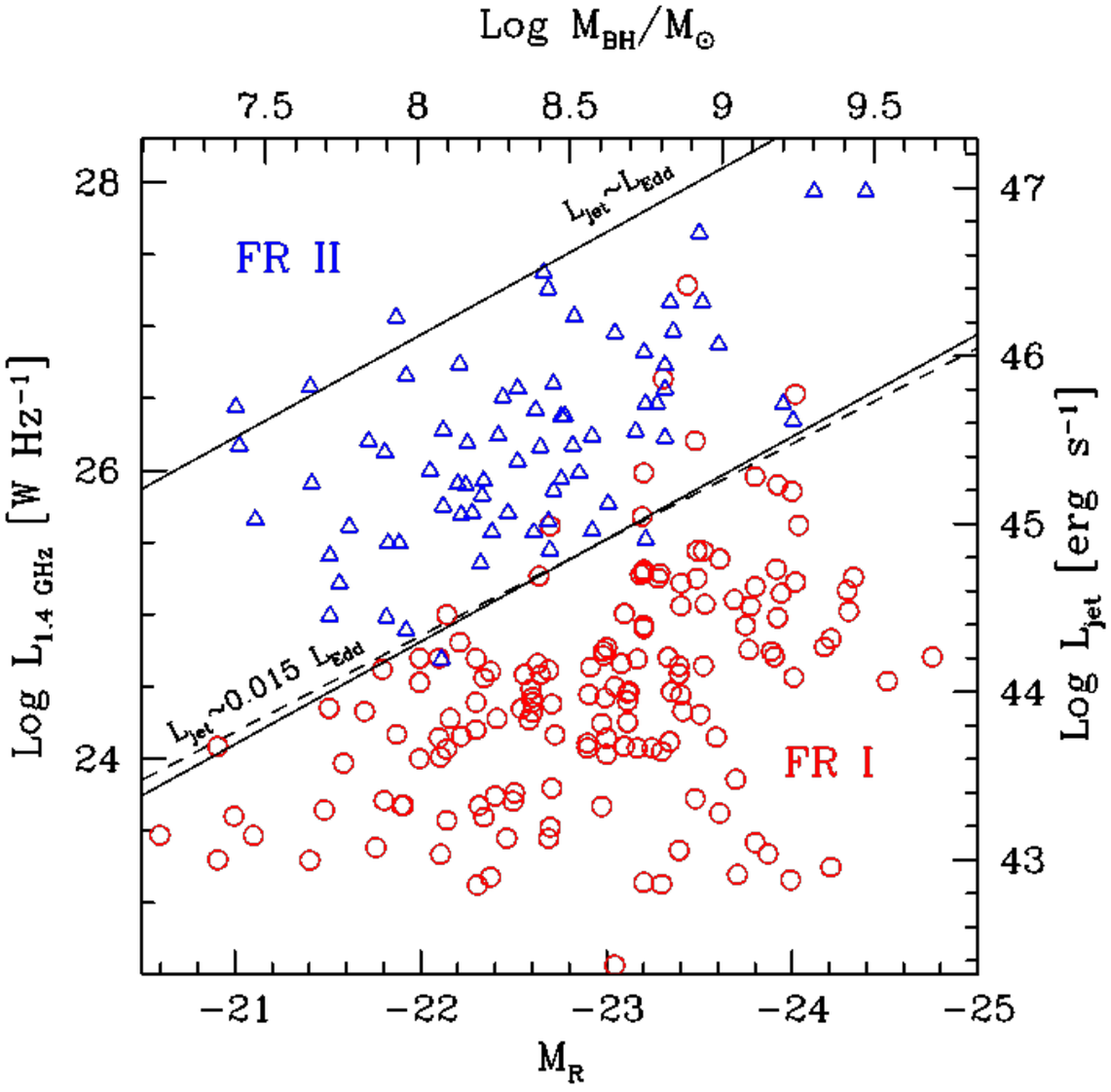
$L_{disk}/L_{Edd} \sim 10^{-2}$

Ghisellini et al 2013

Sbarrato et al 2011, 2014

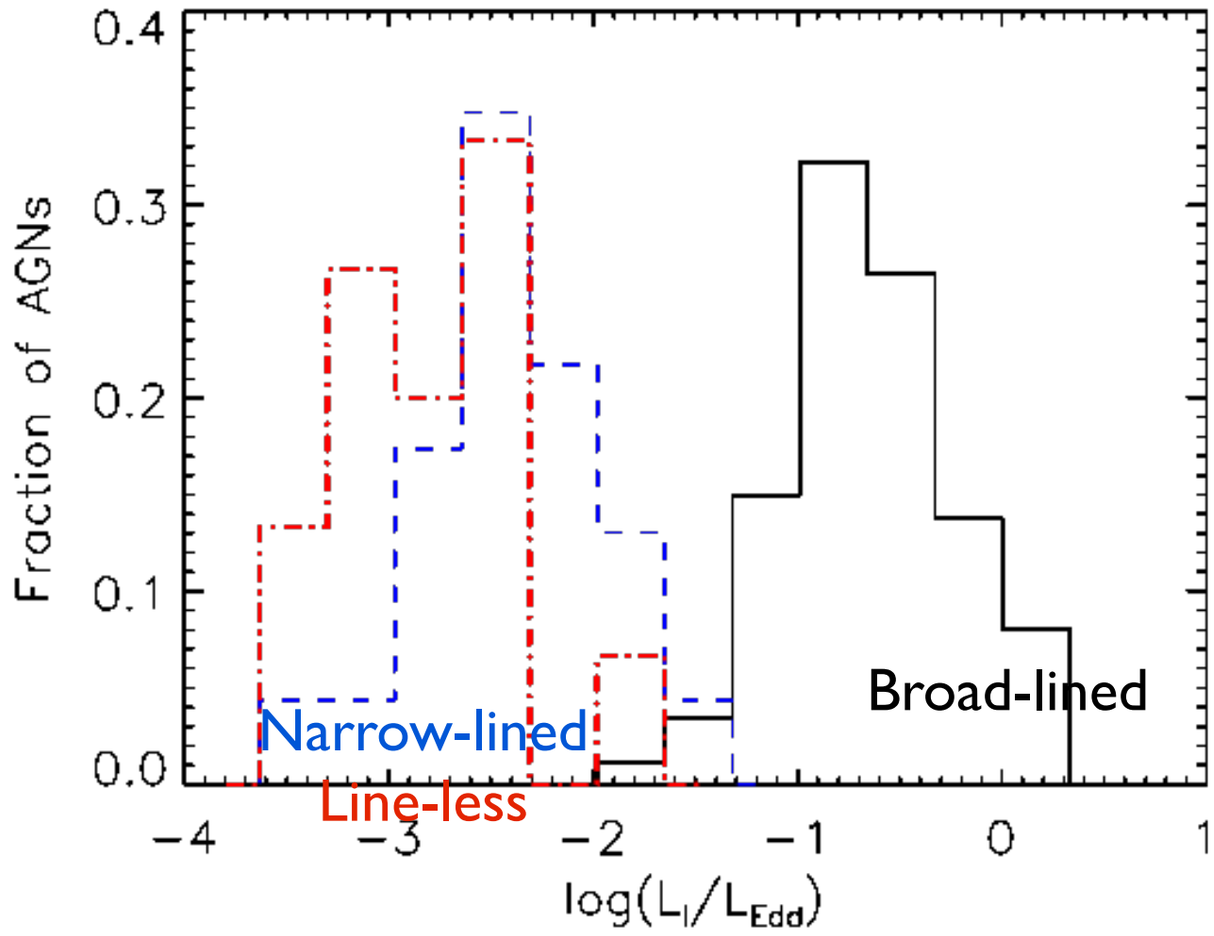
Something is happening at L ~0.01 L_{Edd}

ADAF - Shakura/Sunyaev ?



Ledlow & Owen 1996
Ghisellini & Celotti 2002

Sample 82 unobscured AGNs

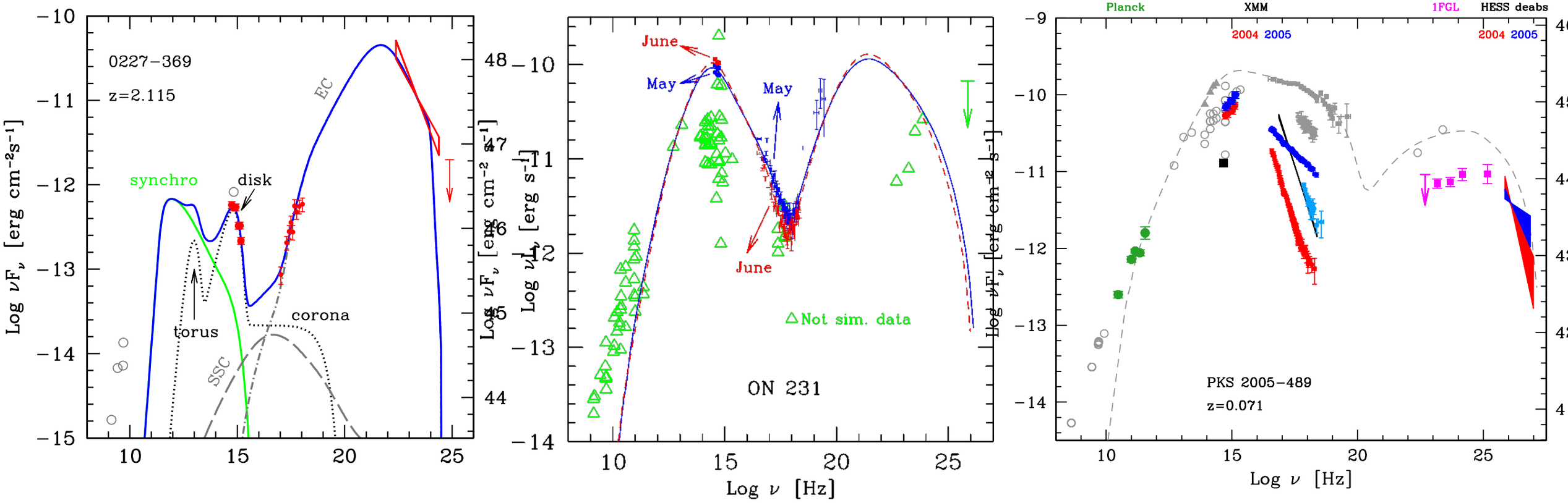


Trump et al. 2011

Changing-look AGN are close to that L !

2) Jet properties: SED Sequence

$\alpha_x < 1$ $\alpha_x \simeq 1$ V-shape $\alpha_x > 1$

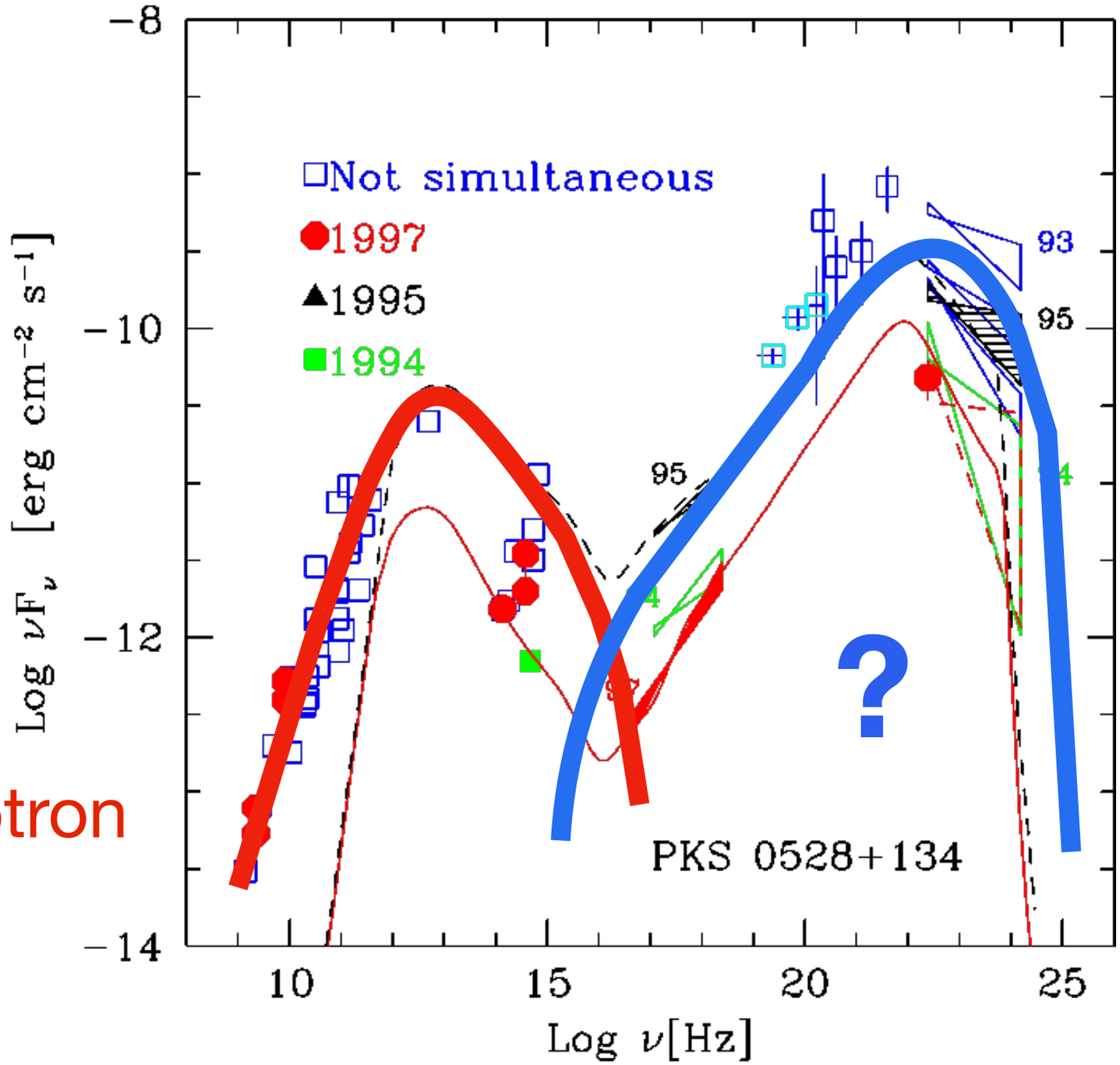


LSP ISP HSP - EHSP

From Low to High-energy peaked Blazars

Giommi & Padovani 1994,1995

Double-humped SED:
which mechanism & location for the γ-ray emission ?



Synchrotron

Proton scenarios:

p-p : not efficient, $L \sim 10^{45}$ erg/s needs target 10^6 cm^{-3}
slow, $t_{pp} \sim 10^{15}/n_p$ s

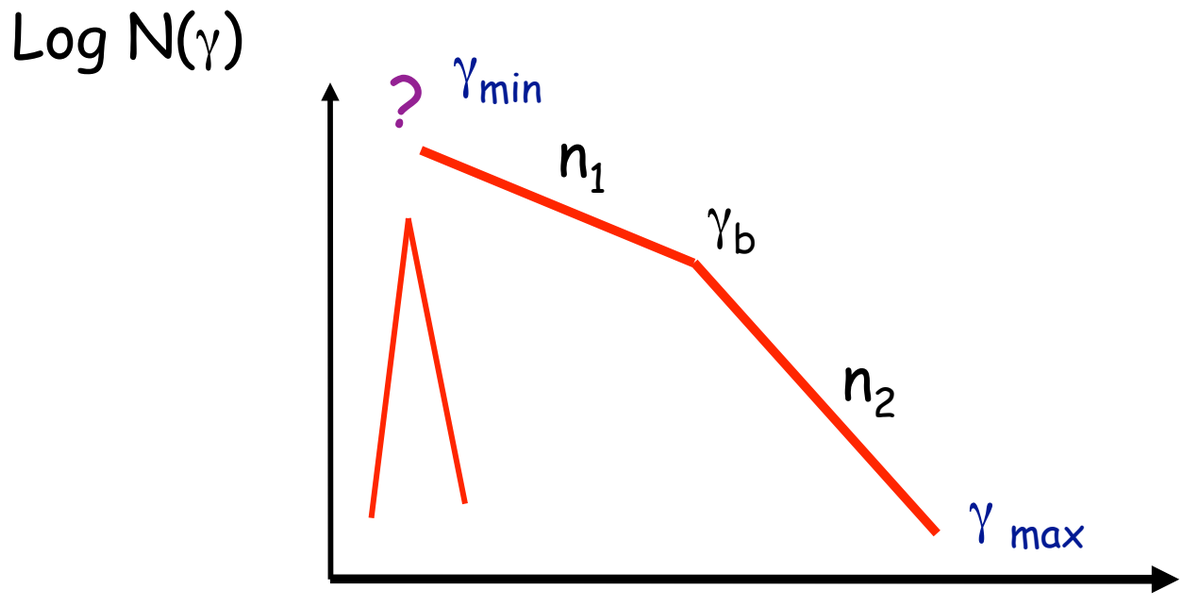
For typical blazar variability (few hrs):

p-γ : $E_p > 10^{19}$ eV, needs large densities of target photons
problem of gamma-ray transparency
generates neutrinos !

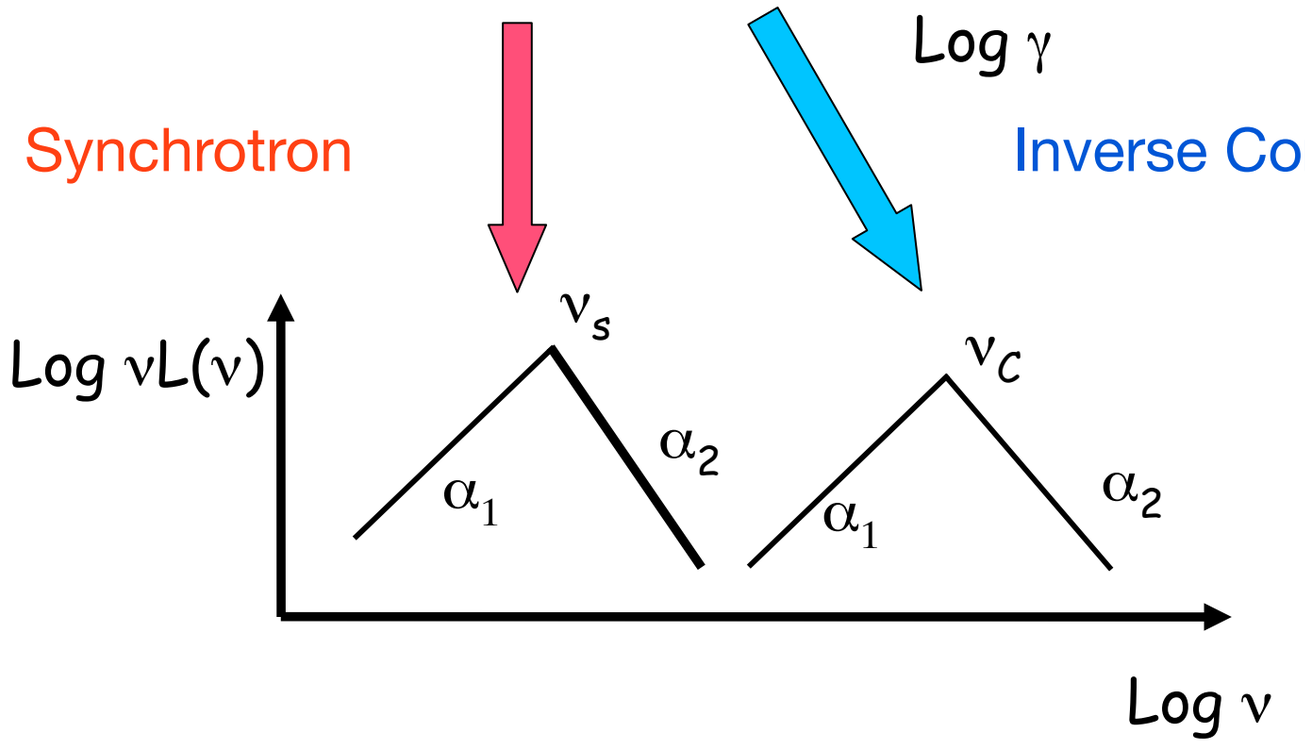
p-B : $E_p > 10^{19}$ eV, needs large magnetic fields (>100 G)

See e.g. Muecke & Protheroe 2000, Aharonian 2000
Petropoulou et al. 2014-18, Boettcher et al. 2012,
Cerruti et al. 2015, 2018

Leptonic Scenario: population of relativistic electrons



U'_{synch} (SSC)
U'_{BLR} (EC)
U'_{disk} (UV)
U'_{dust} (IR)

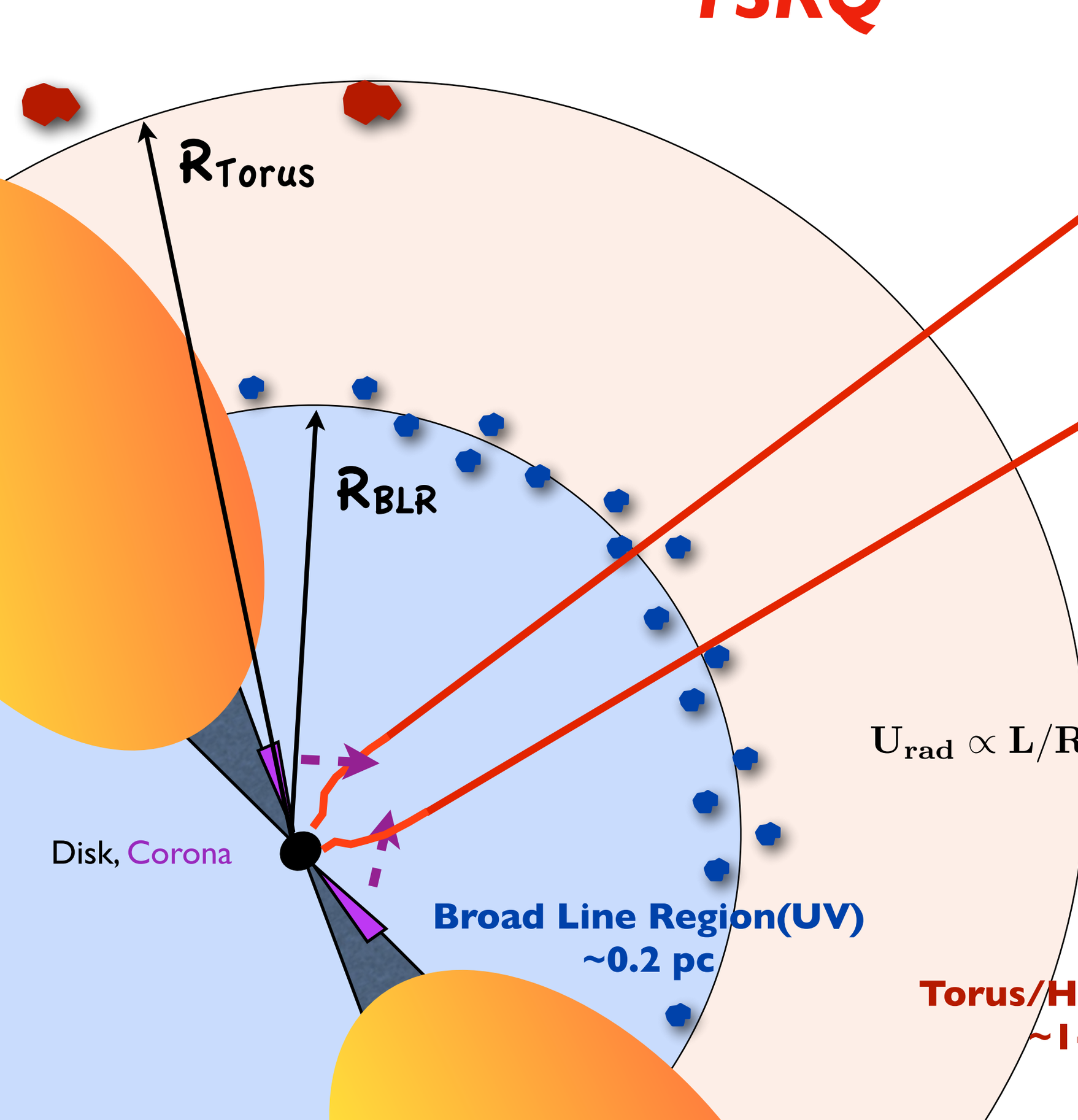


$$\langle \dot{\gamma} \rangle = \frac{4}{3} \sigma_{\mathrm{T}} c \, U'_{rad} \, \gamma^2 \beta^2$$

$$\langle \dot{\gamma} \rangle = \frac{4}{3} \sigma_{\mathrm{T}} c \, U'_{B} \, \gamma^2 \beta^2$$

Main cooling channel ? Highest energy density U' in co-moving frame

FSRQ



$$R_{BLR} \simeq 0.1 \times L_{46}{}^{1/2}\ \mathrm{pc}$$

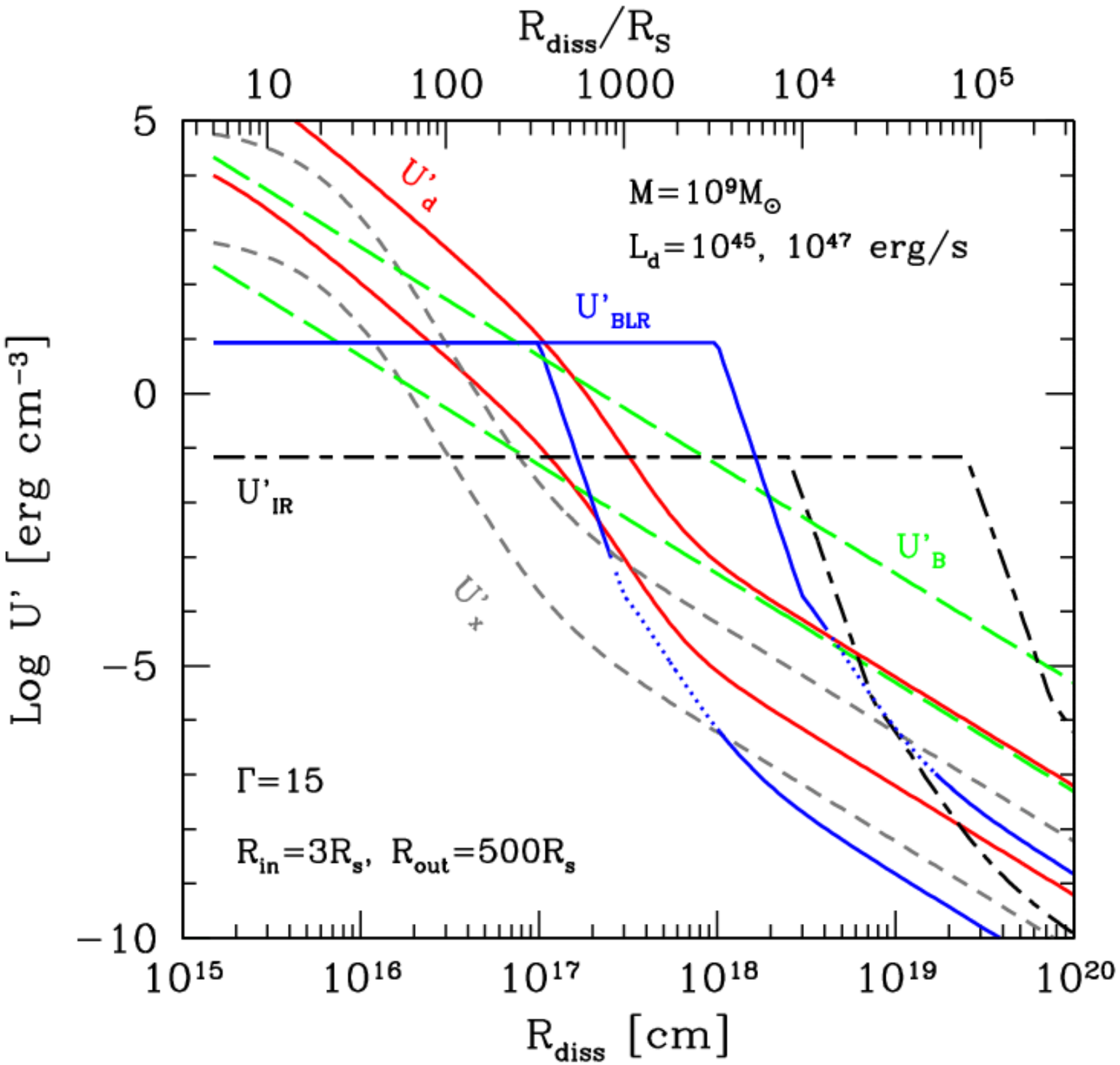
(Bentz et al. 2006 ; Kaspi et al. 2007)

$$R_{HD} \simeq 2.5 \times L_{46}{}^{1/2}\ \mathrm{pc}$$

(Cleary et al. 2007 ; Nenkova et al. 2008)

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

Energy density U along the jet:



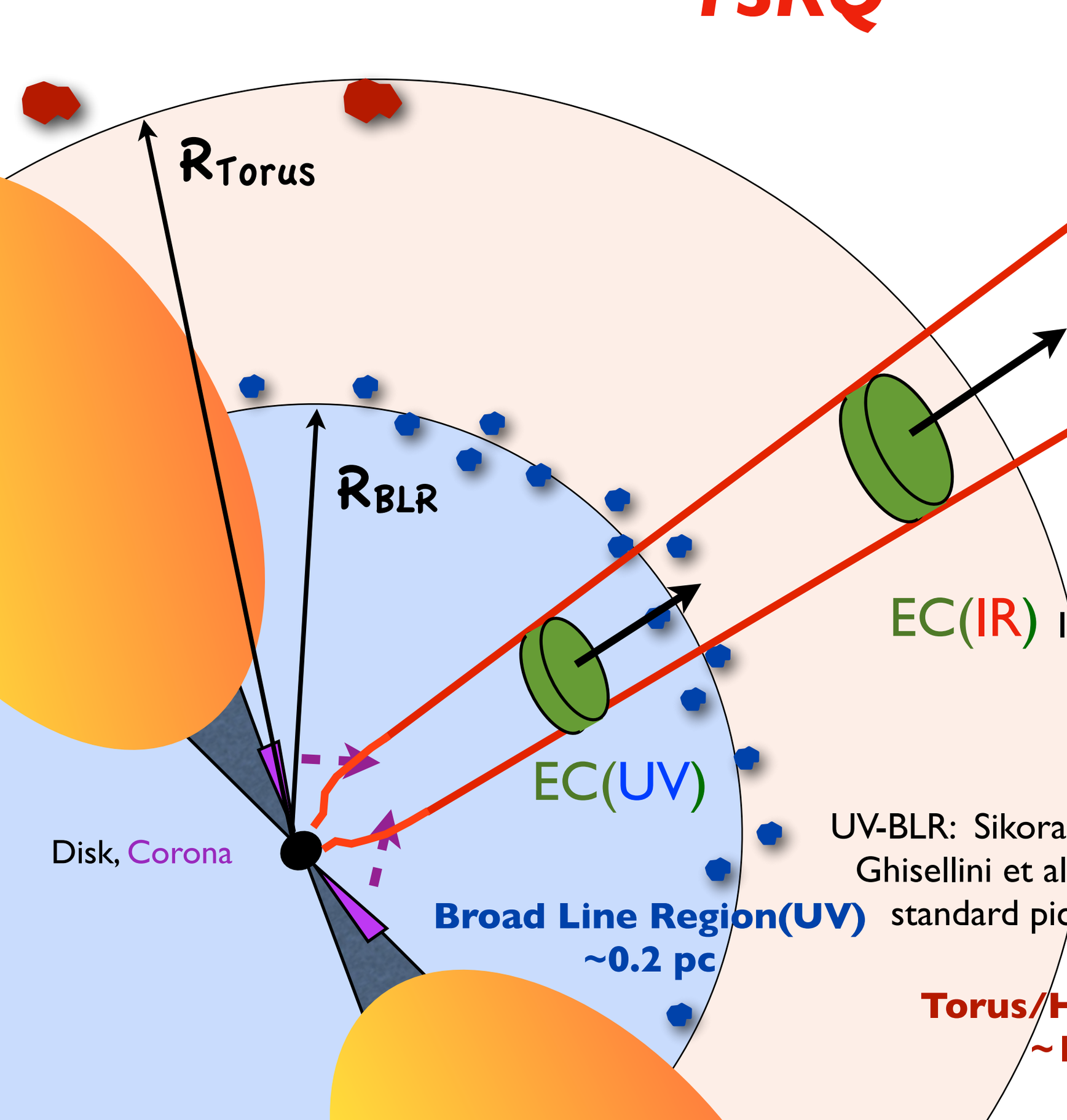
U' in jet frame

$$\dot{\gamma} \propto U'_{rad}\,\gamma^2$$

Ghisellini et al. 2009
Sikora et al. 2009

gamma-rays: Inv.Compton on highest-U' seed photons

FSRQ



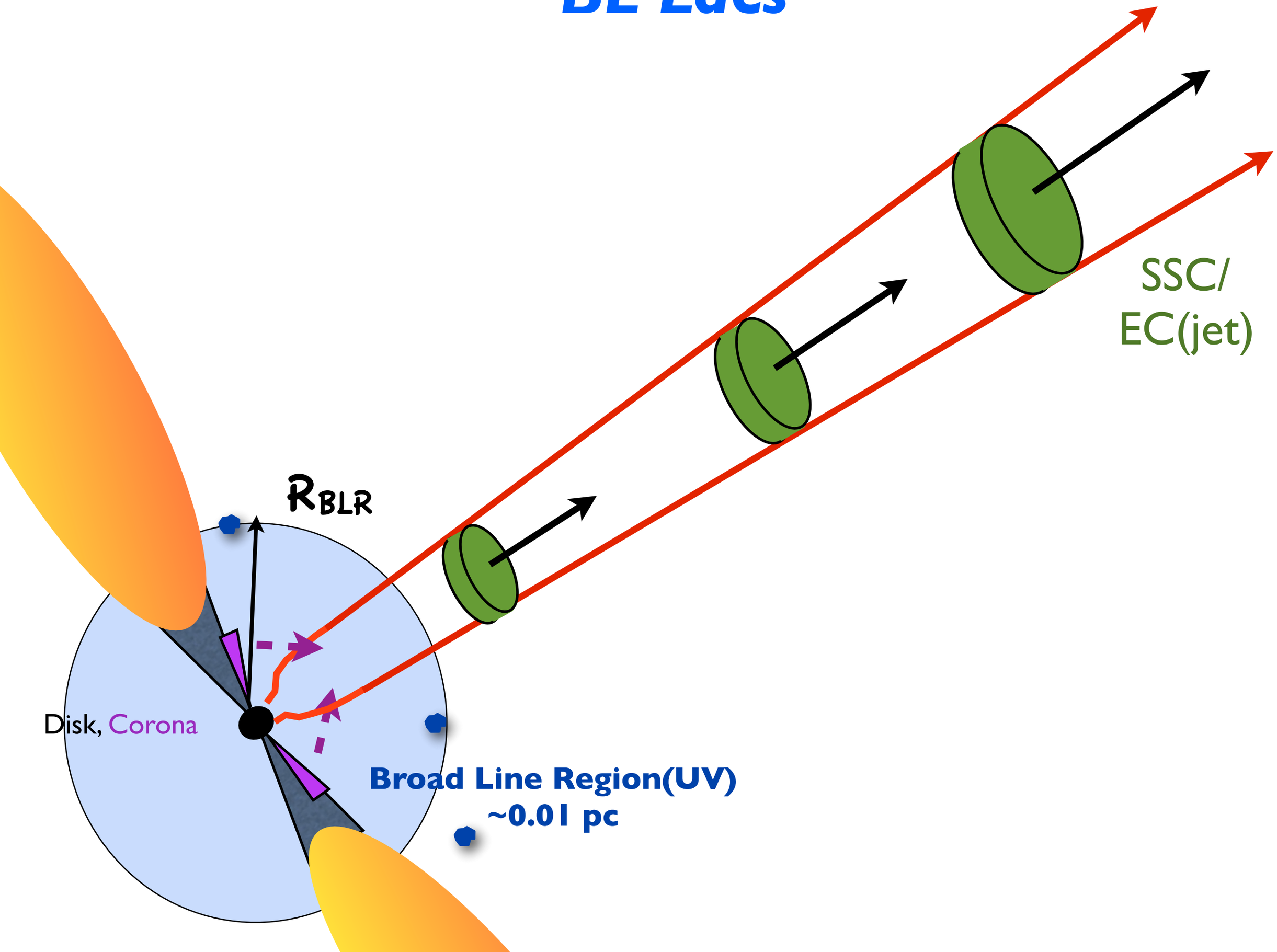
SSC/
EC(jet)

Marscher et al.
VLBI scale, ~20pc away
radio-gamma correl.

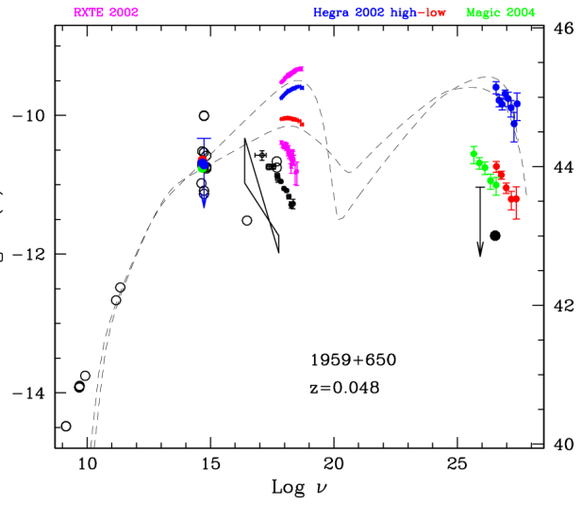
IR: Sikora et al. 98+
mm transparent
MeV blazars

UV-BLR: Sikora et al. 94
Ghisellini et al. 98-22
standard picture

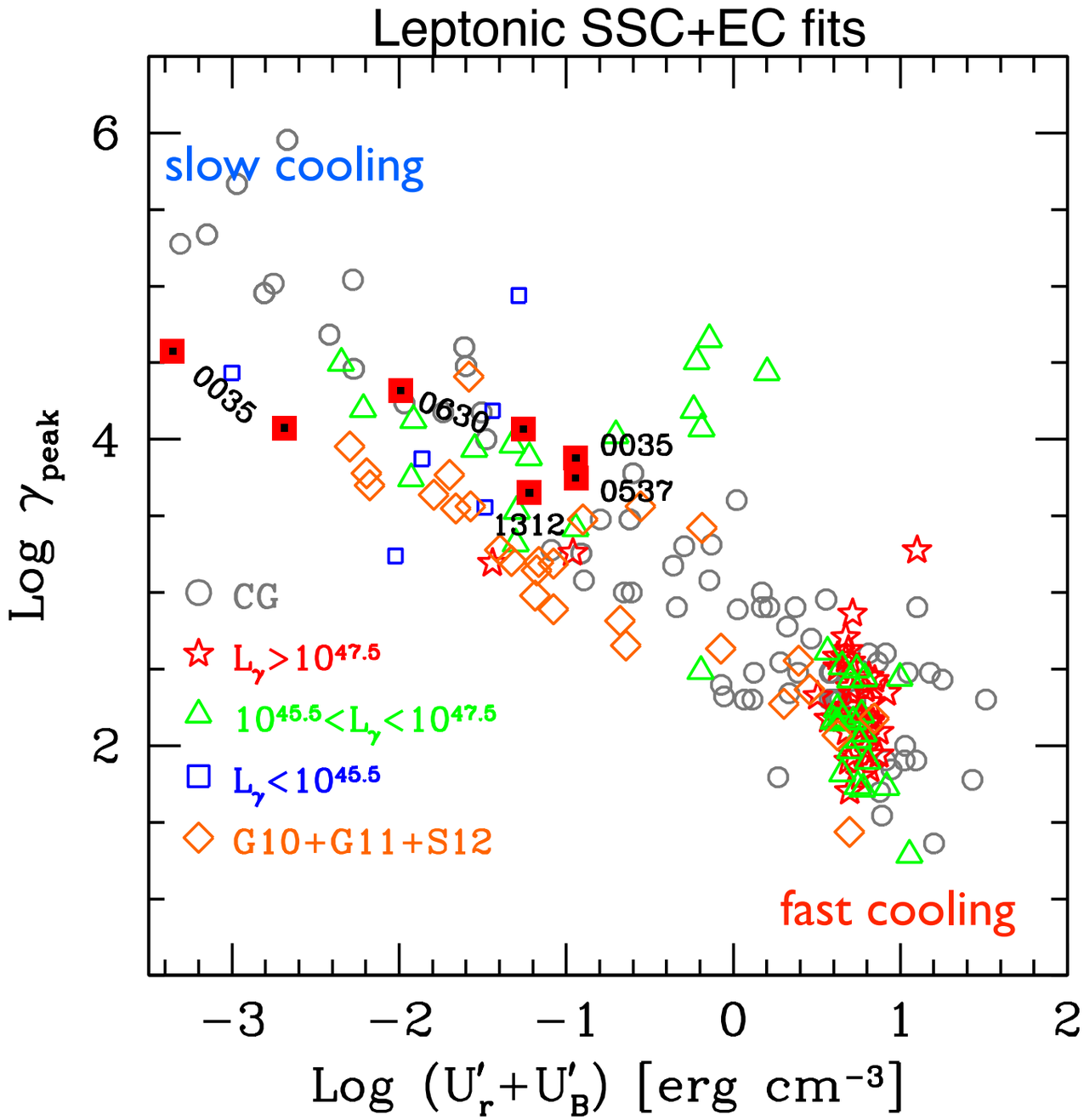
BL Lacs



Interpretation: balance acceleration/cooling

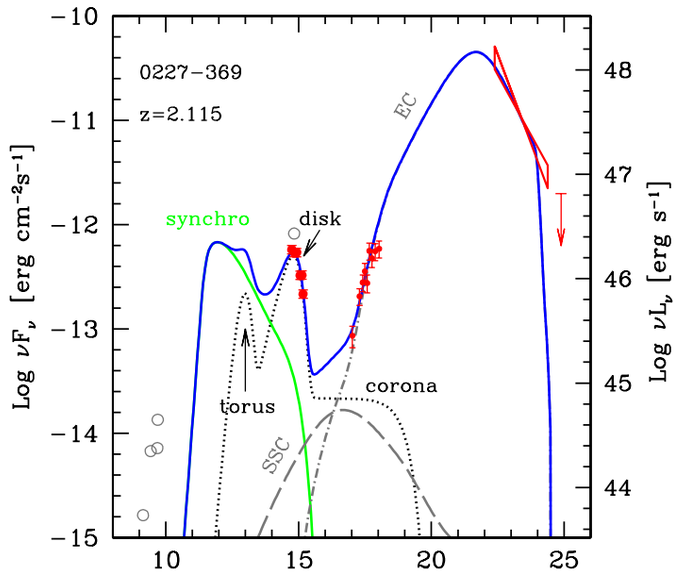


BLLacs: SSC



FSRQ

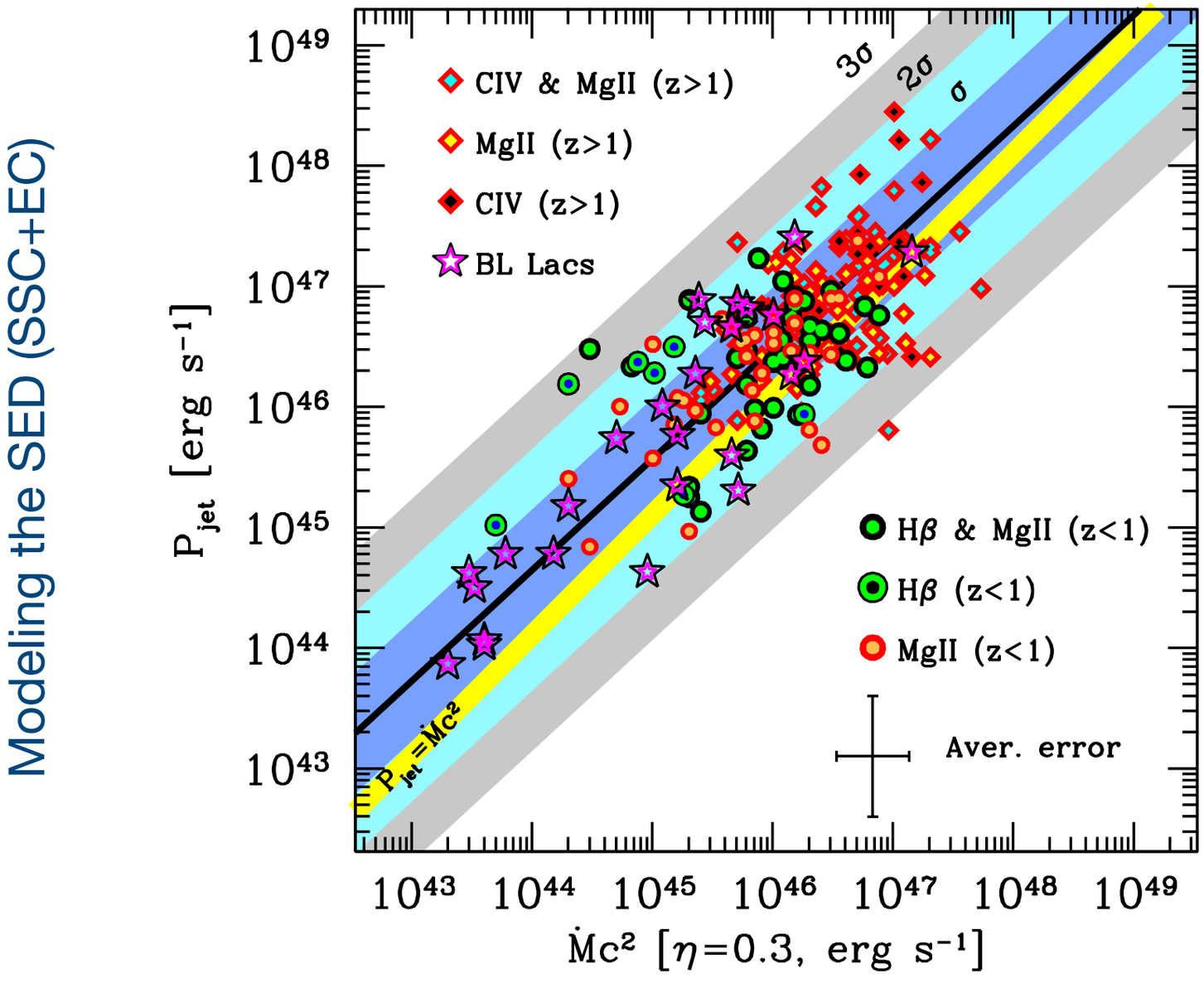
EC(BLR)



Ghisellini et al 1998-2013,
Sikora et al 1994-2013

$P_{jet} > P_{accretion}$

Blazars Jets are powered by BH rotational energy via B

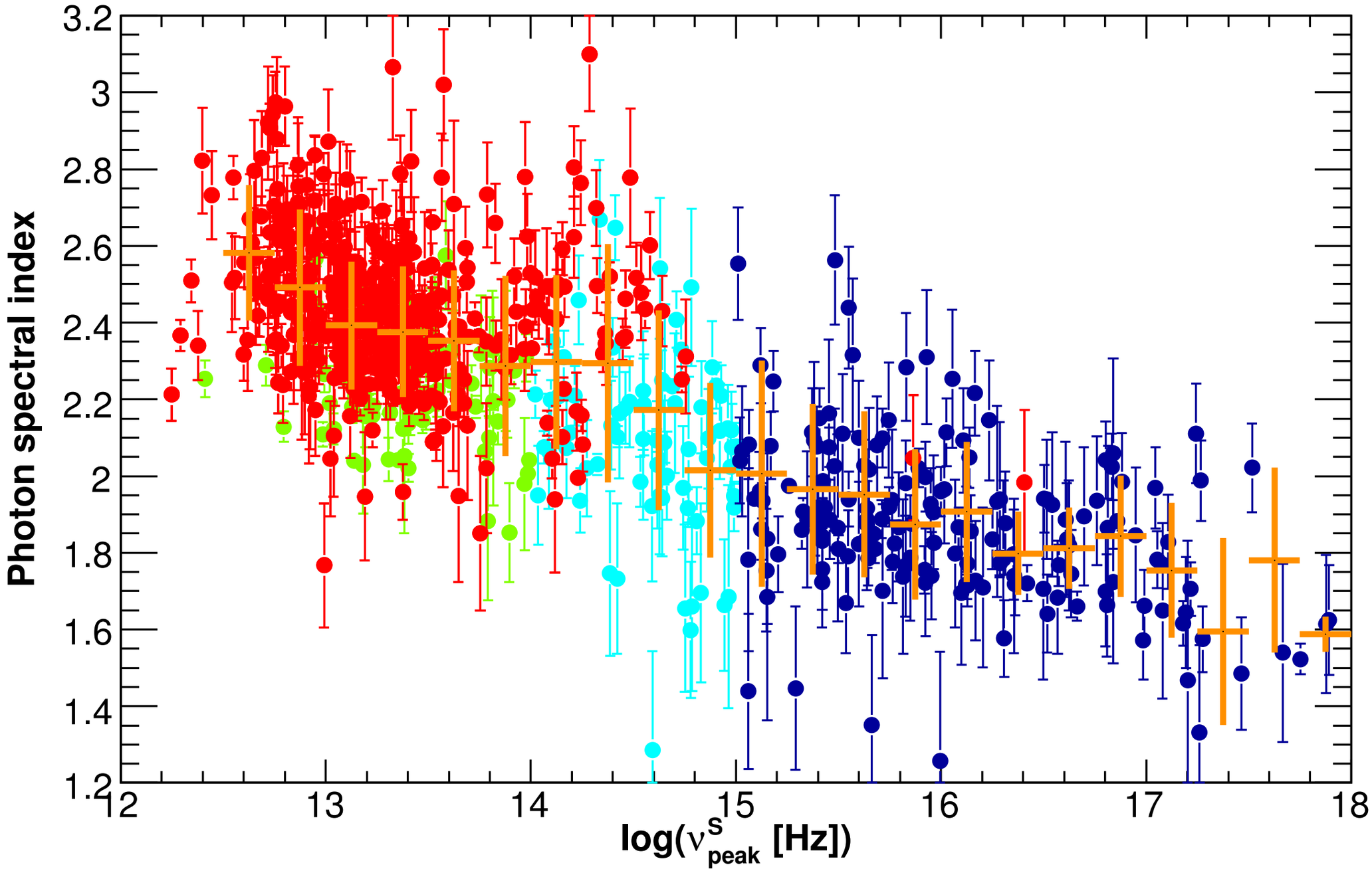


Through M and L_{BLR}

$\dot{M} c^2 = L_{disk}/\eta$

Ghisellini et al. Nature 2015
leptonic modeling

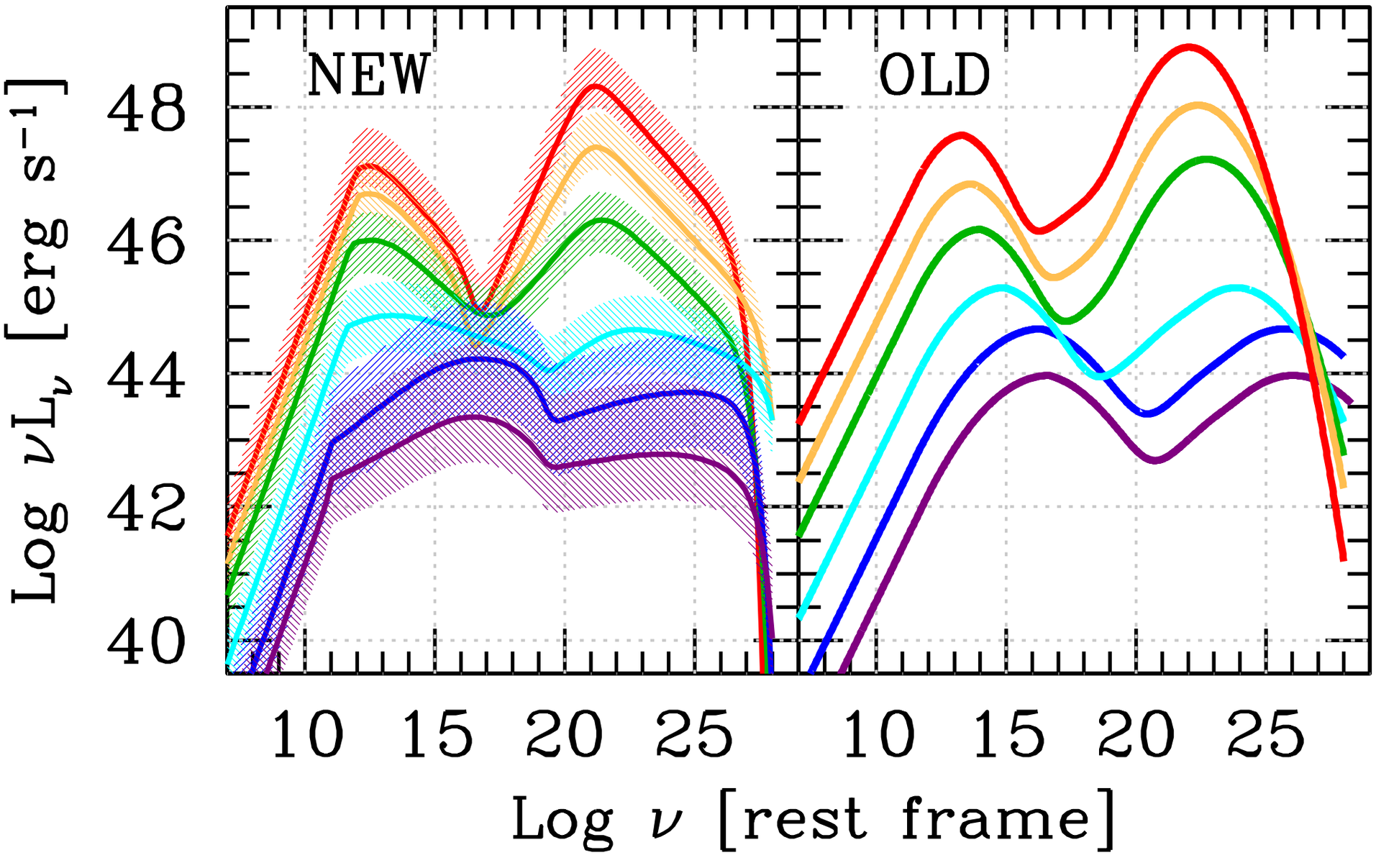
Gamma-ray SED sequence



LAT Coll., 3LAC paper 2015

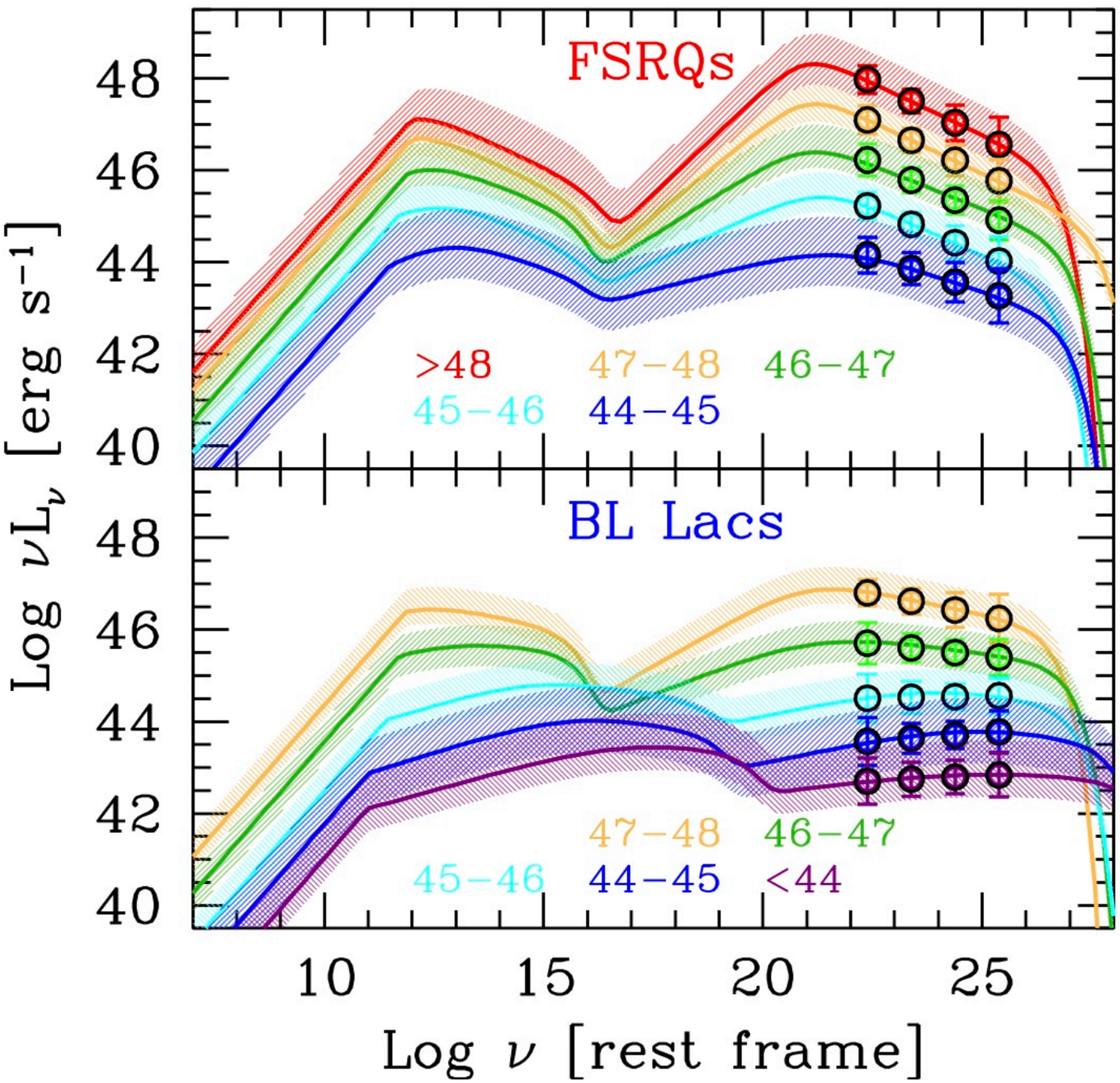
Blazar Sequence 2.0

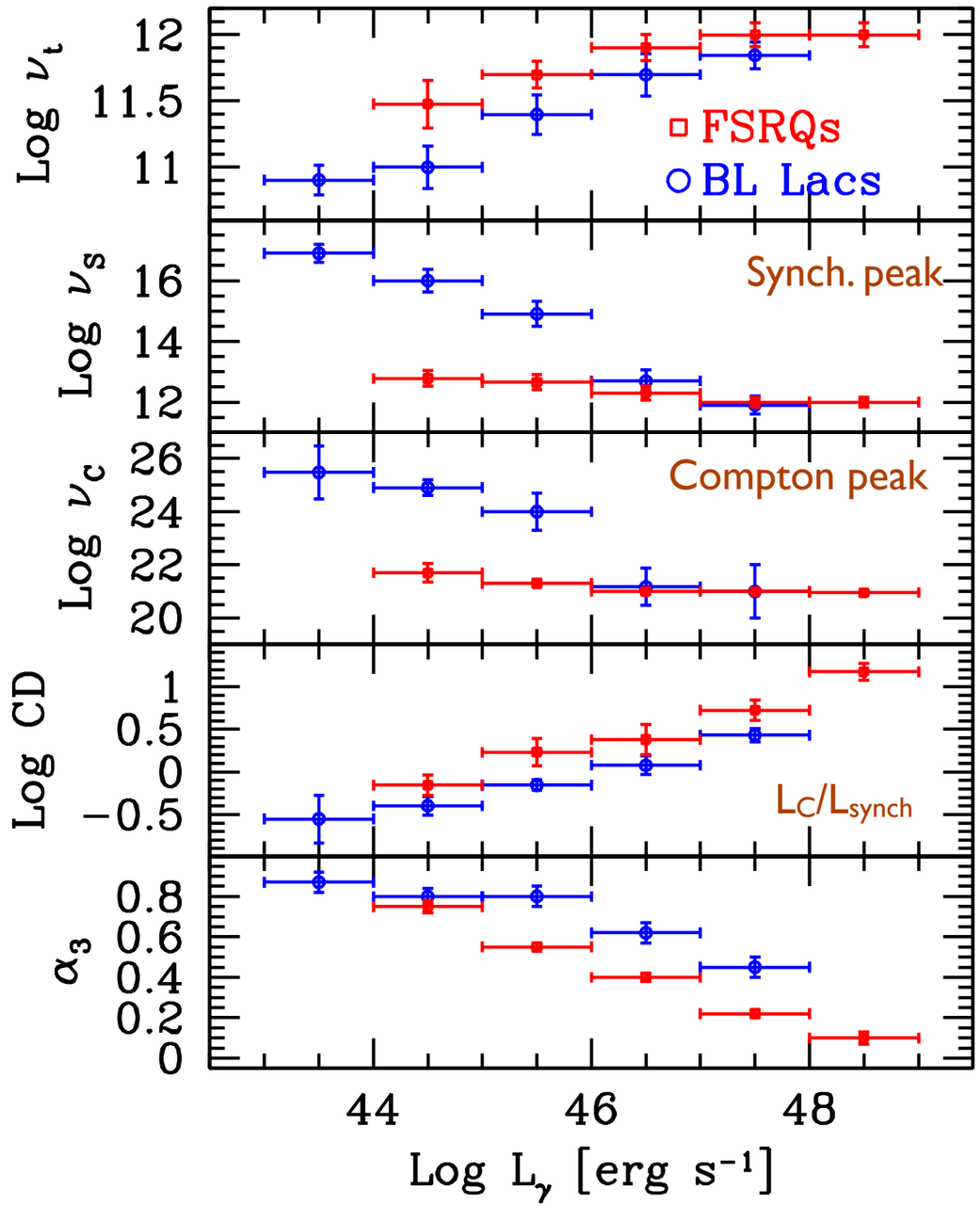
the gamma-ray view



Ghisellini, Righi, LC et al. 2017

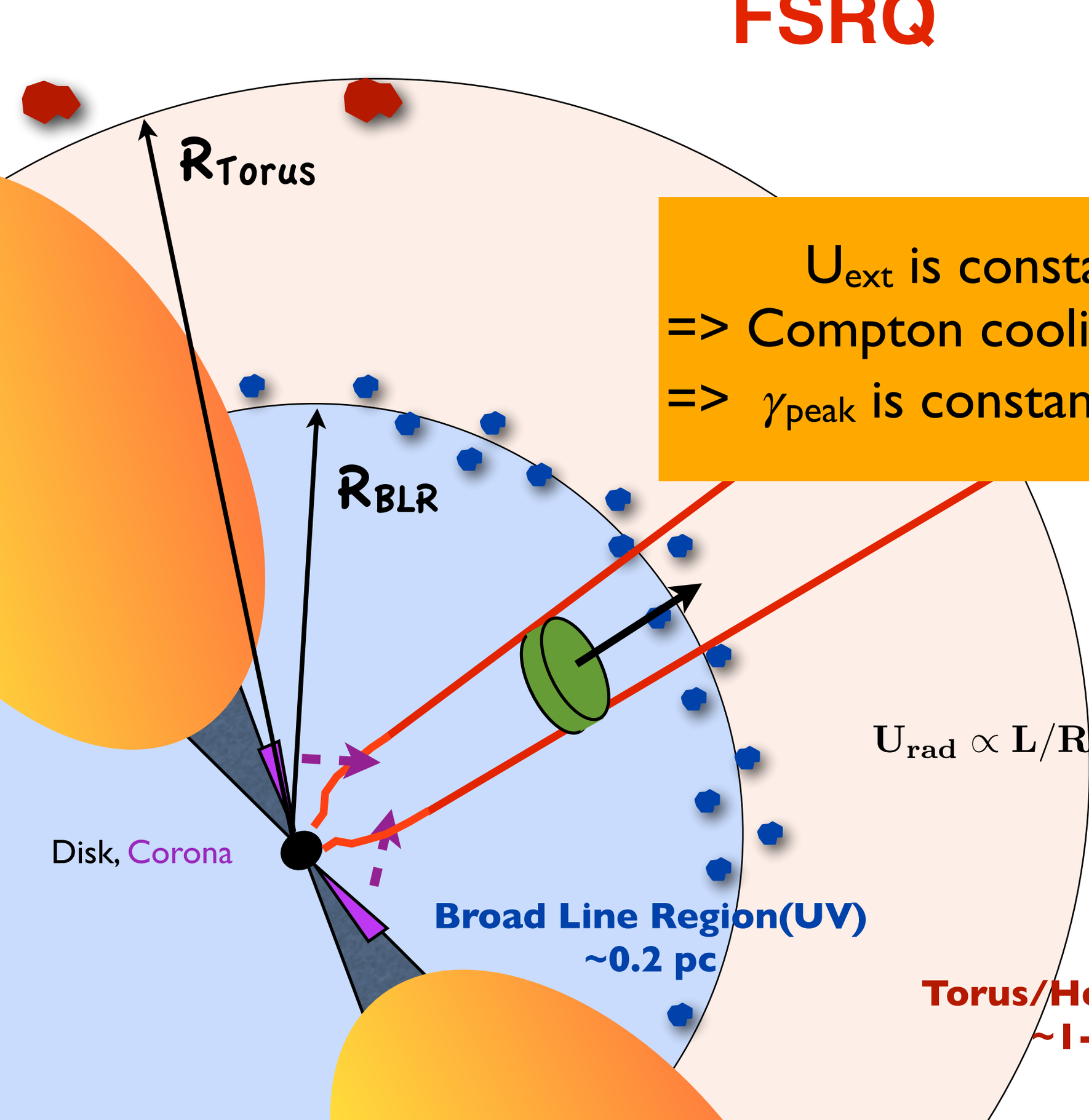
New aspects





Ghisellini, Righi, LC et al. 2017

FSRQ



U_{ext} is constant
=> Compton cooling is constant
=> γ_{peak} is constant

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

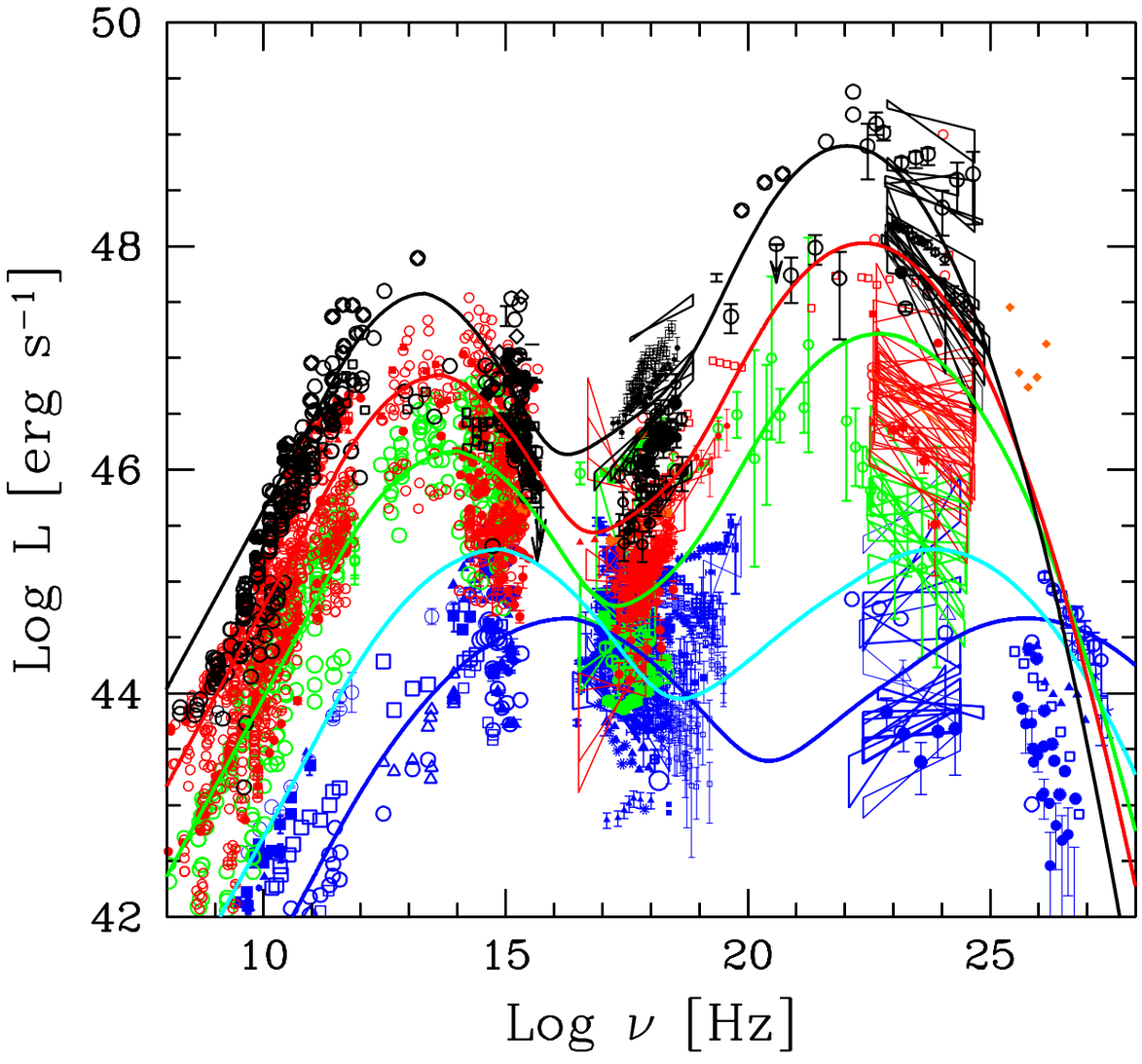
$$R_{HD} \simeq 2.5 \times L_{46}^{1/2}\ pc$$
(Cleary et al. 2007 ; Nenkova et al. 2008)

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

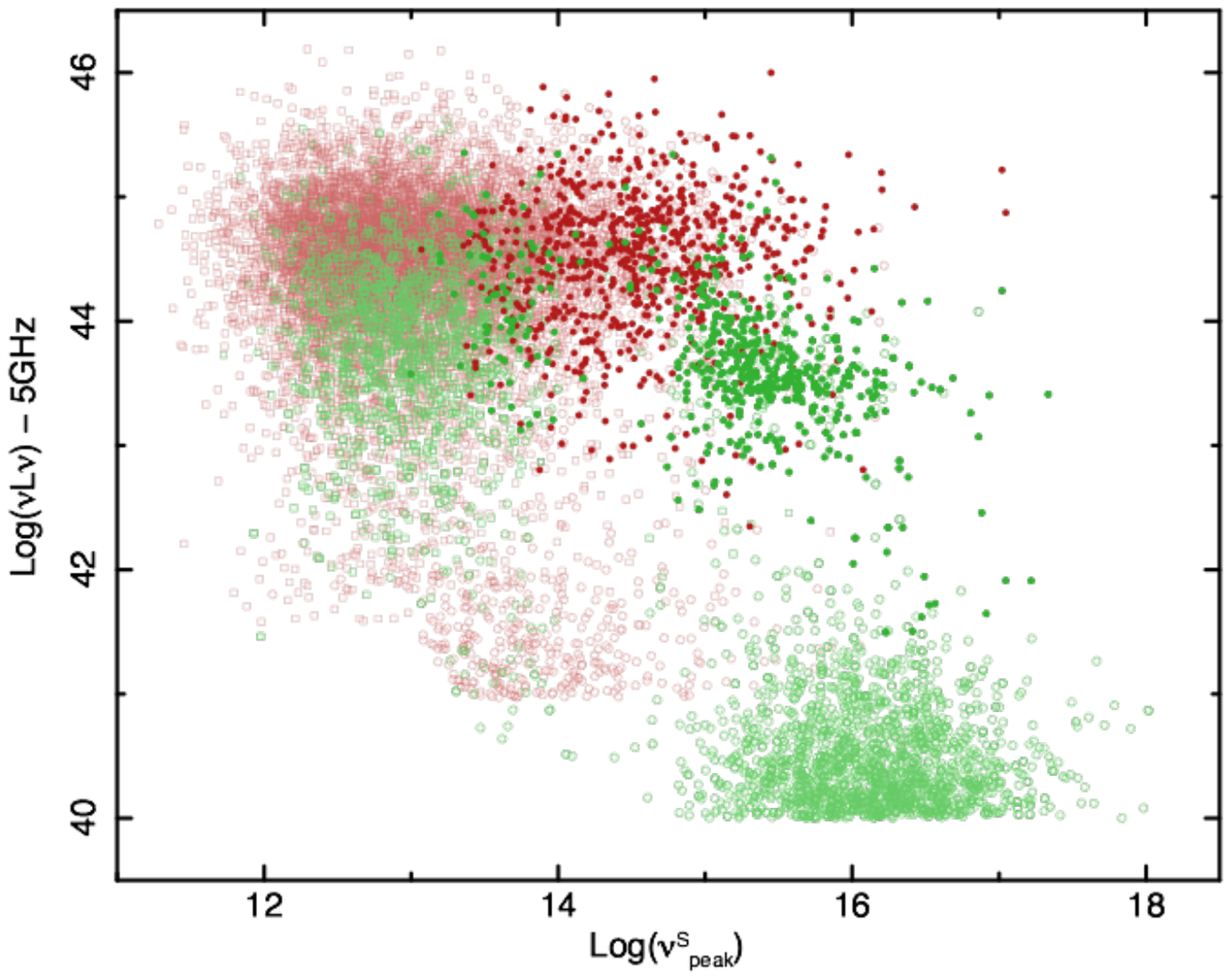
from Ghisellini, Turin 2018

Main problem:

Real or Selection bias ?



Fossati et al 1998
Donato et al 2002

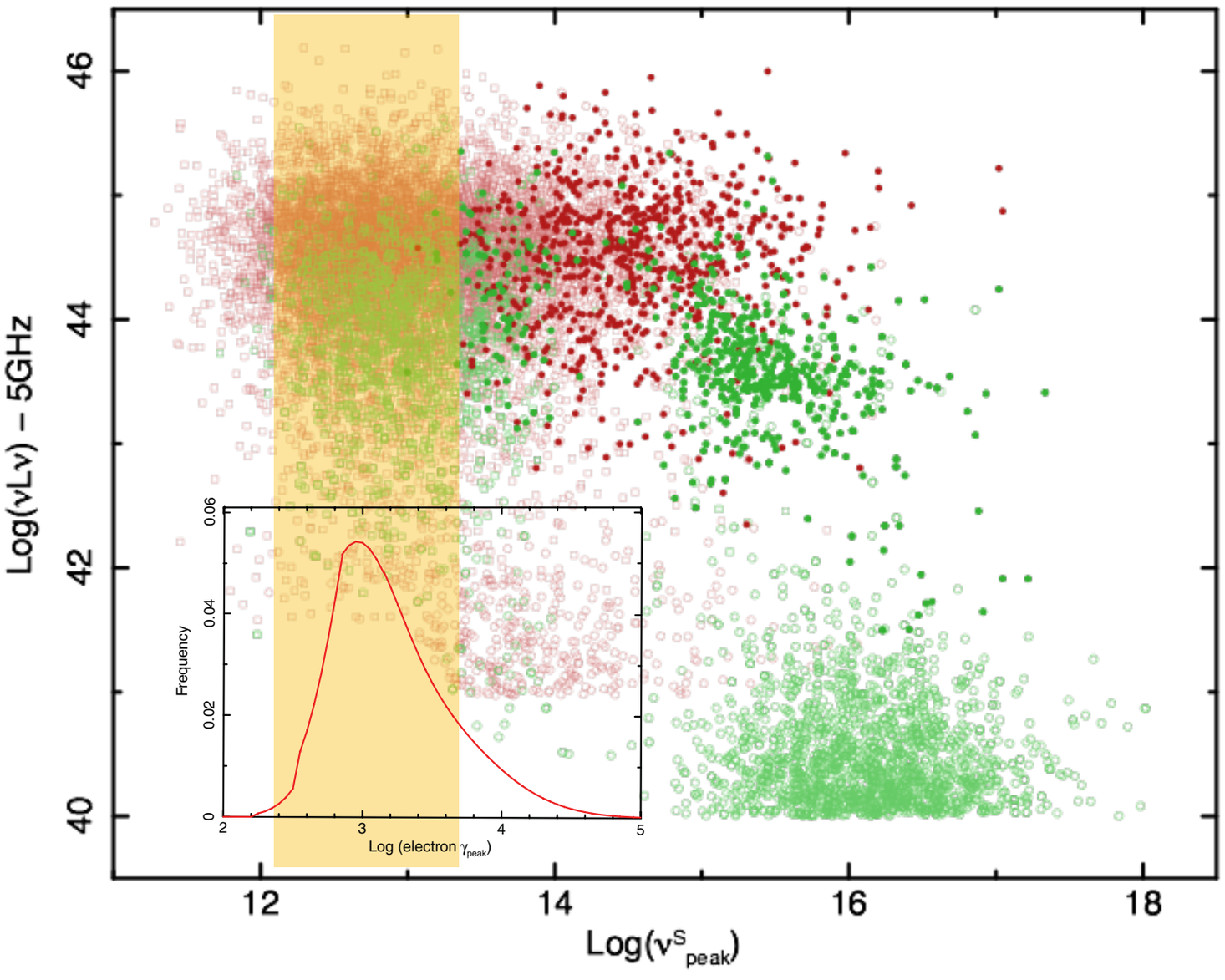


Simulations of observational biases

Giommi, Padovani et al. 2012

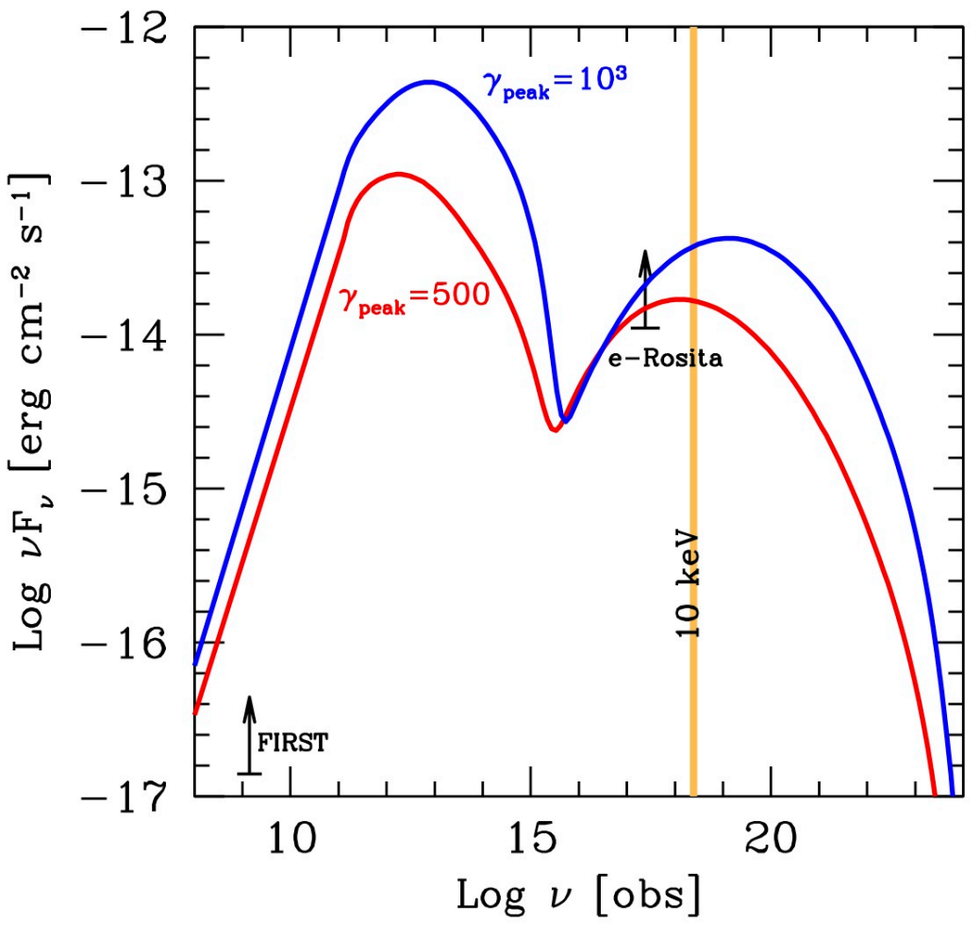
Blazar sequence: selection bias ?

Simulations of observational biases



Giommi, Padovani et al. 2012

There should be lots of low-peak, gamma-quiet BL Lacs



Ghisellini et al. 2017

However… recent developments/surprises

A) Gamma-rays origin/location

B) Ultra-fast variability

C) During flares, sed FSRQ <—> HBL

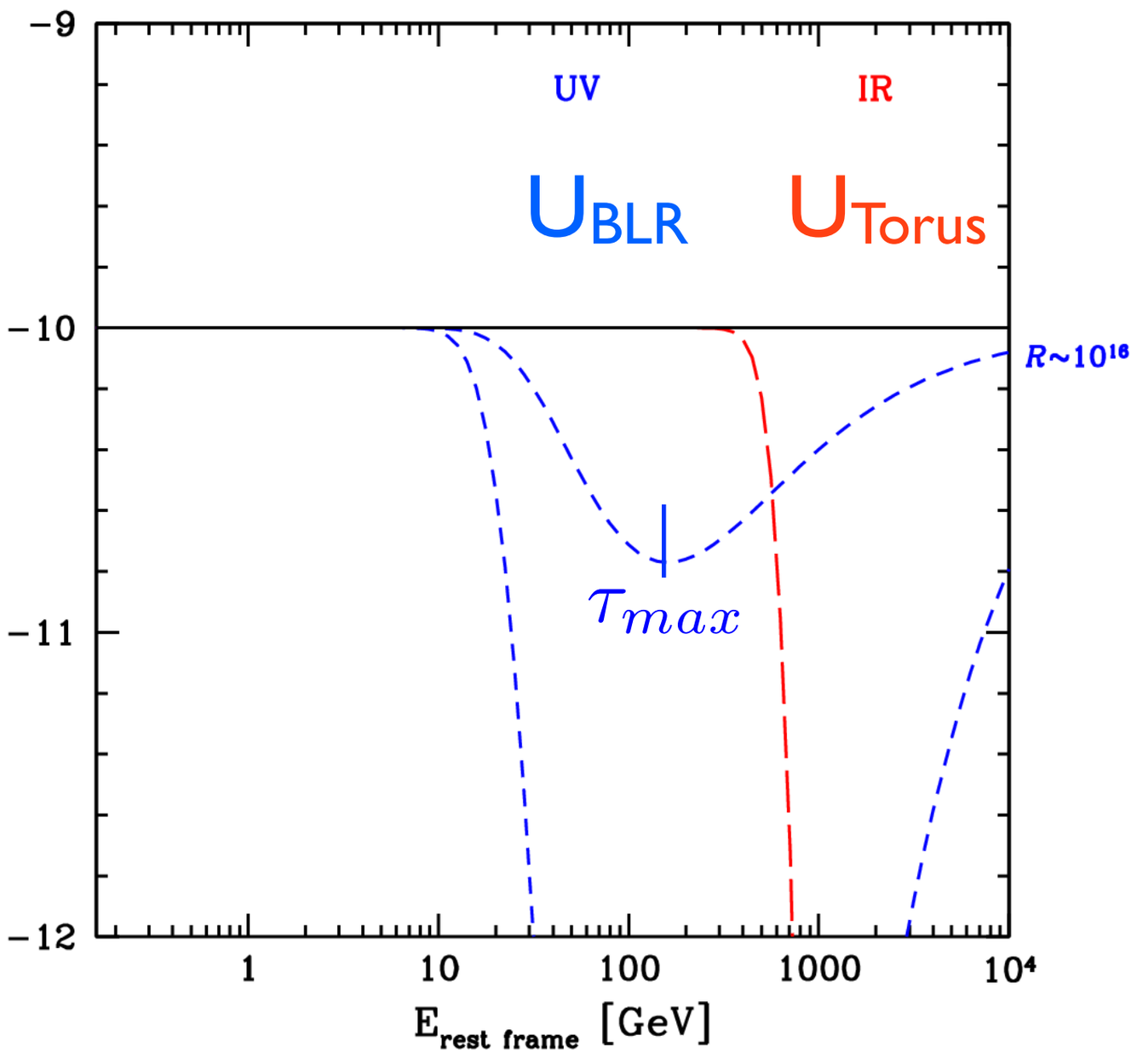
D) Extreme-TeV BL Lacs

E) Polarization (X-ray vs Opt)

F) Neutrinos

Same BLR photons for EC => optical depths >>1

$$\gamma\gamma \rightarrow e^+e^- \qquad x_1 x_2 \geq \frac{2}{1-\cos\theta} \qquad x \equiv h\nu/m_e c^2$$

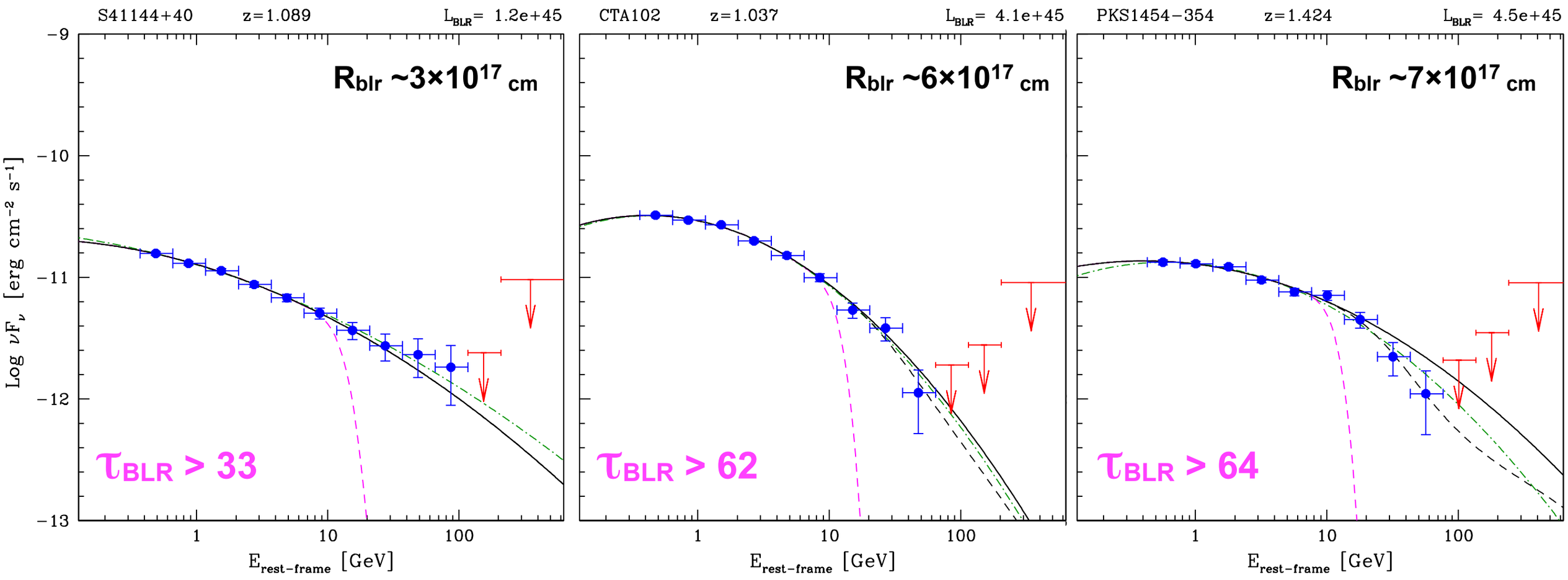


e.g. on BlackBody target field (good approximation to BLR attenuation)

Expected in FSRQ: no VHE detections, cutoff ~10-20 GeV

Test on the 100 brightest FSRQ in Fermi + 6 large BLR, 7.3 years of data

NO evidence of BLR cut-offs !

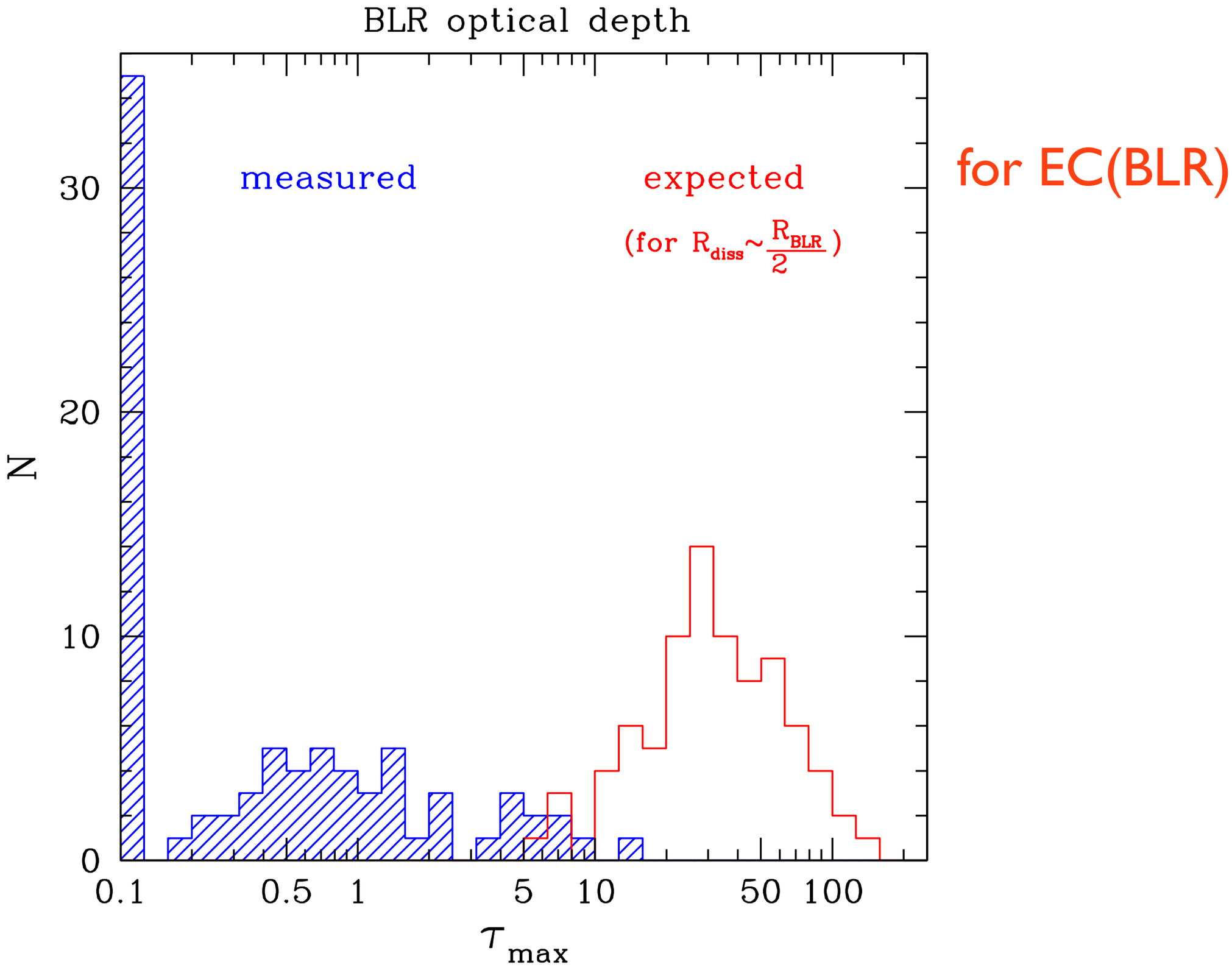


LC et al. 2018

2/3 of the sample: $\tau_{max} < 1$

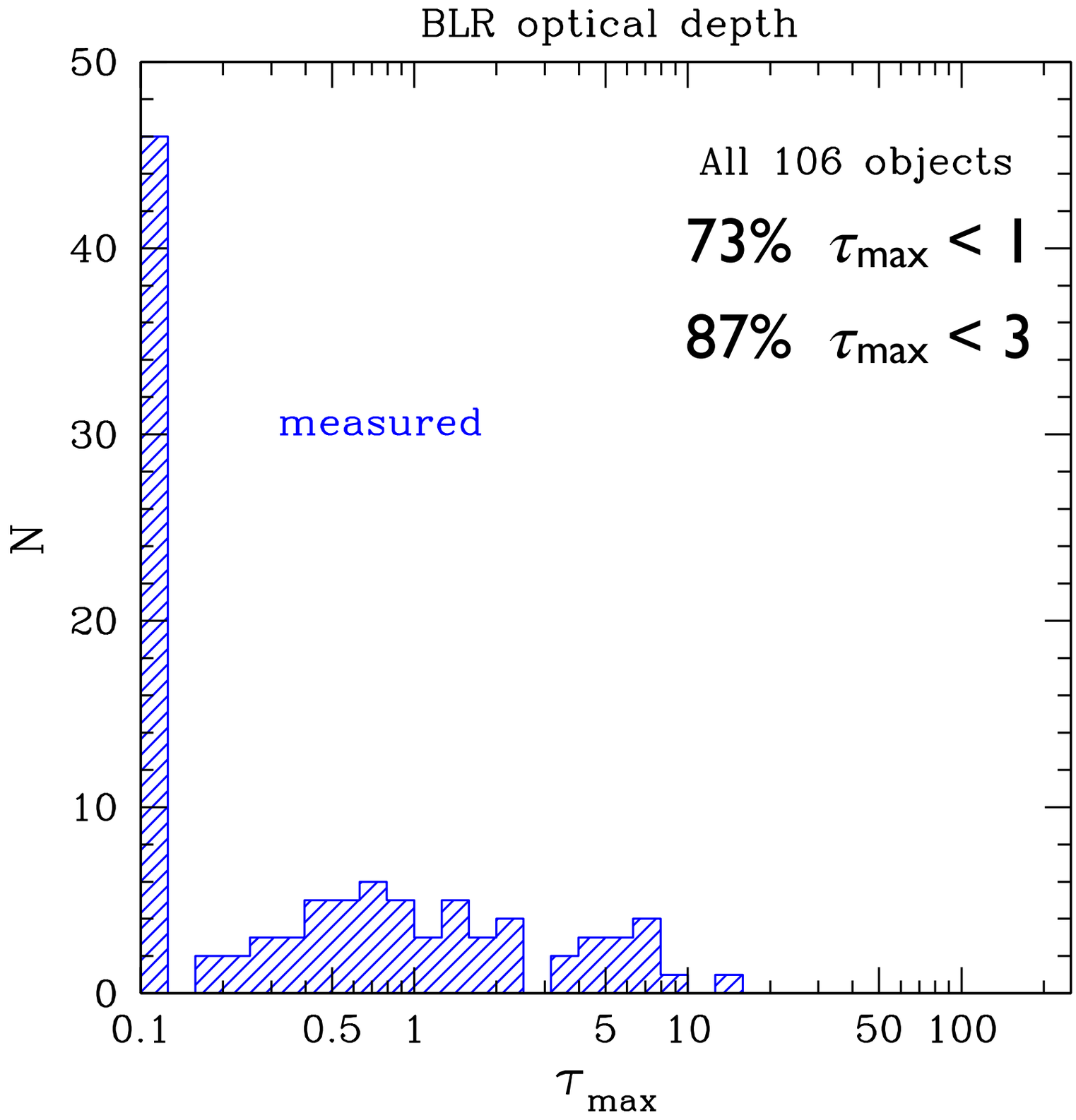
9/10 objects: $\tau_{max} < 3$

Only 1 out of 10 FSRQ compatible with significant BLR absorption



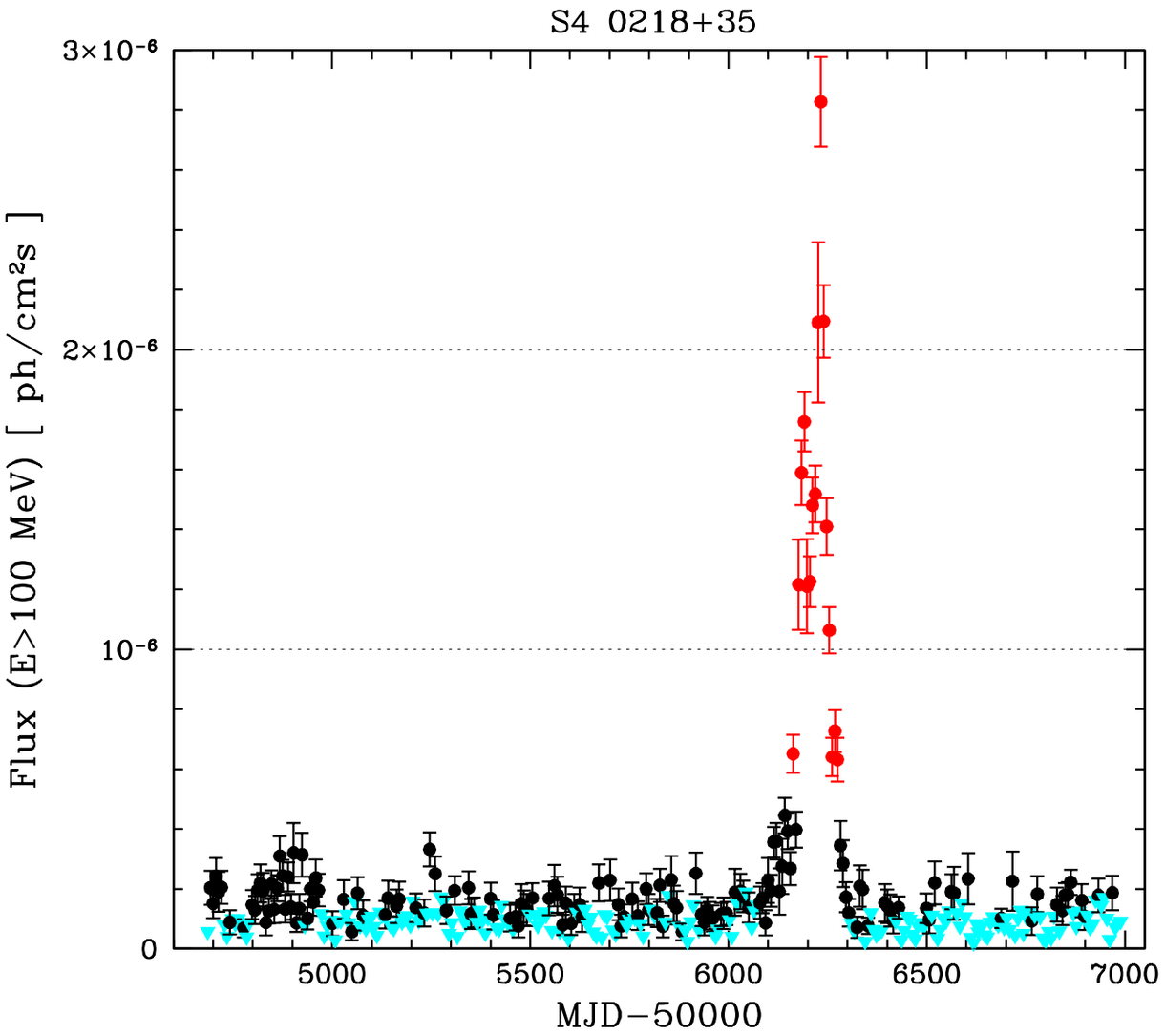
for EC(BLR)

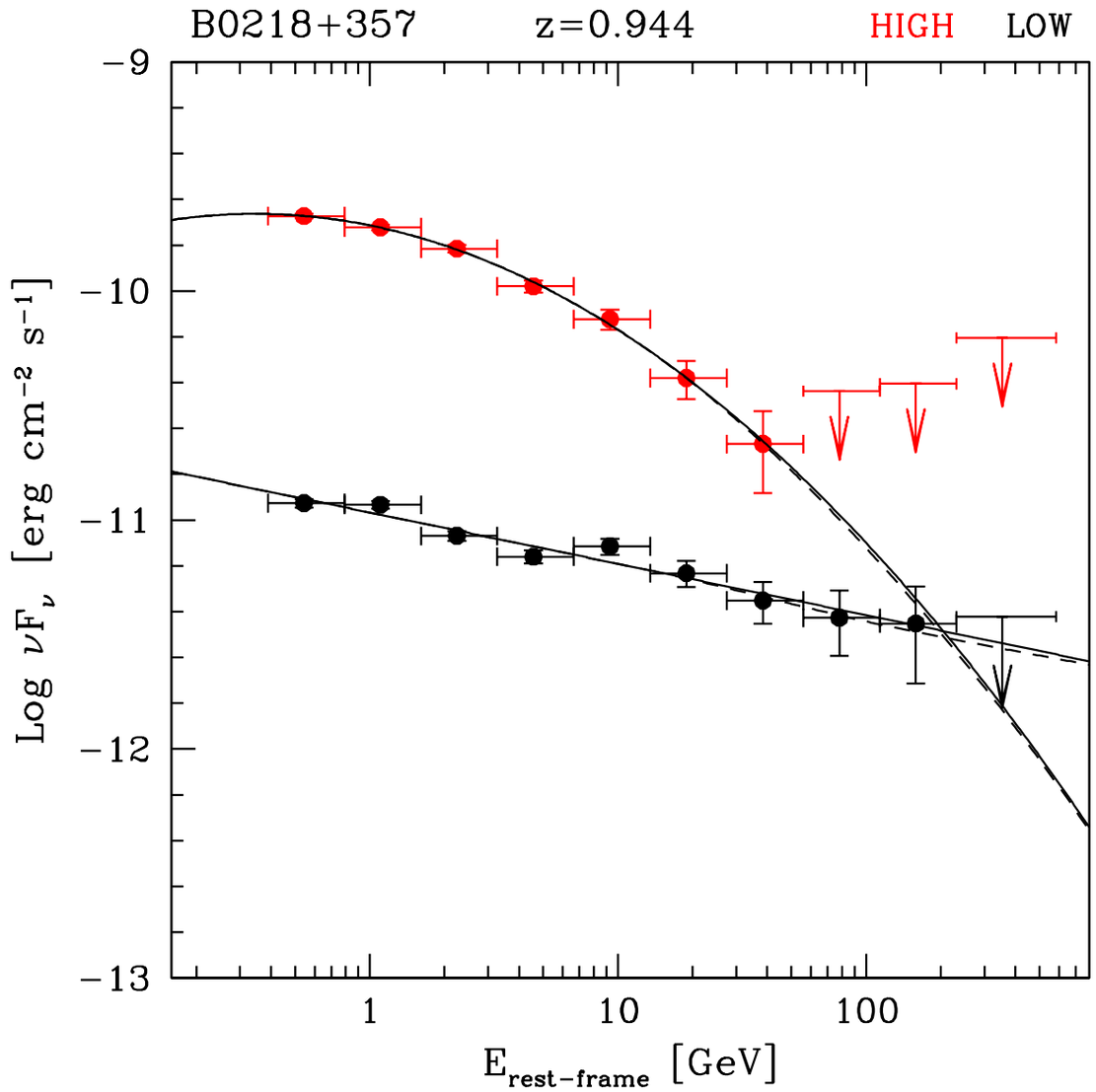
Sample 83 objects with L_{BLR} estimate



Total Sample of 106 objects

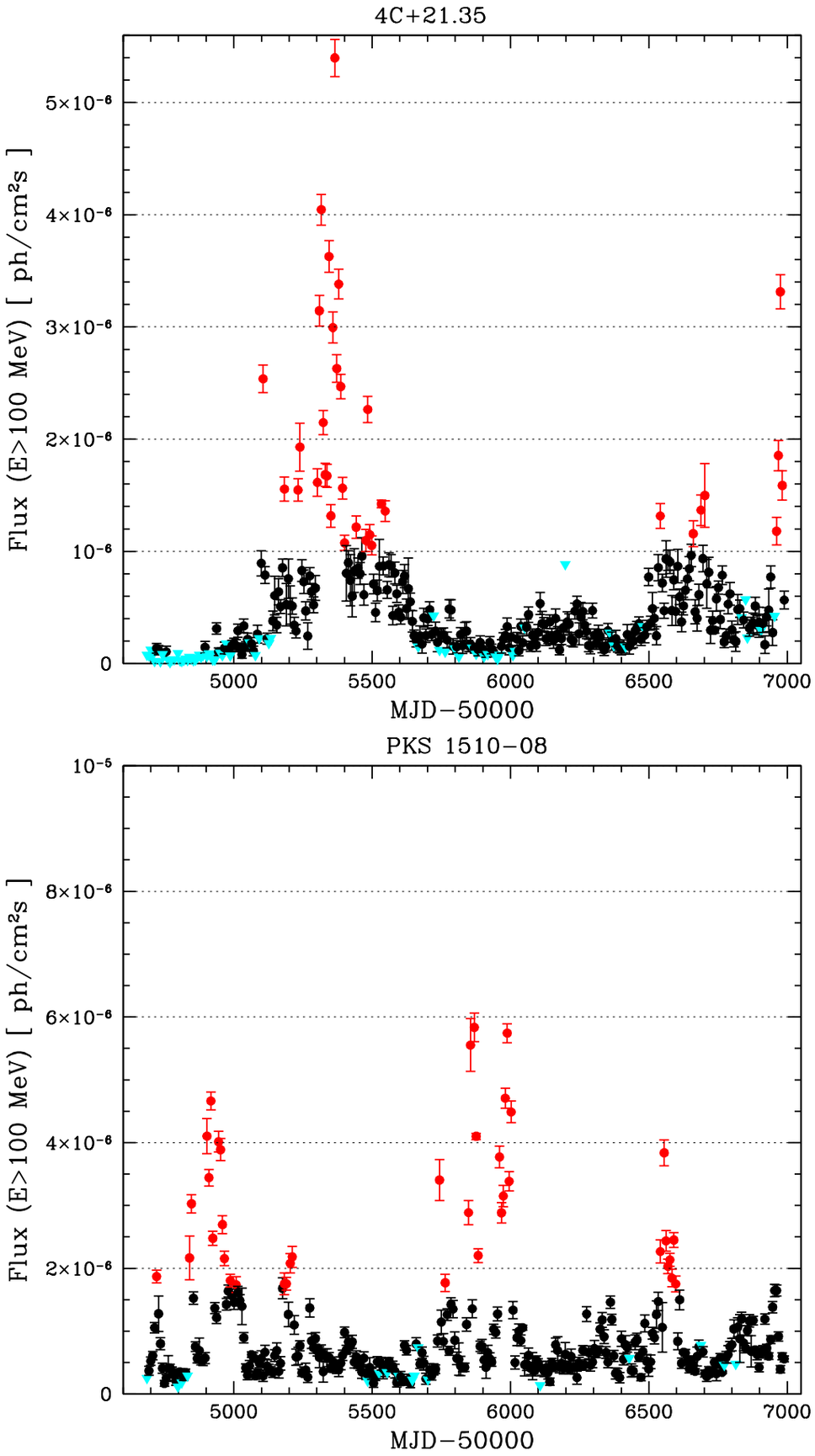
For the brightest 20: difference High/Low state ?

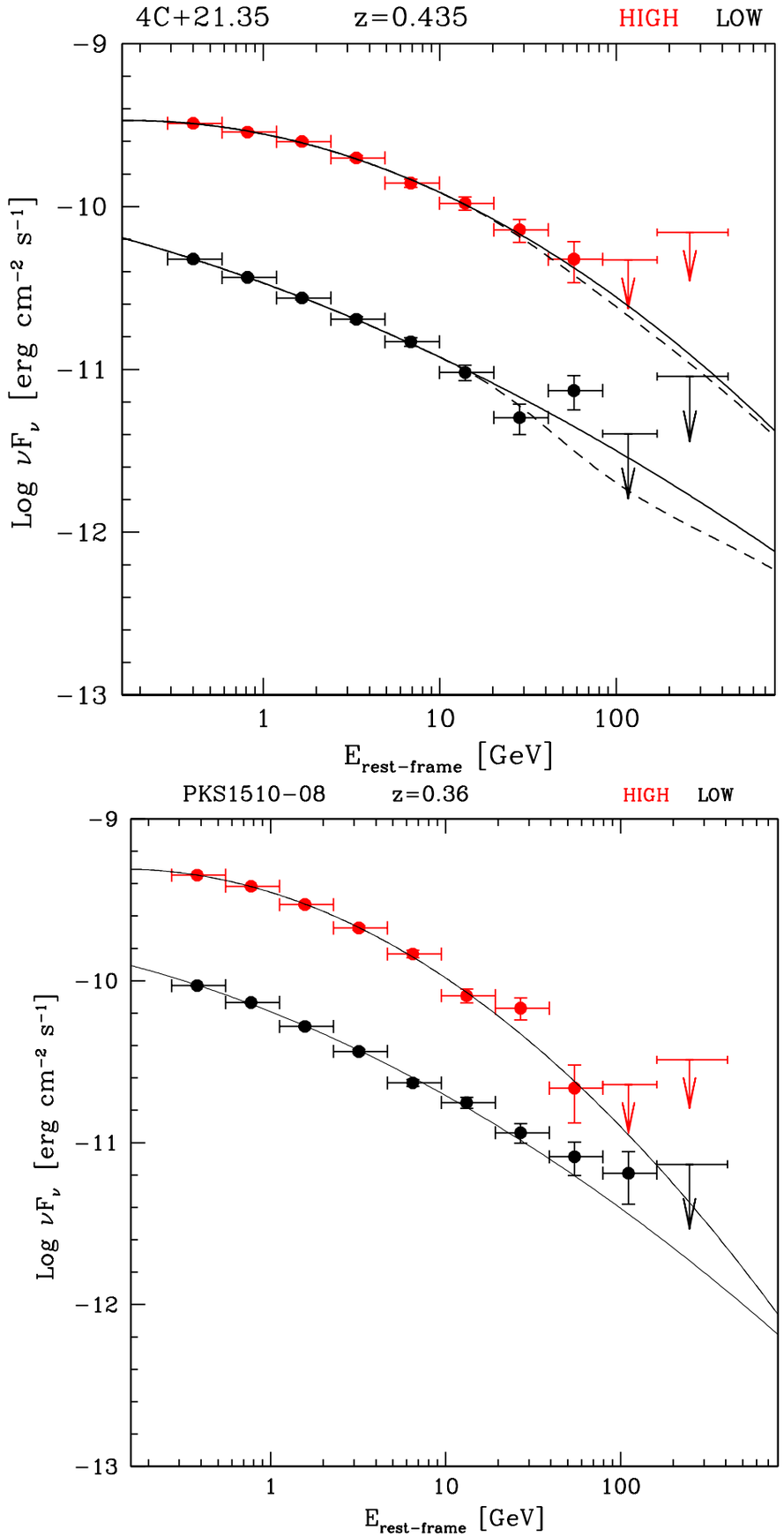




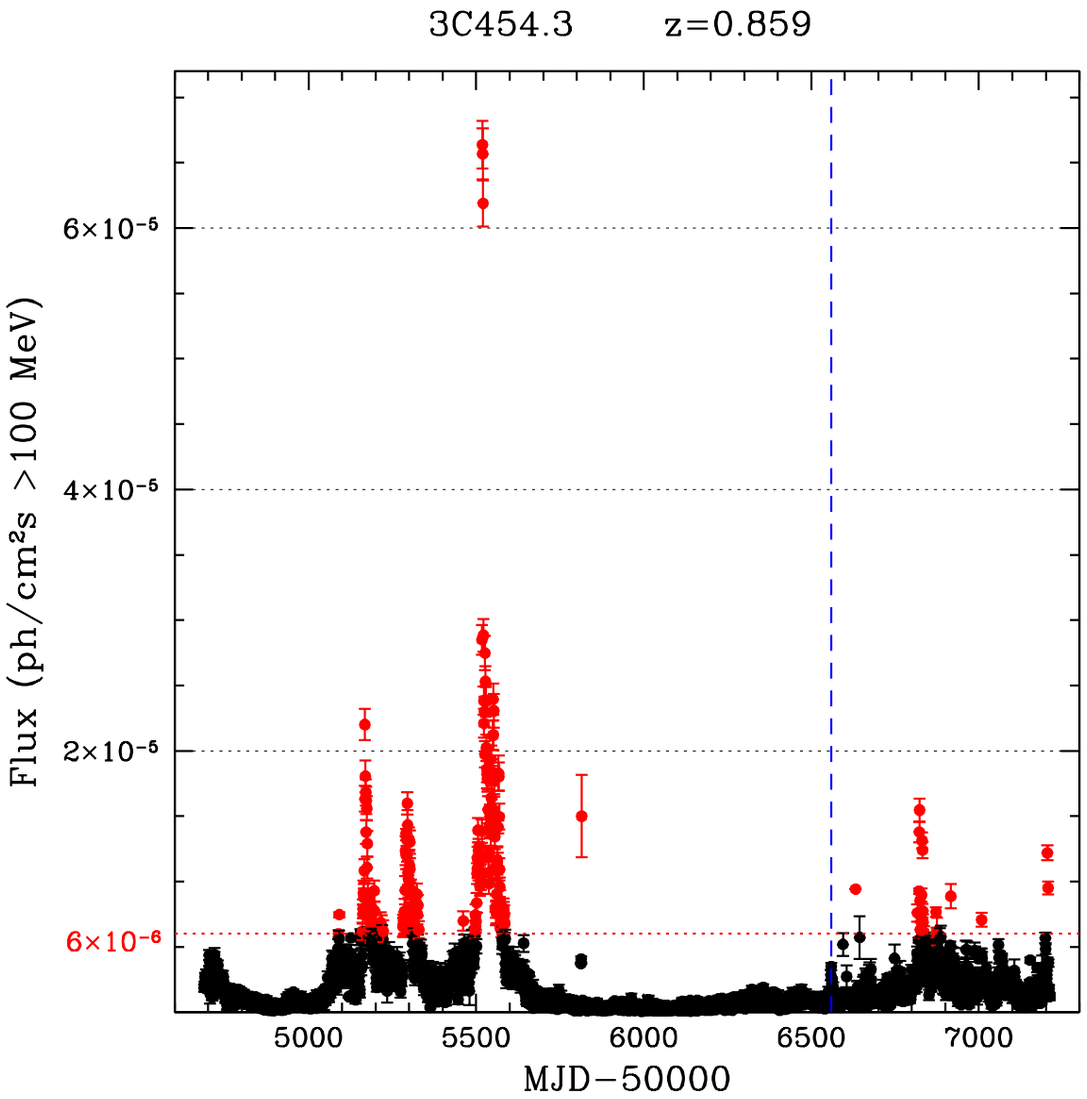
No evidence of strong interaction with BLR photons

VHE-detected FSRQs: no absorption also in Low state

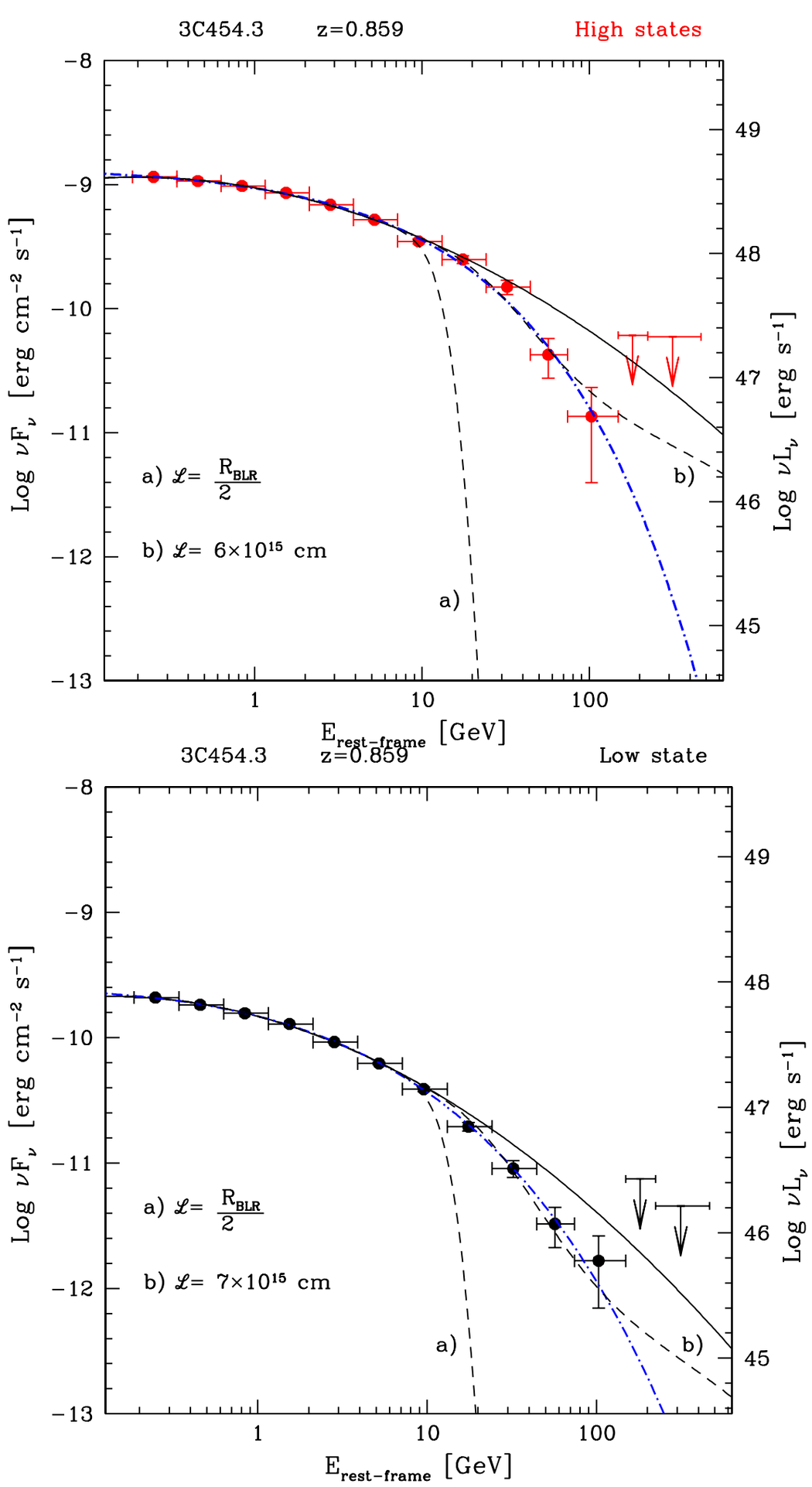




Even 3C 454.3 !



Better fitted with intrinsic electron cutoff !



Consequences

1) EC(BLR) is disfavoured in FSRQ *(EC-IR or SSC or EC-ambient)*

2) Gamma-ray spectrum is mostly intrinsic (particle distribution)
⇒ *new diagnostic possibilities* *(e.g. Lefa et al 2014)*

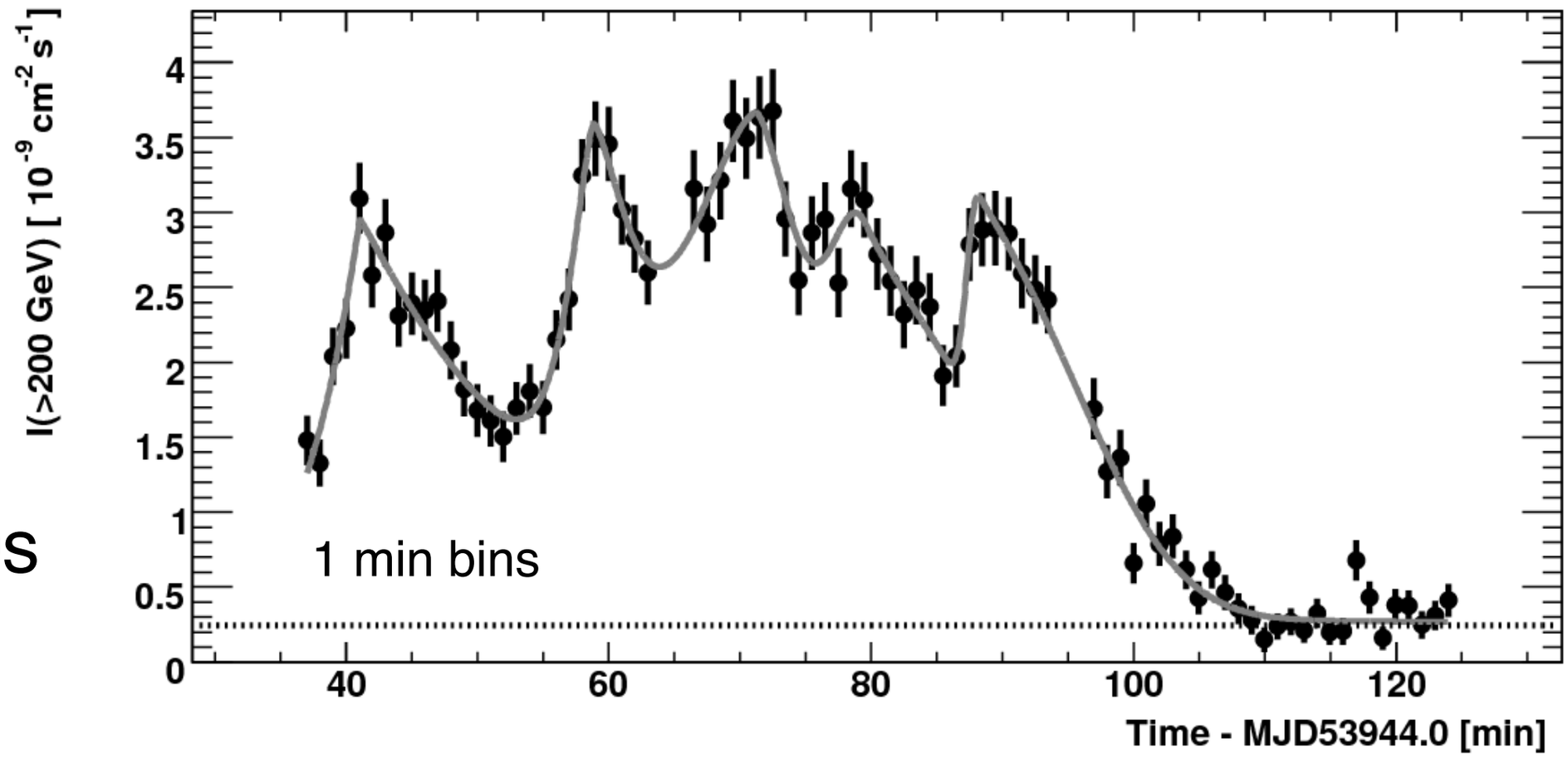
3) Without BLR suppression, FSRQs can be luminous at VHE
(indeed now already 12 detected)

SED Gamma-ray Bump produced far away from BH ?

B) Ultra-fast Variability ($t \lesssim \tau_0 = R_s/c$)

HBL

PKS 2155-304 in July 2006



10^{47} erg/s

t≈200s

1 Crab

$R \sim 5 \times 10^{12}\, \delta$ cm $\approx 0.01\, \delta\, R_S$

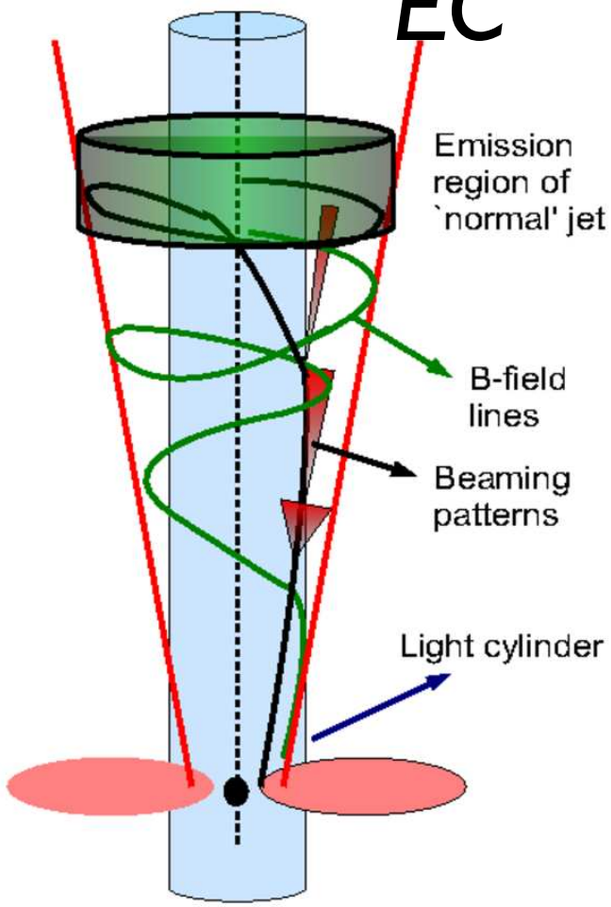
$\Gamma \geq 50\text{-}100$ for $R \sim R_S$

Aharonian et al. (HESS coll) 2007

But… if perturbations propagate from BH, stationary in LAB frame…
=> emitter size either $R << r_g$ (external) or relativistic in jet frame

Possible explanations ?

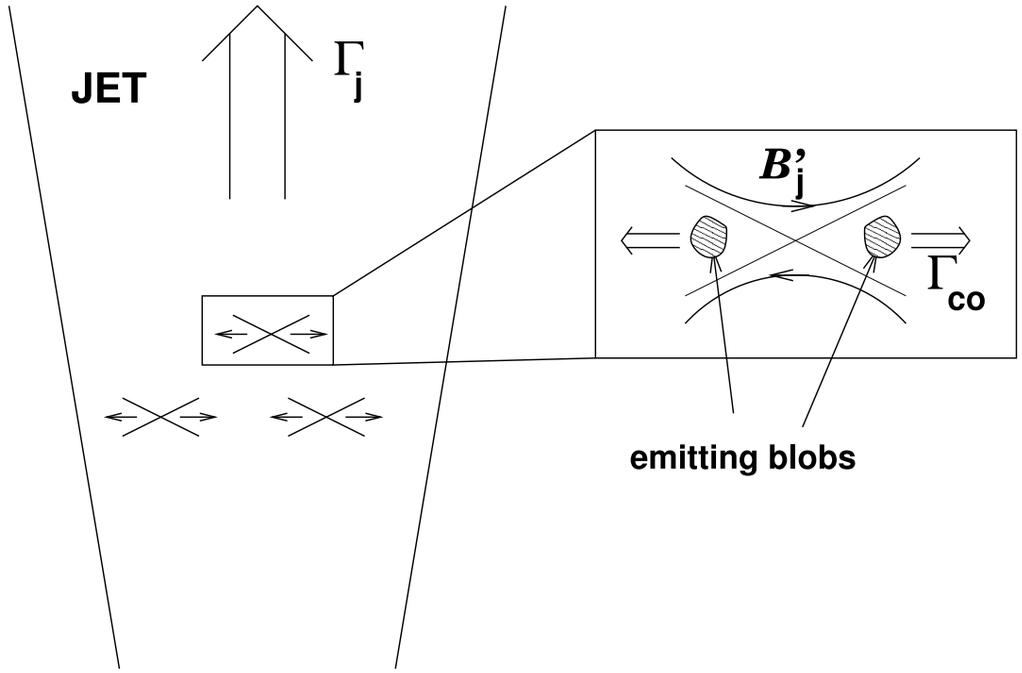
EC



Magneto-centrifugal accel ?

(Ghisellini & Tavecchio 2008; Ghisellini 2009)

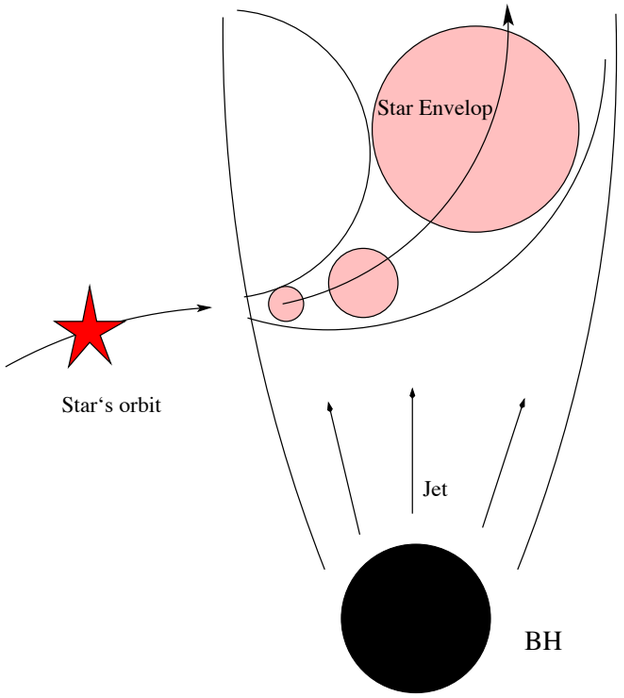
SSC



Jets-in-Jet ?

(Giannios et al 2009)

p-γ EC



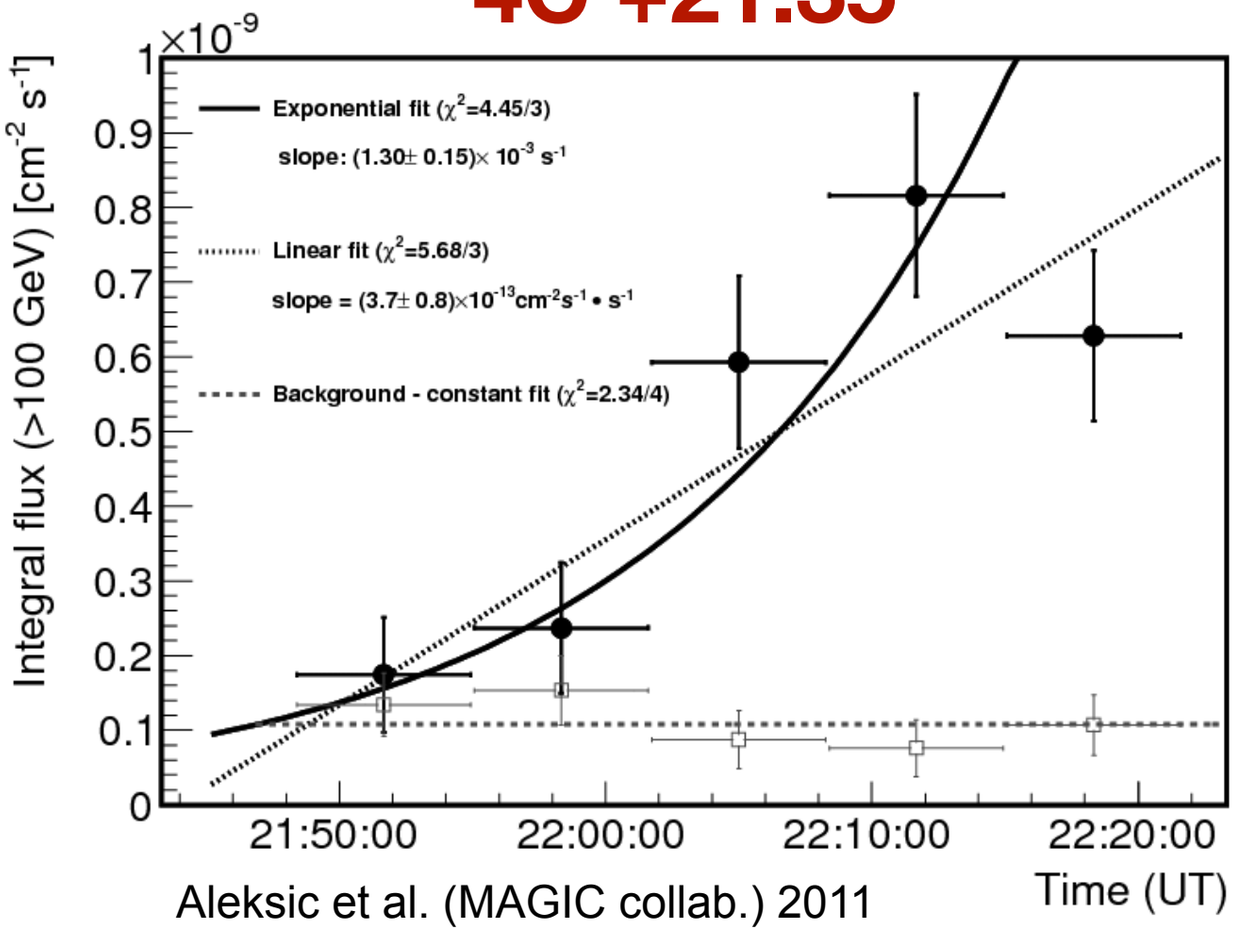
Jet-Star interaction ?

(Barkov et al. 2010, 2011)

See e.g. discussion in Aharonian et al. 2017

Also in FSRQs !

4C +21.35



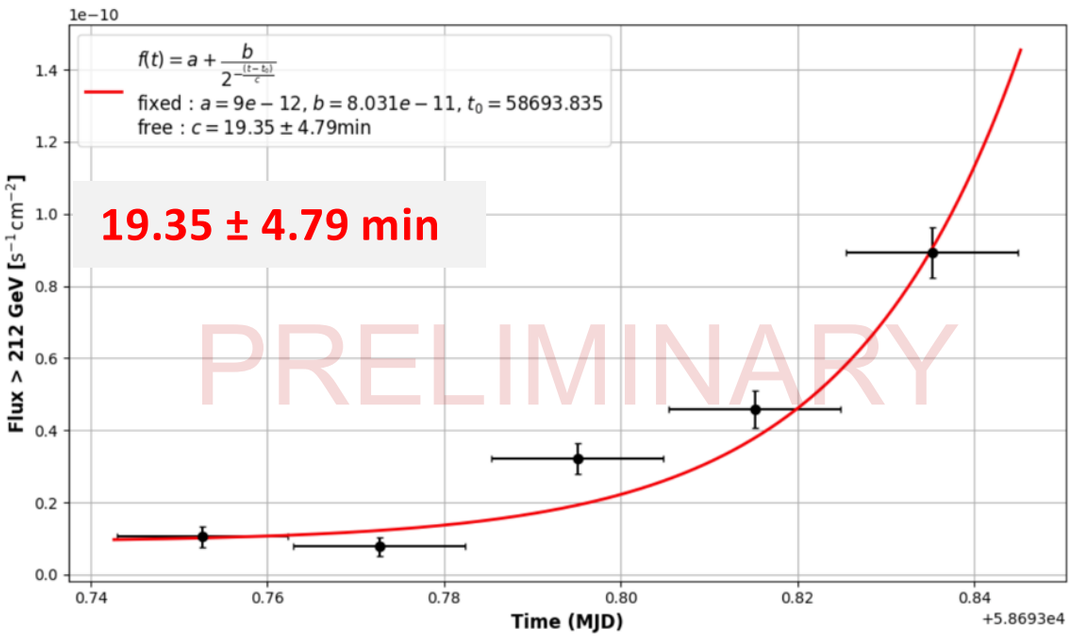
Aleksic et al. (MAGIC collab.) 2011

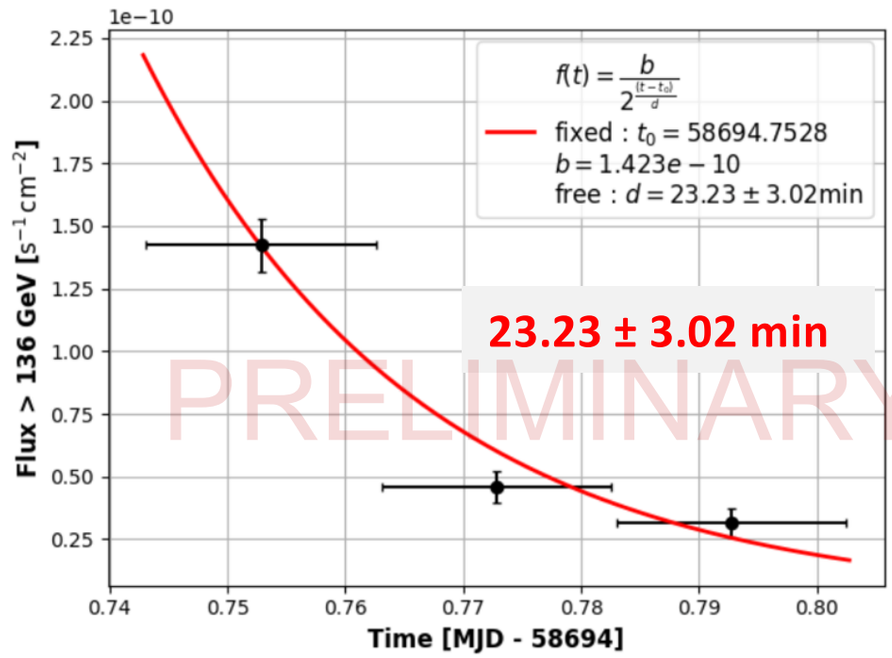
10-min variability !

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

at several pc from Black Hole

PKS 1510-089



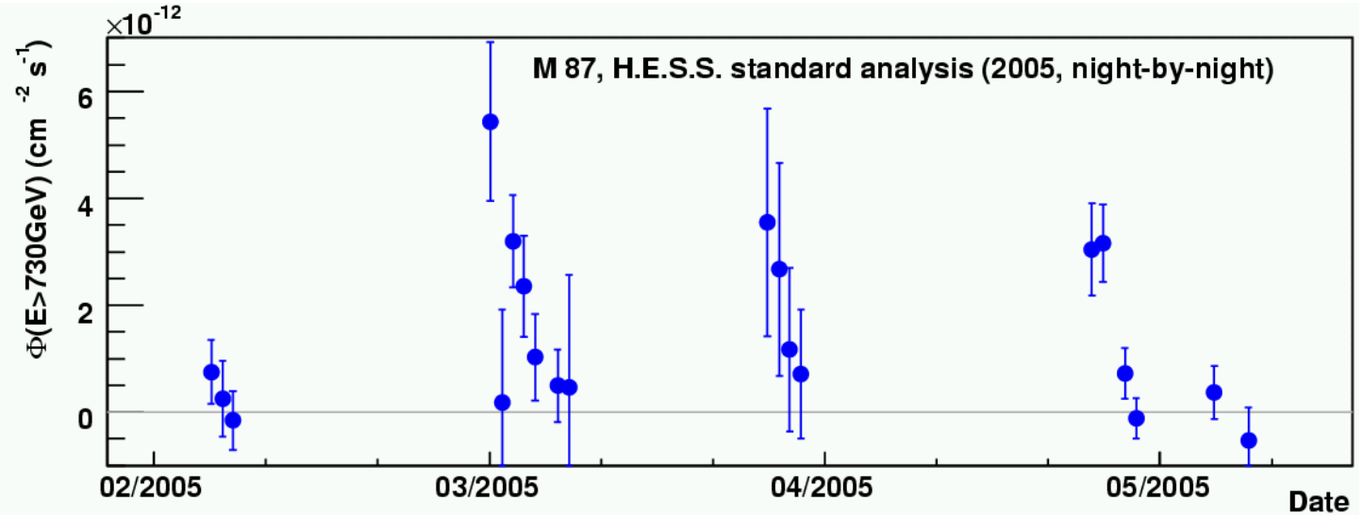


Pichard et al. (HESS Coll), Gamma26 conf

Radio Galaxies

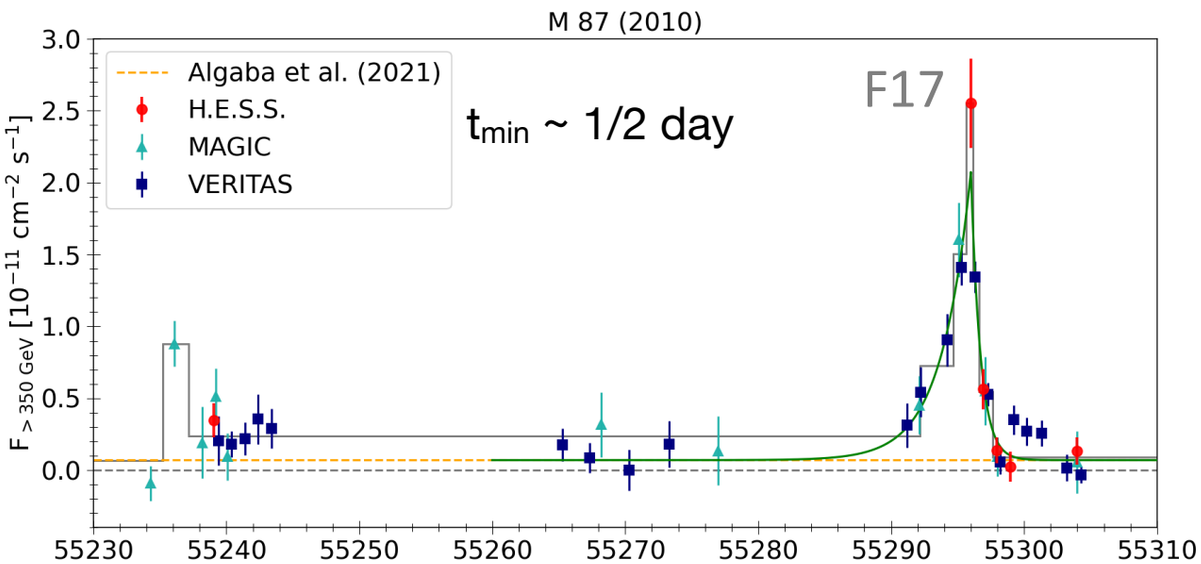
$$\tau_0 = r_g/c \approx 5 \times 10^2 M_8 \text{ s.}$$

M87



Aharonian et al. (HESS) 2007

$$t_{var} \sim 2 - 4\ \tau_0$$



Luashvili et al. (HESS), Gamma26

IC 310

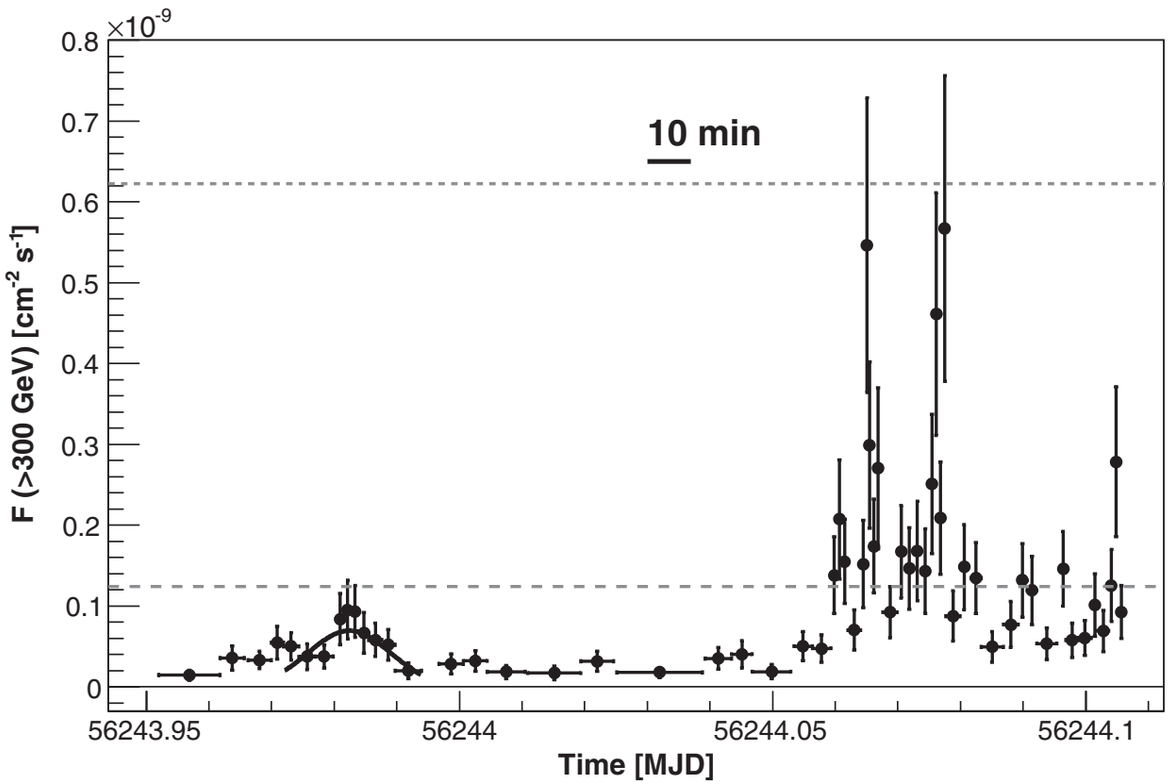
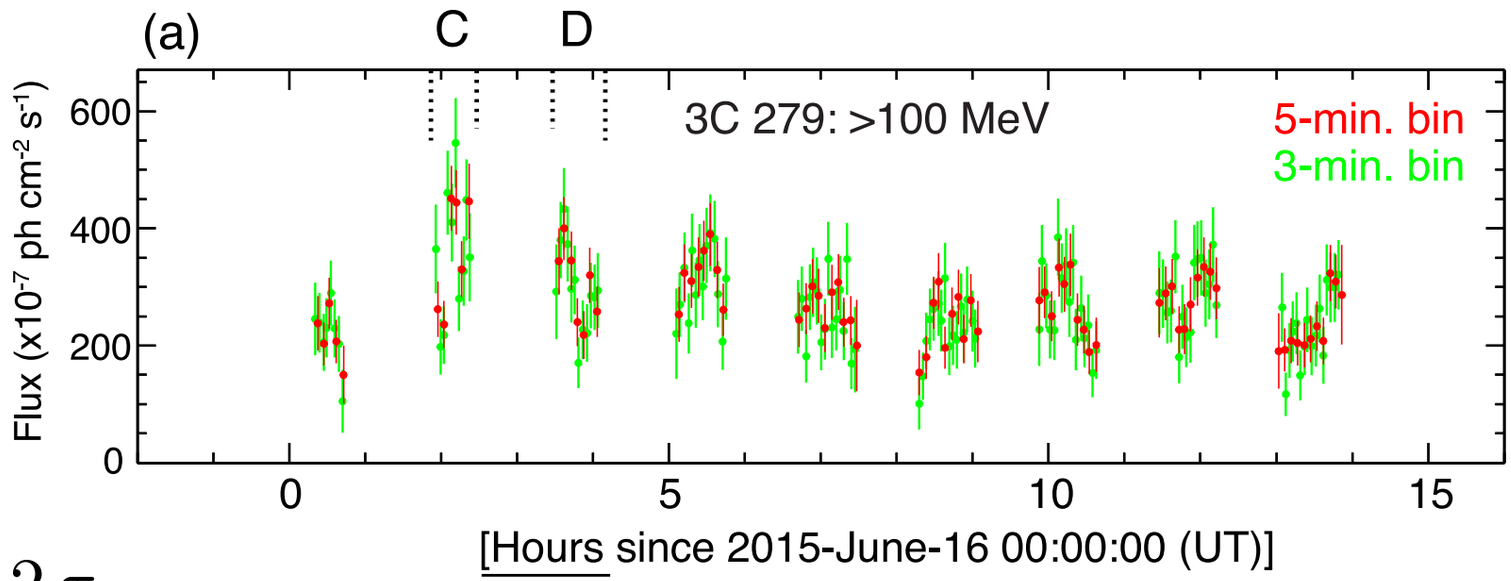


Fig. 4. Light curve of IC 310 observed with the MAGIC telescopes on the night of 12/13 November 2012, above 300 GeV. As a flux reference, the two gray lines indicate levels of 1 and 5 times the flux level of the Crab Nebula, respectively. The precursor flare (MJD 56243.972-56243.994) has been fitted with a Gaussian distribution. Vertical error bars show 1 SD statistical uncertainity. Horizontal error bars show the bin widths.

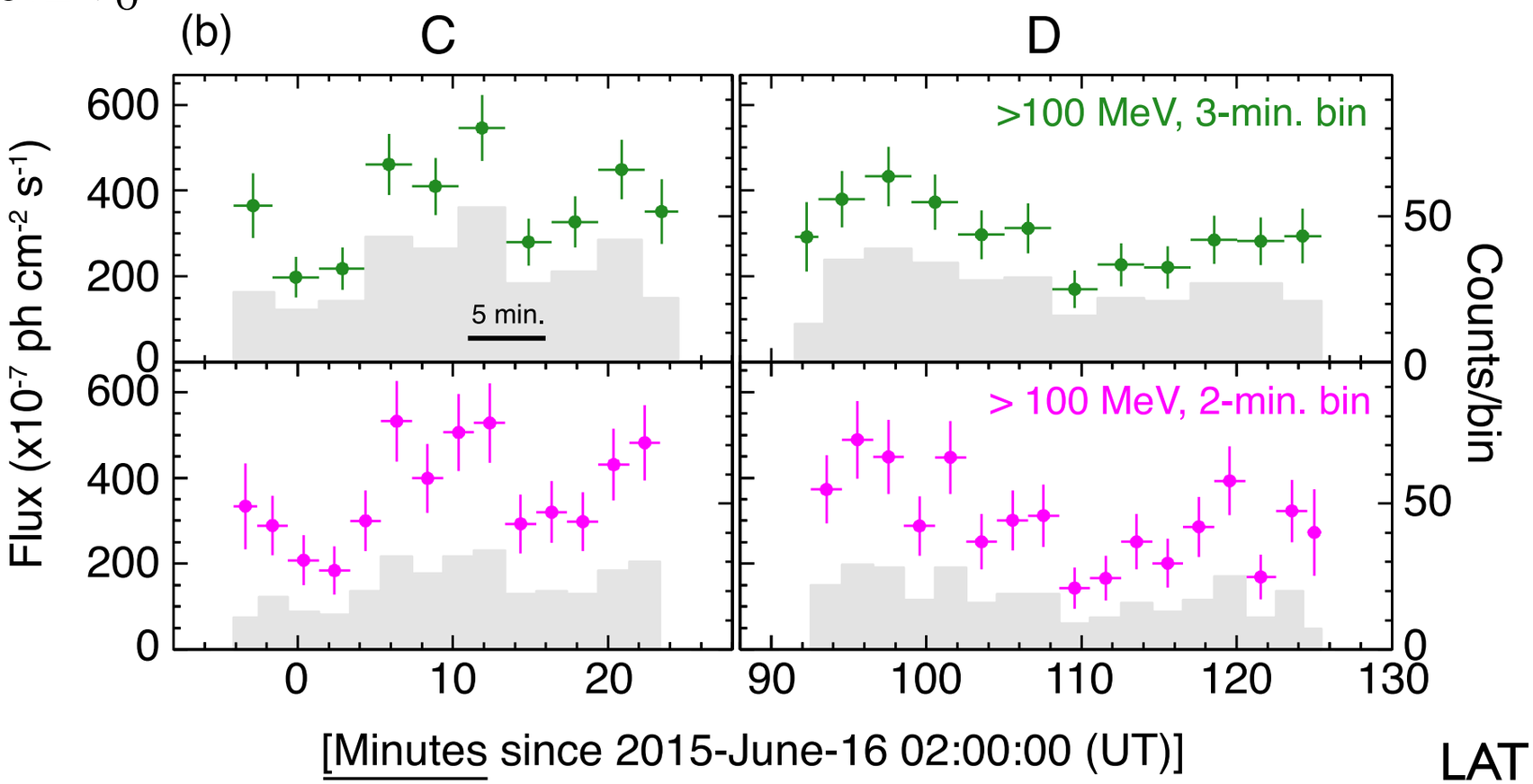
Aleksic et al. (MAGIC) 2014

$$t_{var} \sim 0.2 - 0.5\ \tau_0$$

…even at GeV: 3C 279 huge flare in 2015



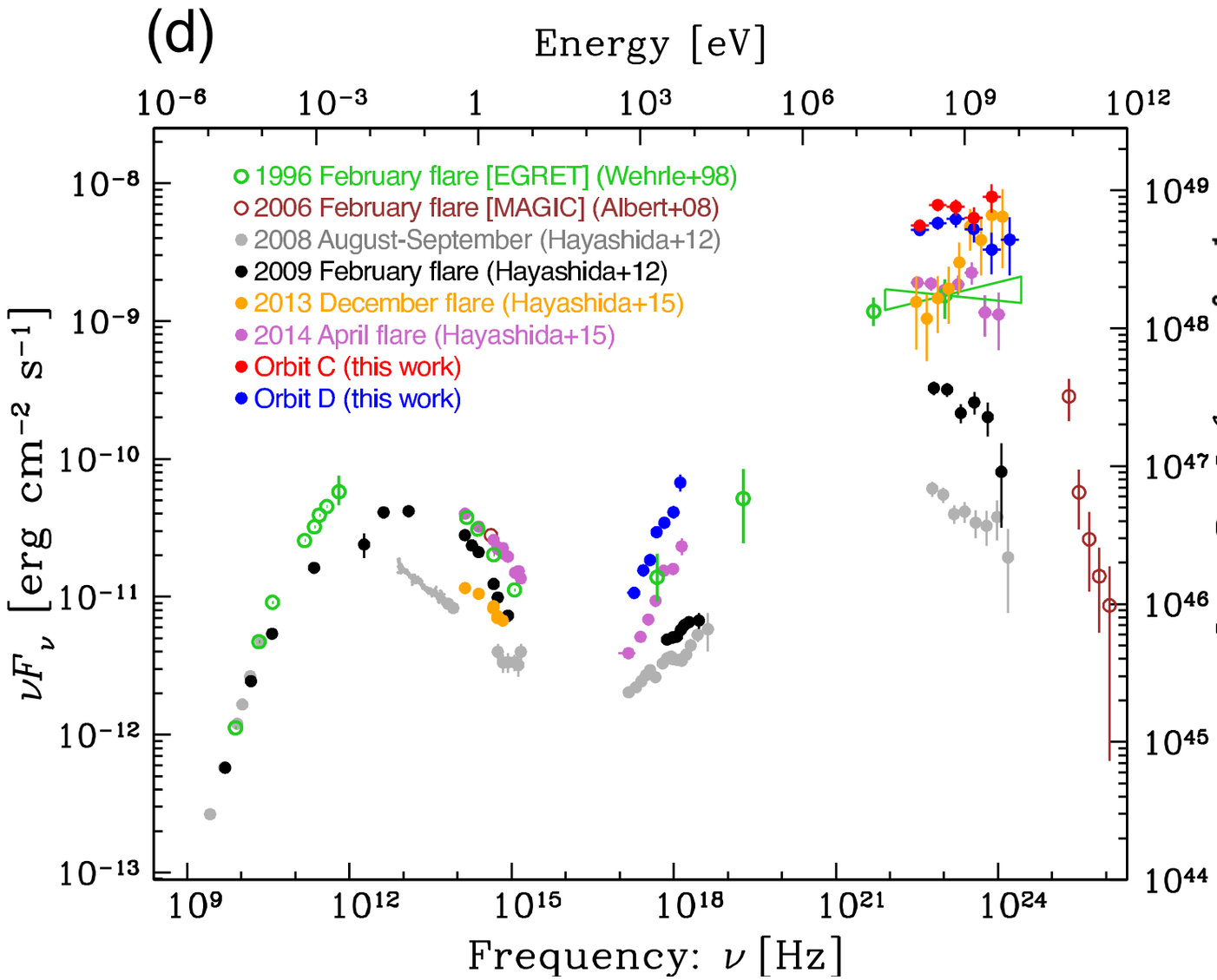
$t_{var} \sim 0.1 - 0.2\,\tau_0$



LAT Coll. 2016

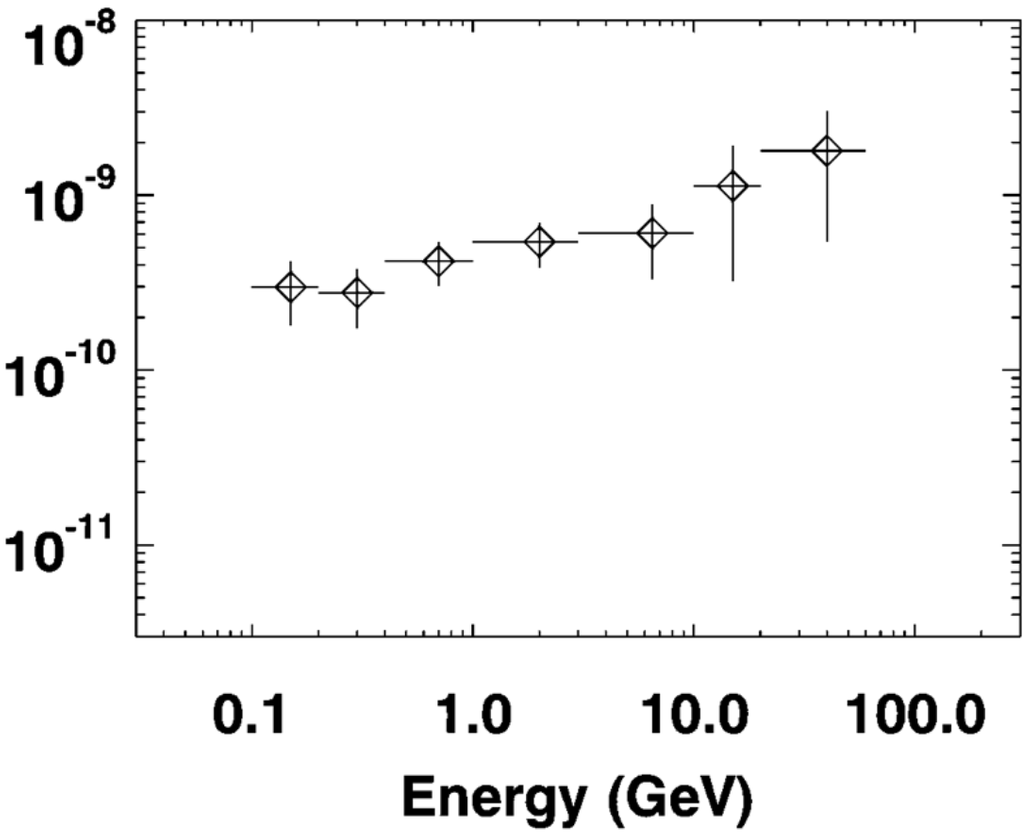
C) also FSRQ can have HBL-like gamma-ray spectra
also HBL can have high Compton Dominance

3C 279



LAT Collab. 2016

3C 454.3



Pacciani et al 2013

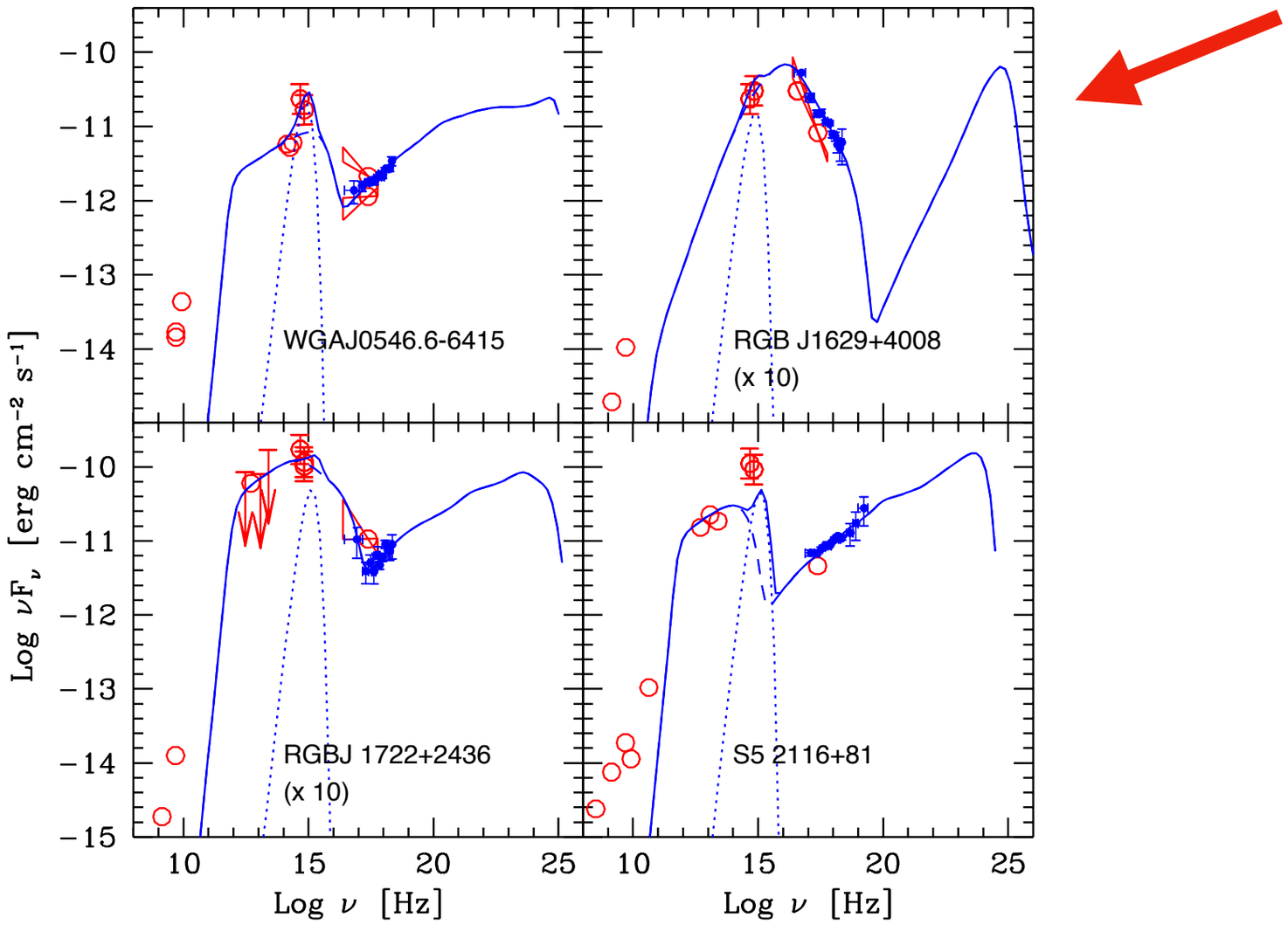
BeppoSAX OBSERVATIONS OF SYNCHROTRON X–RAY EMISSION FROM RADIO QUASARS

Paolo Padovani[1]
Space Telescope Science Institute, 3700 San Martin Drive, Baltimore MD 21218, USA
Luigi Costamante[2]
Università degli Studi di Milano, Milano, Italy
Gabriele Ghisellini
Osservatorio Astronomico di Brera, Via Bianchi 46, I-23807 Merate, Italy
Paolo Giommi
ASI Science Data Center, c/o ESRIN, Via G. Galilei, I-00044 Frascati, Italy

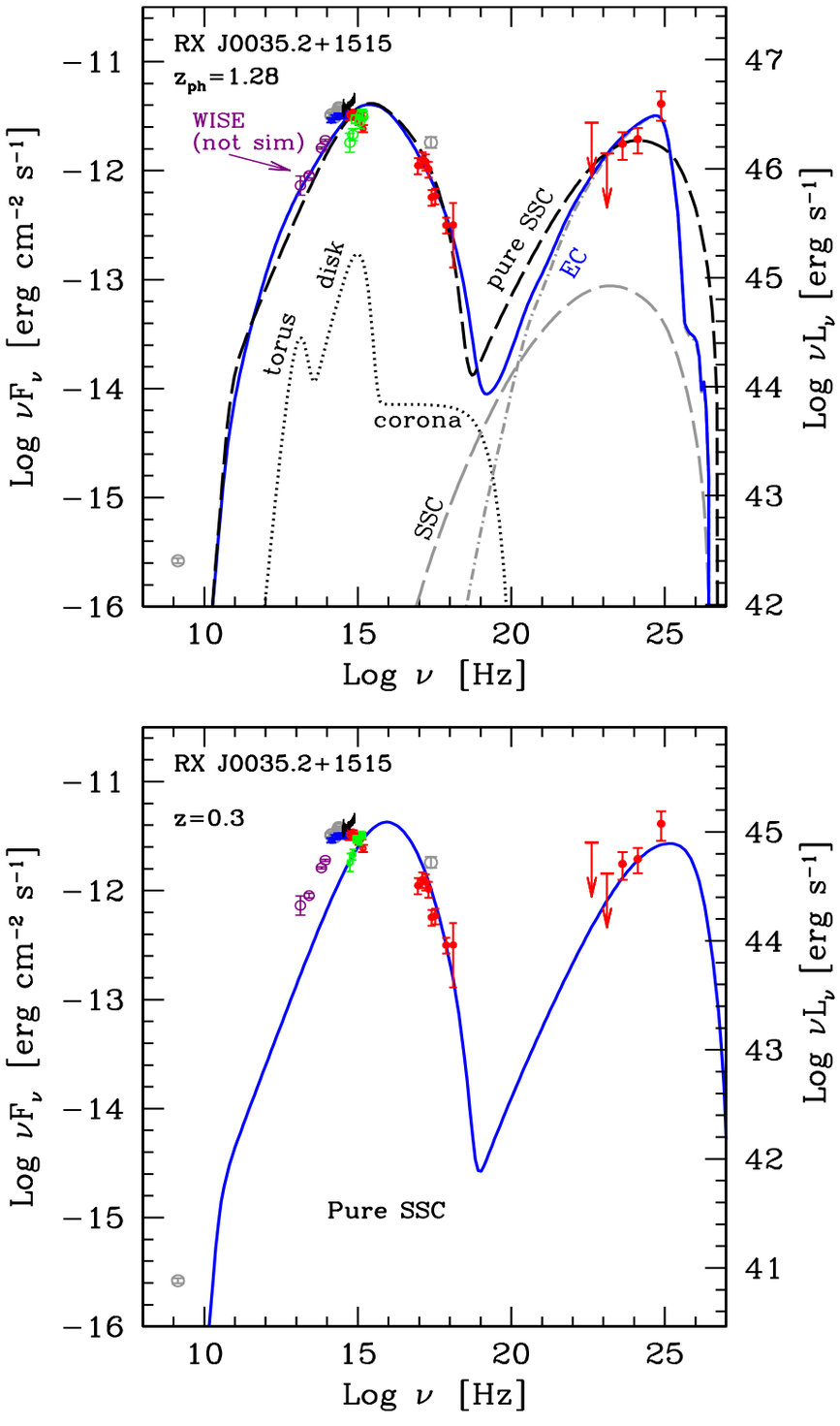
AND

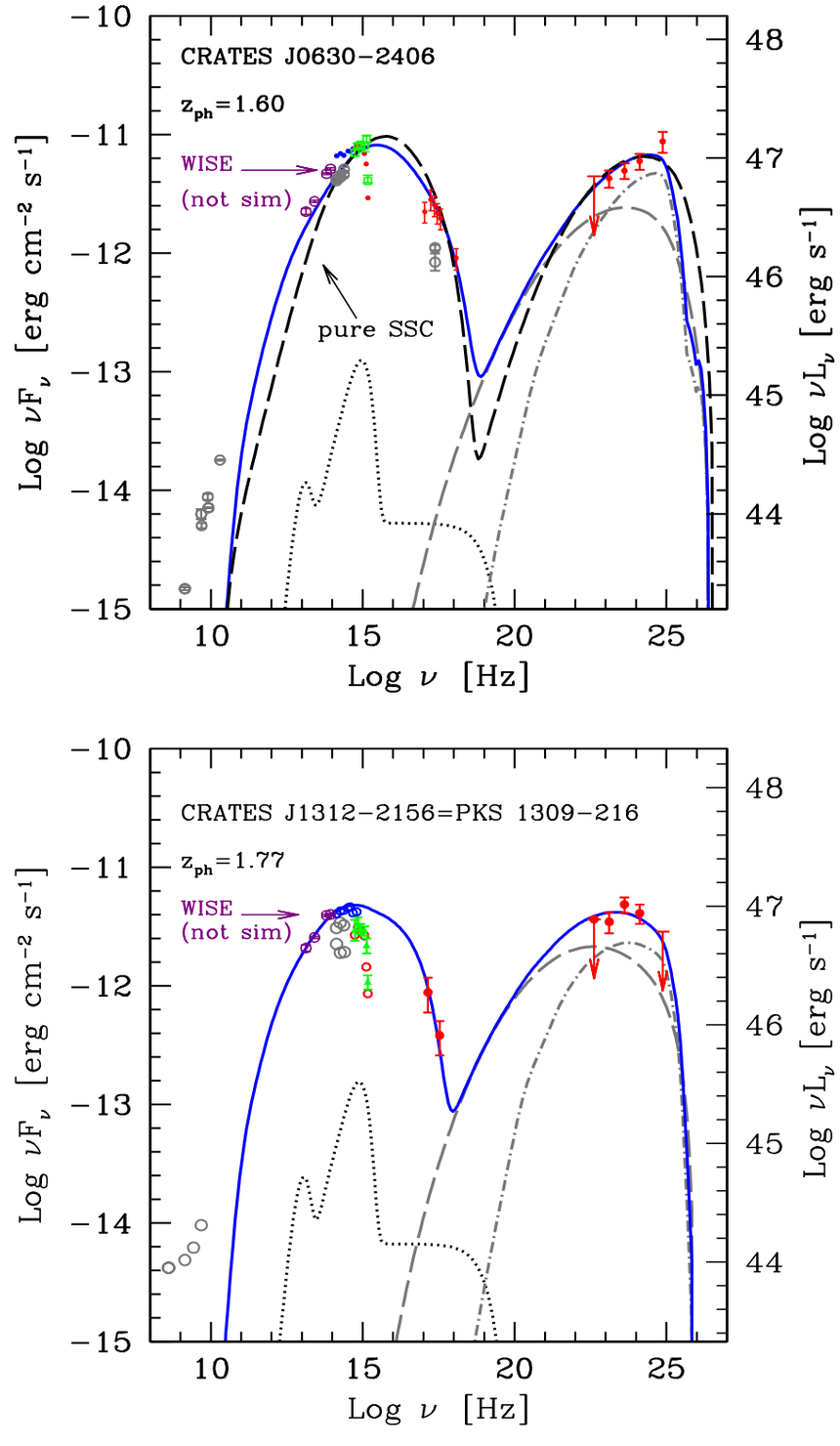
Eric Perlman
Joint Center for Astrophysics, University of Maryland, 1000 Hilltop Circle, Baltimore, MD 21250, USA

Draft version September 23, 2018



Blue (or H-) FSRQ

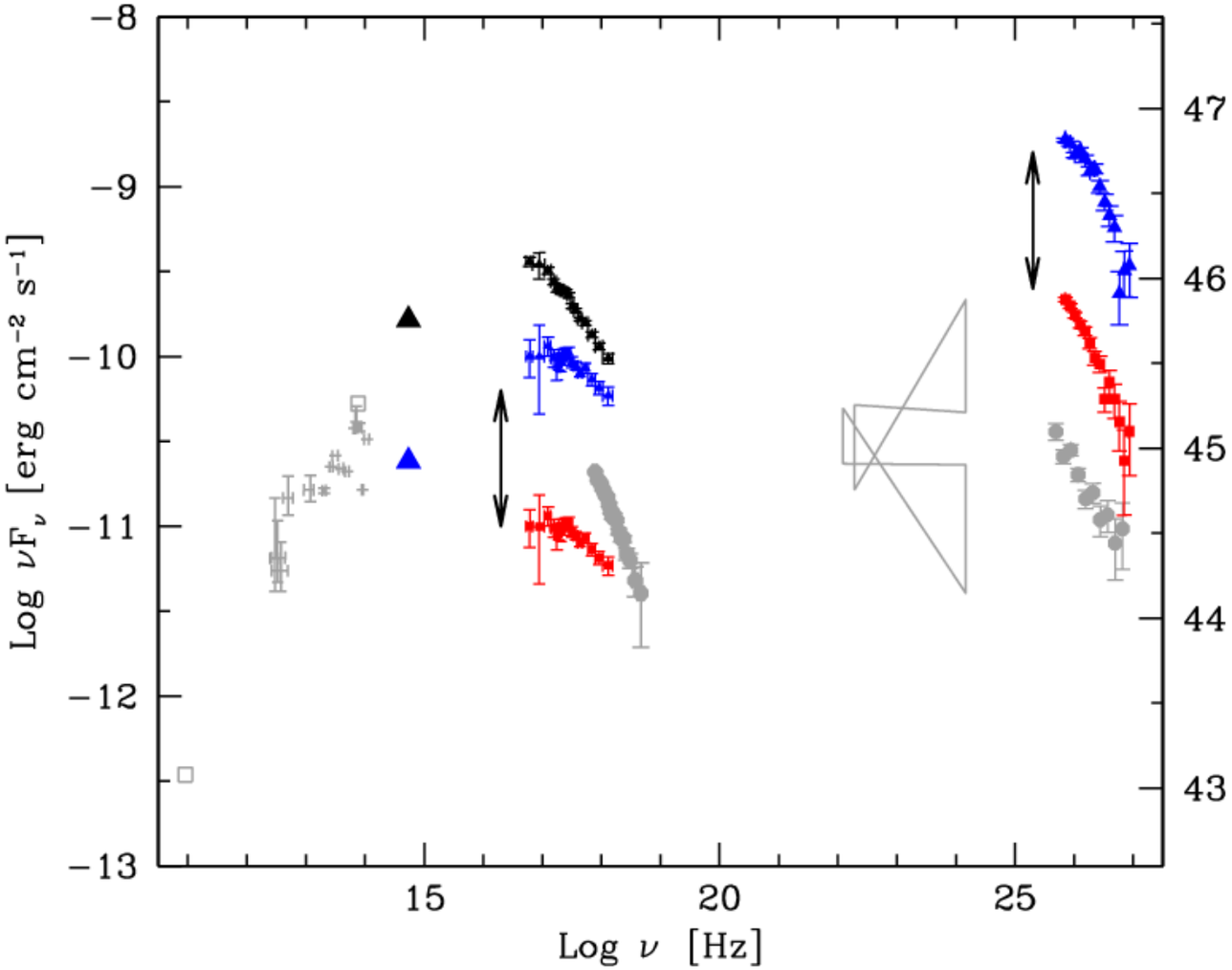




Padovani et al. 2002, Padovani et al. 2012, Ghisellini et al. 2012

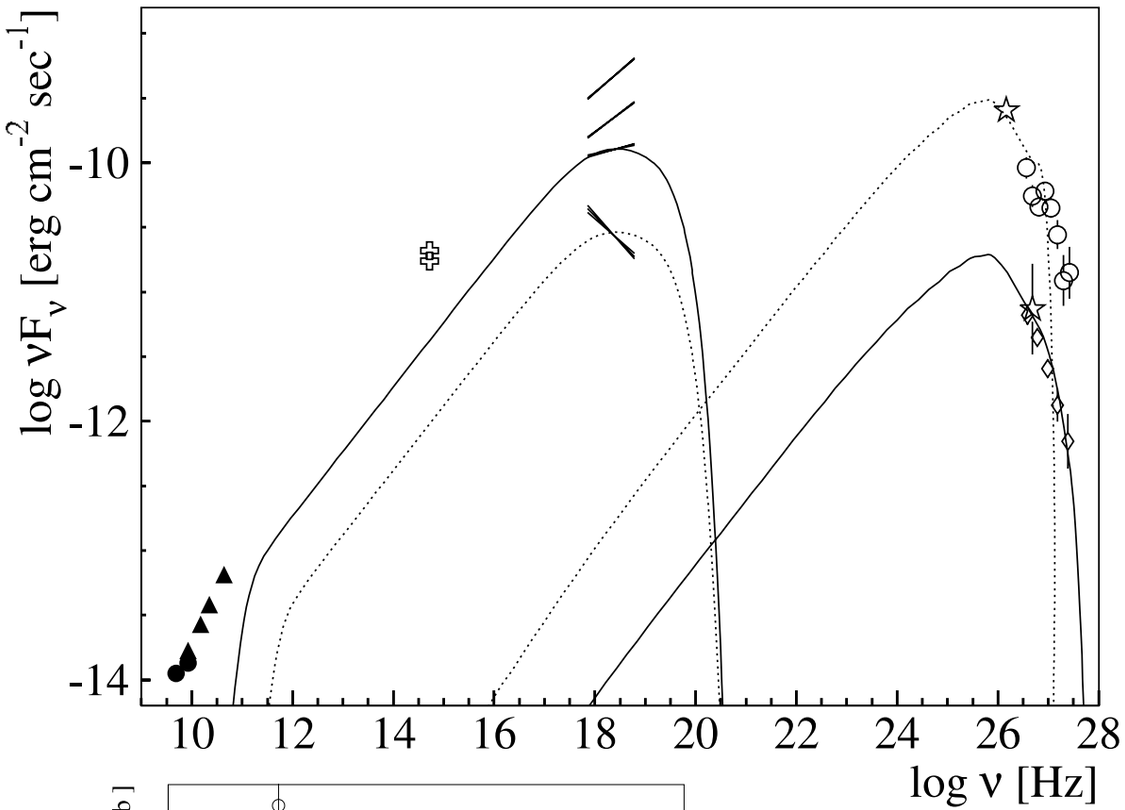
C) also FSRQ can have HBL-like gamma-ray spectra
also HBL can have high Compton Dominance

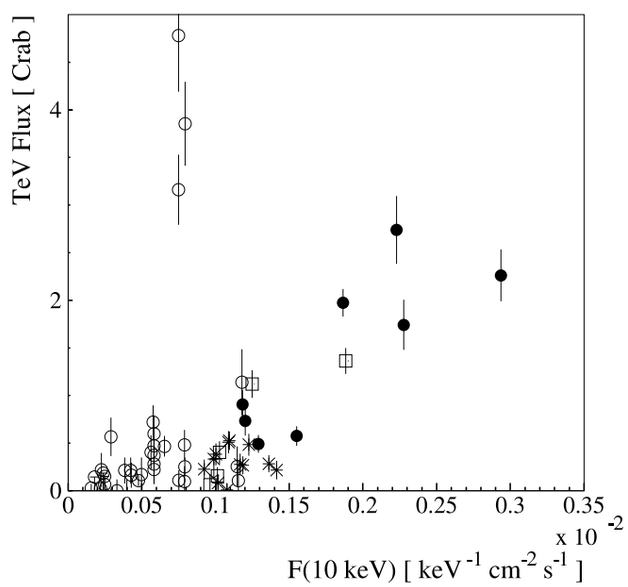
PKS 2155-304 giant flare 2006



Aharonian et al. (HESS) 2009

1ES 1959+650 "orphan flare" 2002

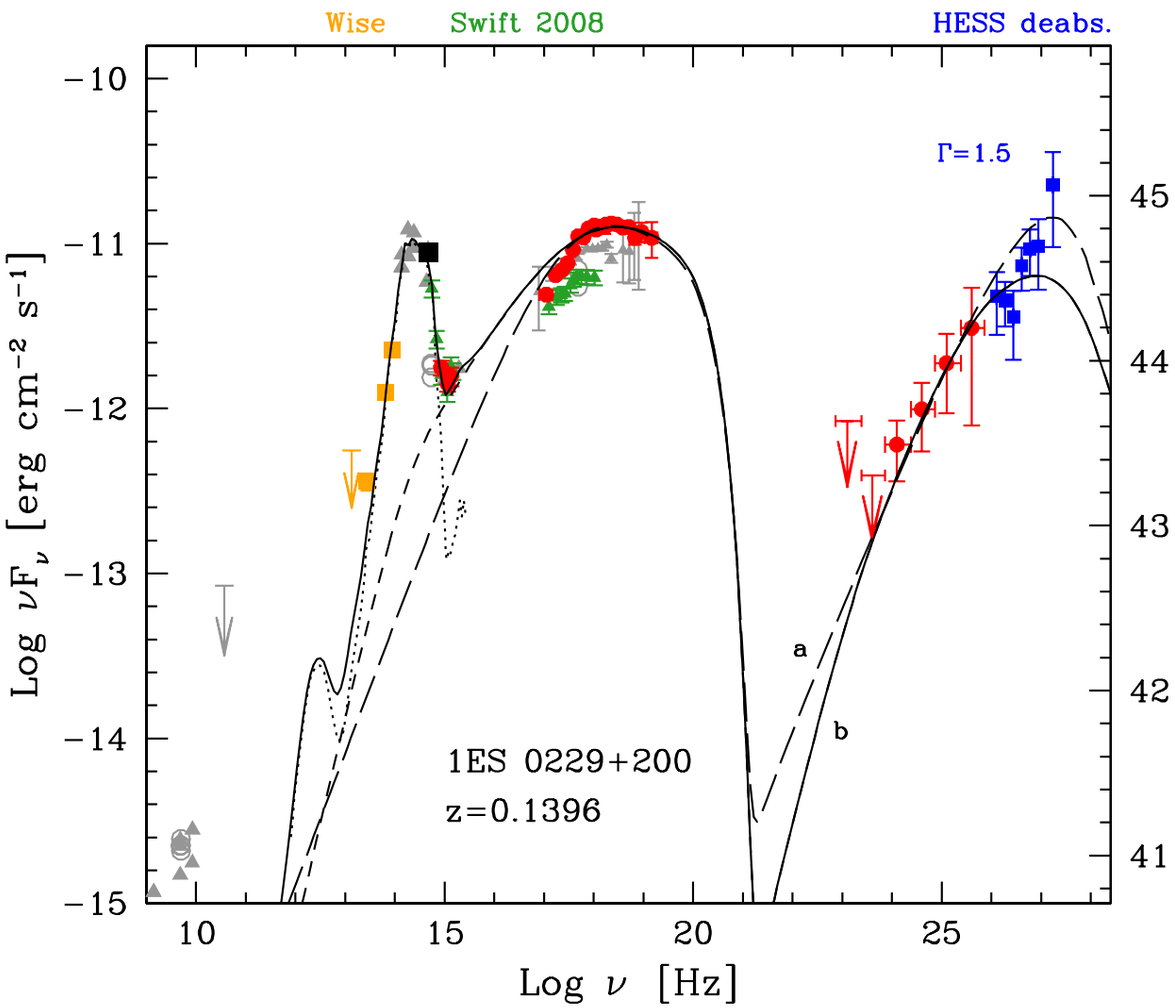


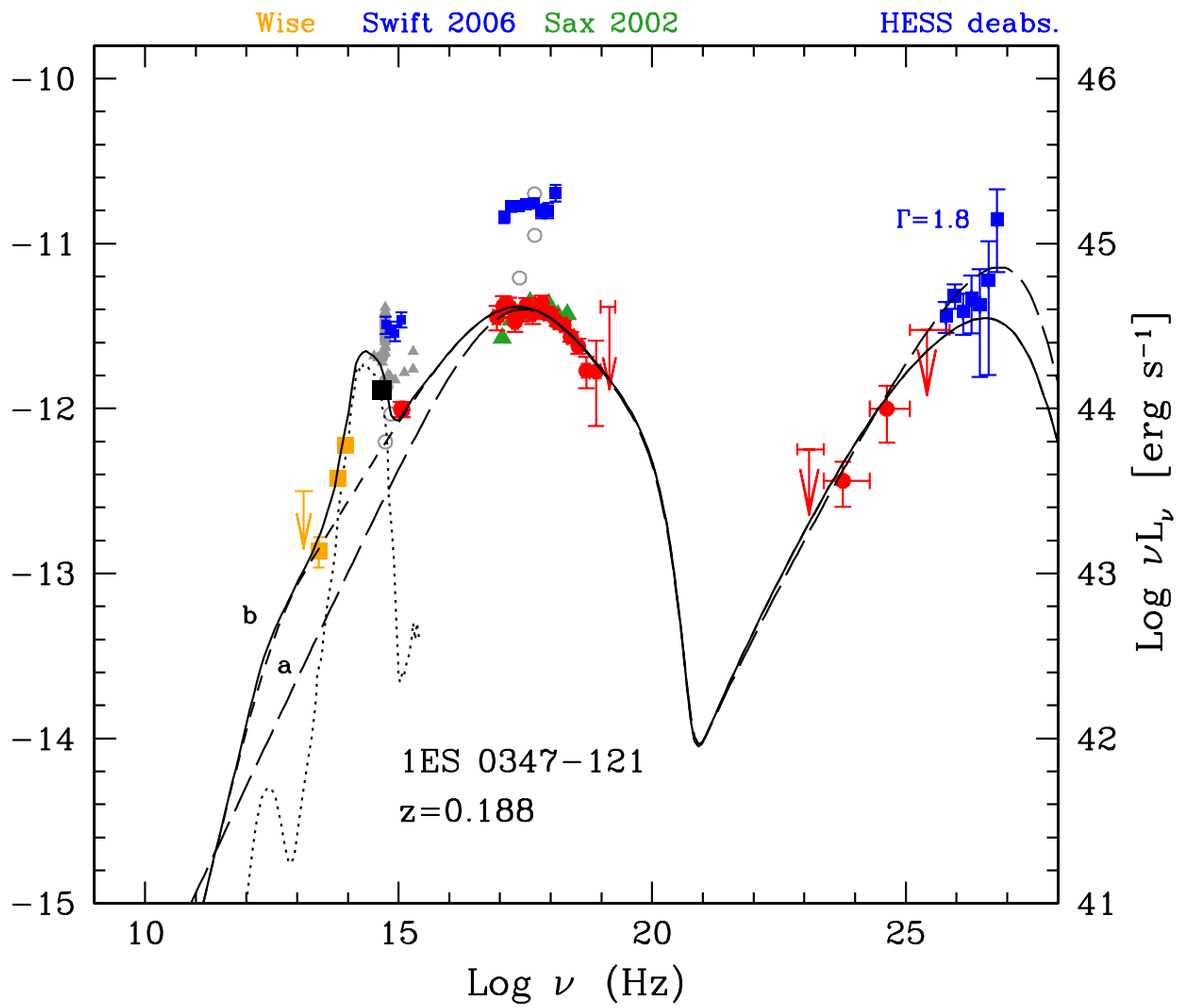


Krawczynski et al. 2004

D) Discovery of Extreme-TeV BL Lacs

⇒ Gamma peak ≥ 1-10 TeV





LC et al. 2018

LC et al. 2026, in prep.

leptonic modeling:

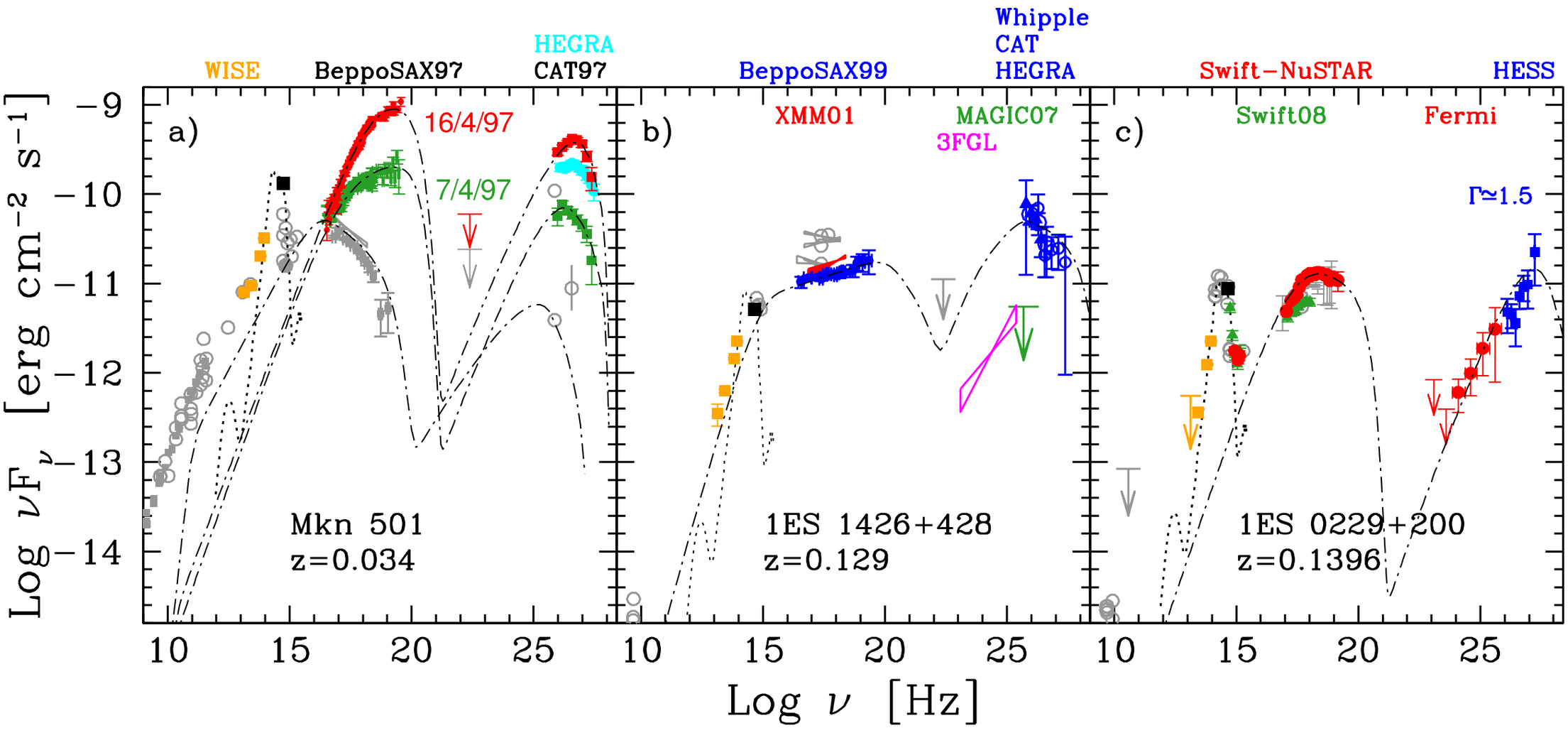
Source [1]	γ_0 [2]	n_0 [3]	γ_1 [4]	γ_b [5]	γ_2 [6]	n_1 [7]	n_2 [8]	B [9]	K [10]	R [11]	δ [12]	U_e/U_B [13]
1ES 0229+200 a	-	-	100	1.1×10^6	2×10^7	1.4	3.35	0.002	6	0.8	50	1.7×10^5
1ES 0229+200 b	-	-	2×10^4	1.5×10^6	2×10^7	2.0	3.4	0.002	10^3	2.1	50	2.0×10^4
1ES 0347-121 a	-	-	100	7.5×10^5	1.8×10^7	1.7	3.8	0.0015	1.2×10^2	1.2	60	1.5×10^5
1ES 0347-121 b	-	-	3×10^3	7.5×10^5	1.8×10^7	2.0	3.8	0.0015	8×10^2	2.5	60	3.4×10^4
1ES 0414+009 a	10	1.7	1×10^4	10^5	10^6	3.0	4.6	0.3	8×10^6	2.1	20	0.5
1ES 0414+009 b	-	-	3×10^4	5×10^5	3×10^6	2.0	4.3	0.0025	1.6×10^2	6.5	60	9.3×10^2
RGB J0710+591	-	-	100	6×10^5	10^7	1.7	3.8	0.011	1.2×10^2	0.92	30	2.7×10^3
1ES 1101-232 a	-	-	3.5×10^4	1.1×10^6	6×10^6	2.2	4.75	0.0035	7.0×10^3	2.5	60	2.4×10^3
1ES 1101-232 b	-	-	1.5×10^4	9.5×10^5	4×10^6	2.2	4.75	0.005	2.4×10^3	3.8	50	6.0×10^2
1ES 1218+304	100	1.3	3×10^4	10^6	4×10^6	2.85	4.2	0.0035	1.2×10^7	3.5	50	4.5×10^3

SSC can work but: 1) dropping one zone (fit no data below UV)
2) strongly out of equipartition (E-3 to E-6)
3) extremely low radiative efficiency

LC et al. 2018

Extreme-synchrotron

Extreme-TeV



If Extreme-TeV = Gamma-ray peak >1 TeV

Numbers are ~1/4 of all VHE-detected HBL
(15/59, 3 only temporarily)

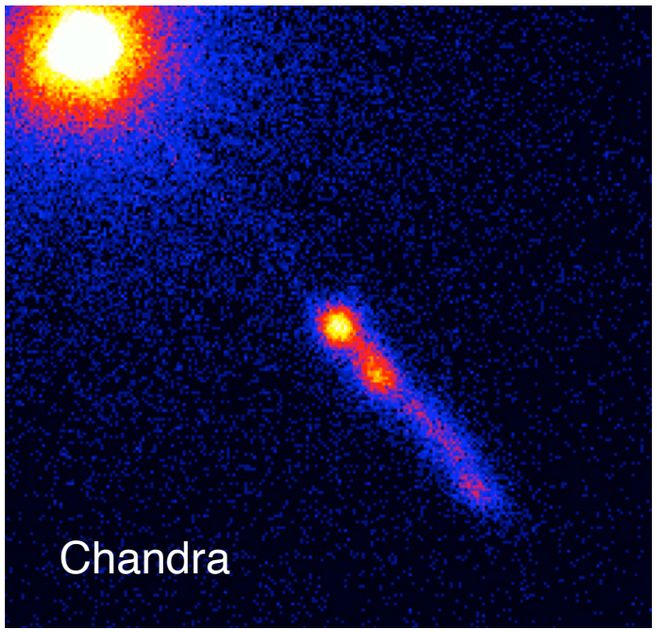
See review Biteau et al. (PP, LC), Nature Astr. 2020

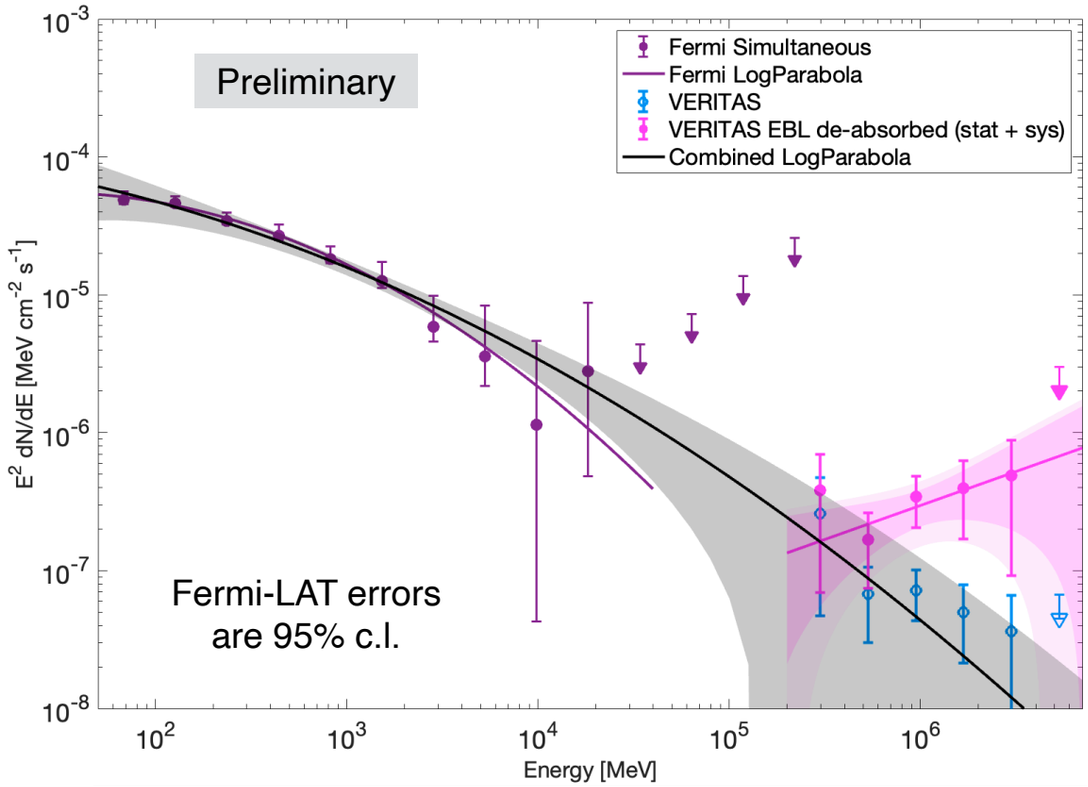
VHE Discovery of 3C 273

- ~231 h (quality-selected) from 2008-25 => Excess = 214 γ; 5.2σ => 4.9σ post-trials
- Constant VHE flux; F(>350 GeV) = (2.3 ± 0.5) x 10^{-13} cm^{-2} s^{-1}; ~0.2% Crab

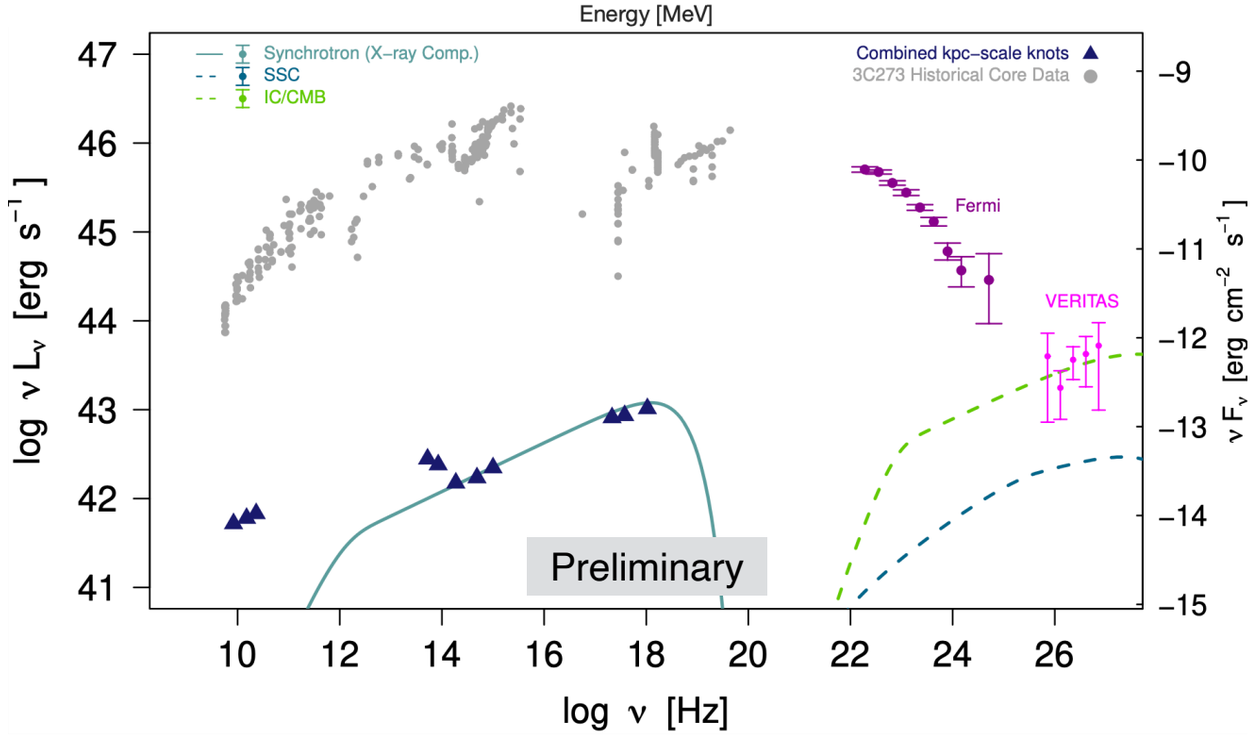
VERITAS Coll.
Benbow et al. Heidelberg 2026 conf.

Hard Γ (0.225 - 4.0 TeV): = 2.45 ± 0.44





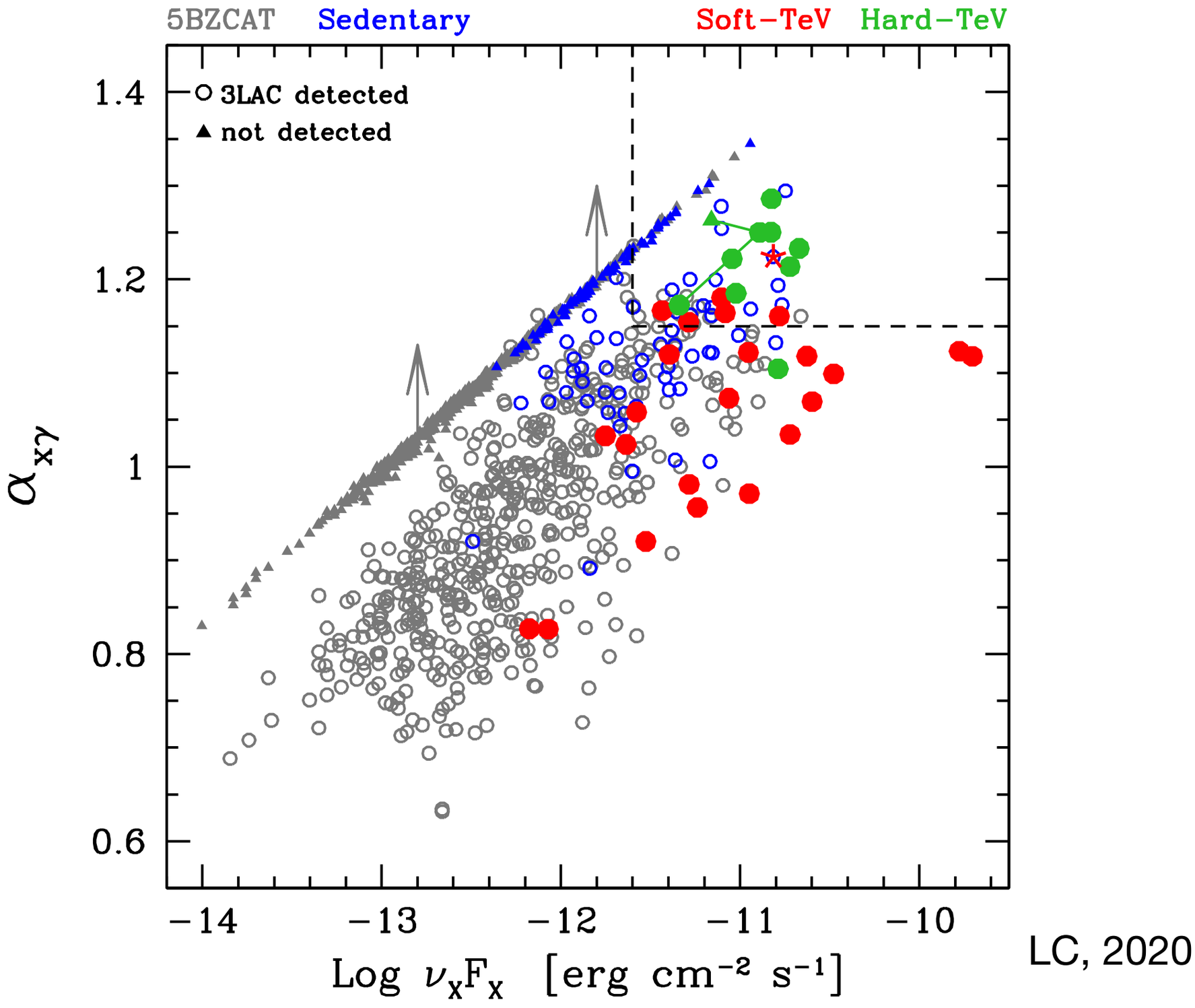
z=0.159



Model Shown:
Doppler factor δ = 12
Electron PL index: 2.45
γ_{min}, γ_{max} = (3e4, 7e7)
B: 2e-5 G
R: 1e19 cm (~3 pc)
Co-moving L: 1e43 erg/s

Core via SSC
or SSC + EC

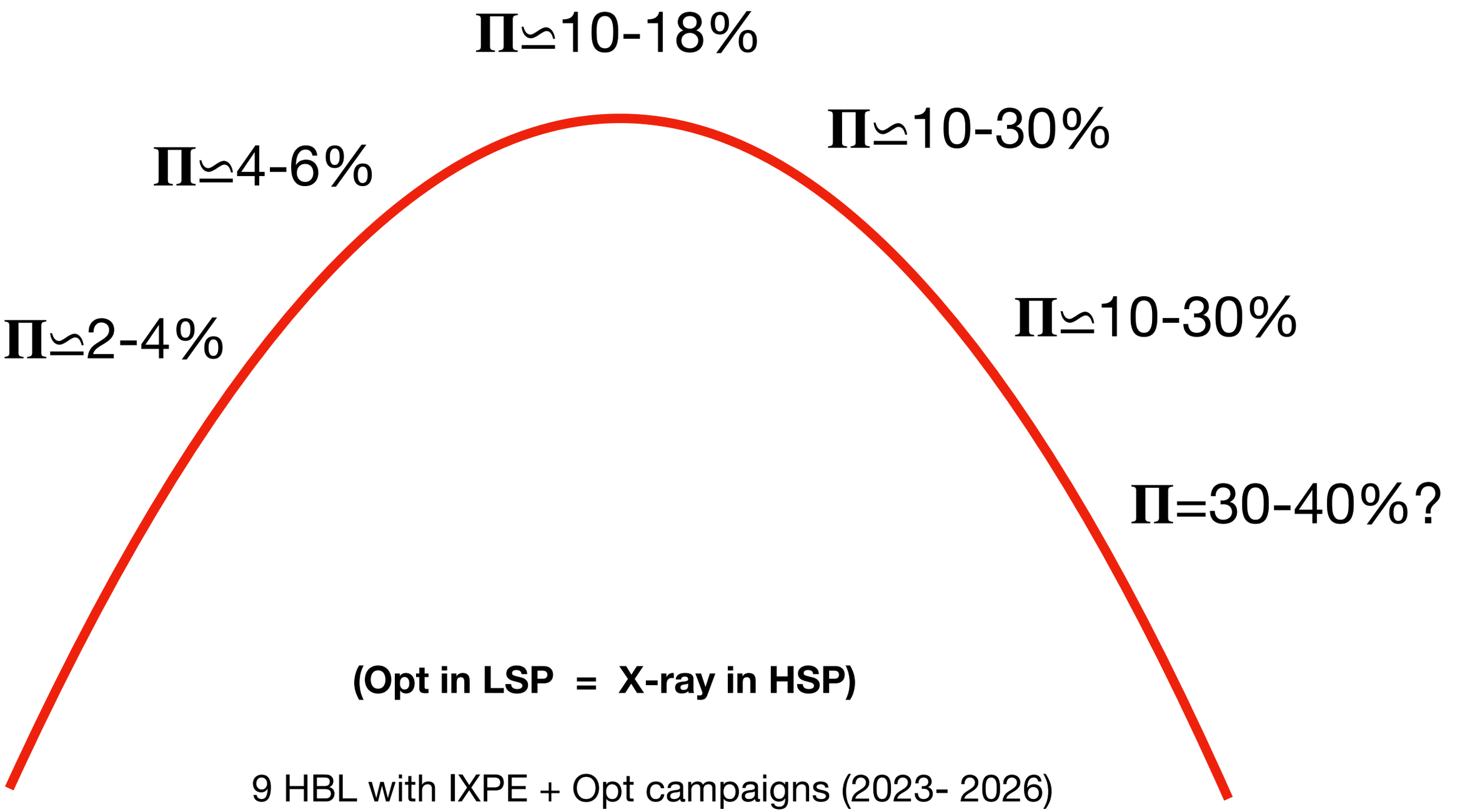
How to find more of them ?



LC, 2020

E) Synchrotron bump polarization:

(with respect to the peak)



(Opt in LSP = X-ray in HSP)

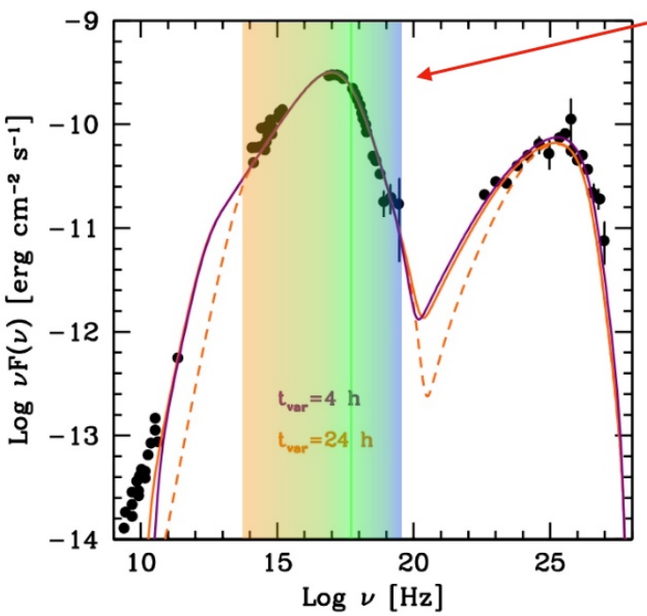
9 HBL with IXPE + Opt campaigns (2023- 2026)

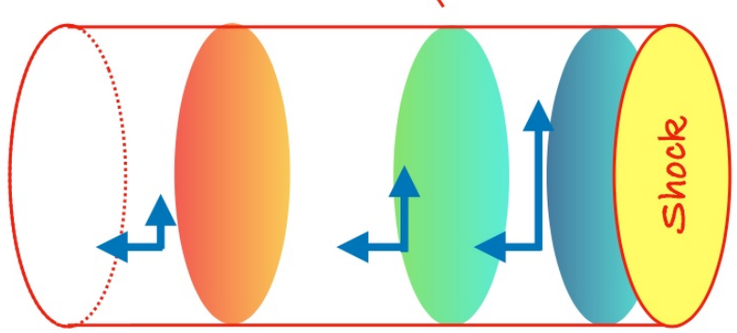
$\Pi_X > \Pi_O$

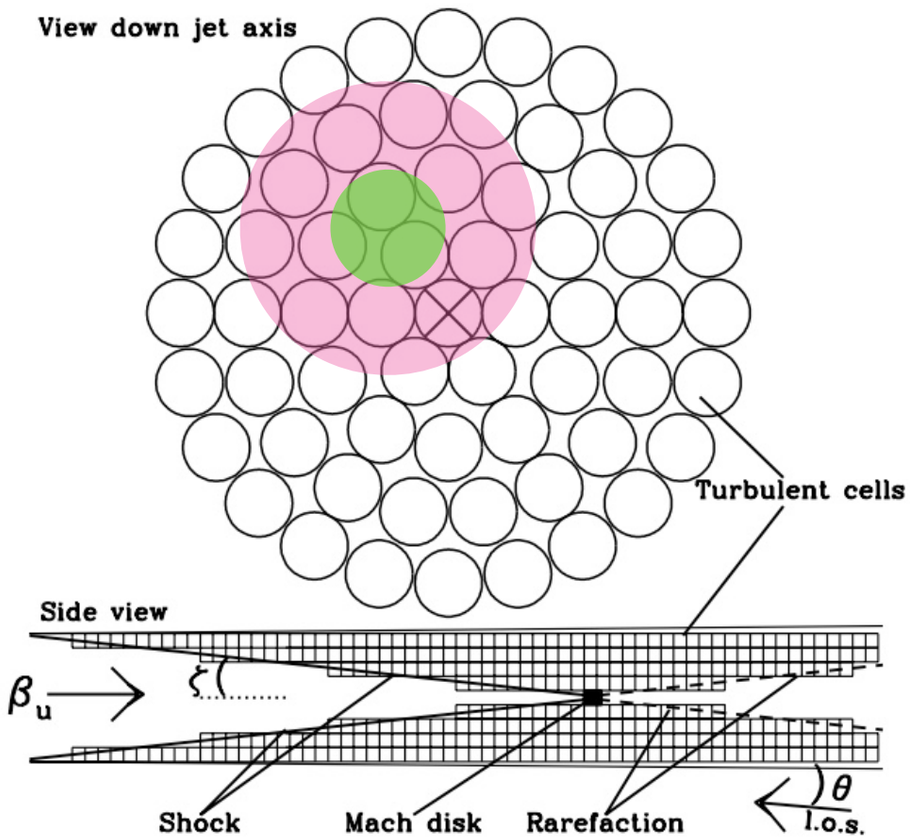
Tavecchio et al. 2018, 20, 21

$$\nu_s \propto \gamma^2 B$$

$$t_{\rm cool} = 7.8 \times 10^5 B_{-1}^{-2} \gamma_5^{-1} \ {\rm s}$$





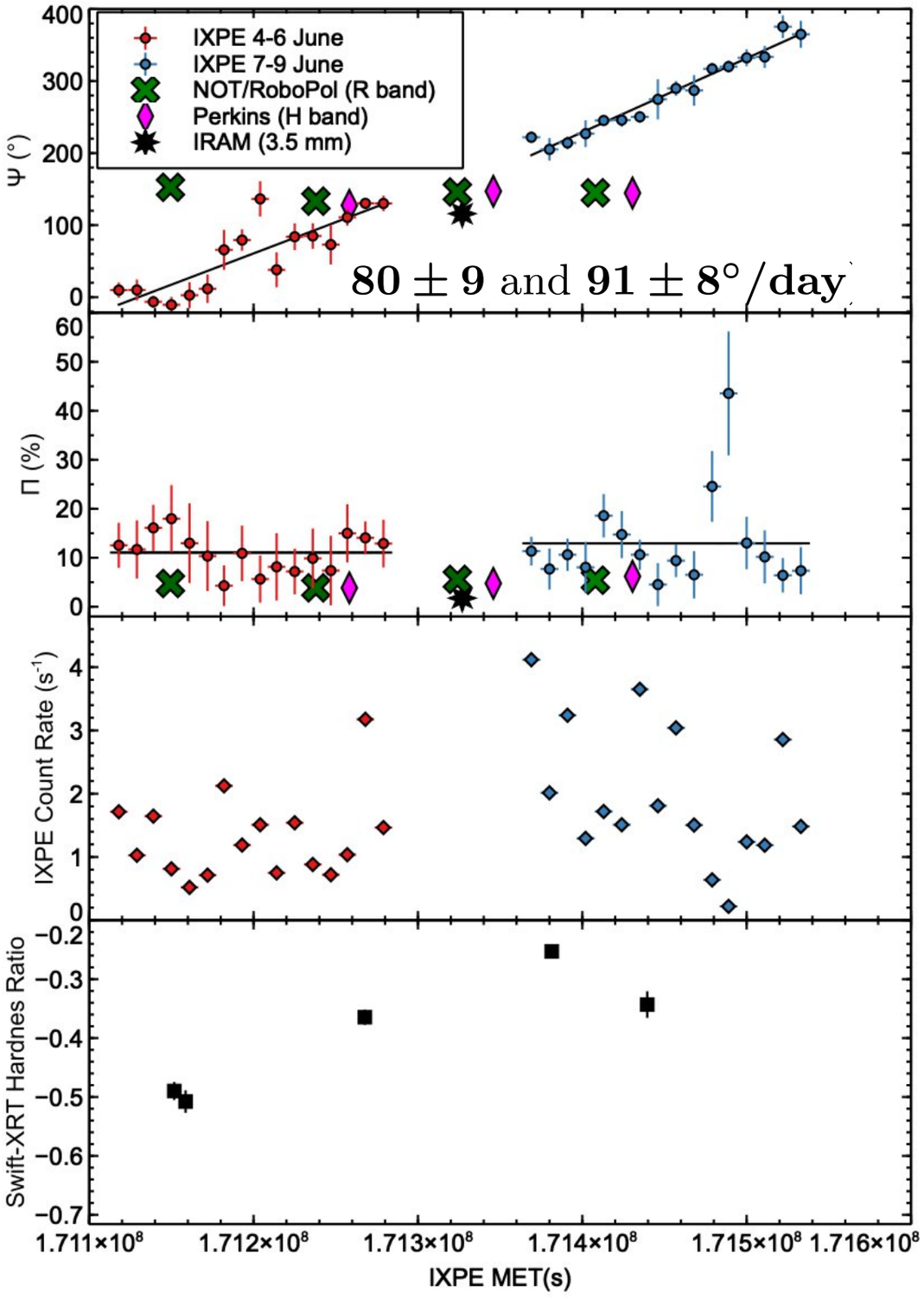


Turbulence destroys polarization
(unless scale stops at larger r than t_cool)

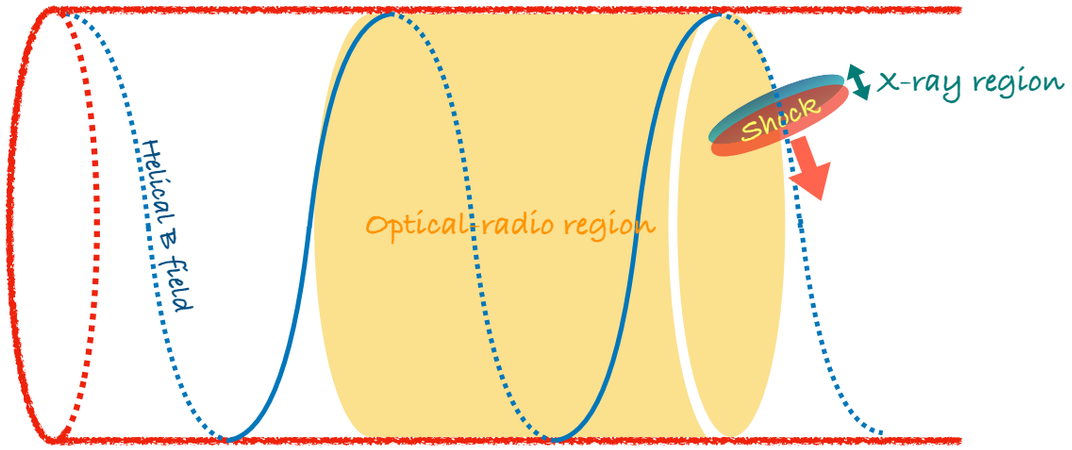
Multiple cells $\Pi_\nu \propto 1/\sqrt{N_\nu}$

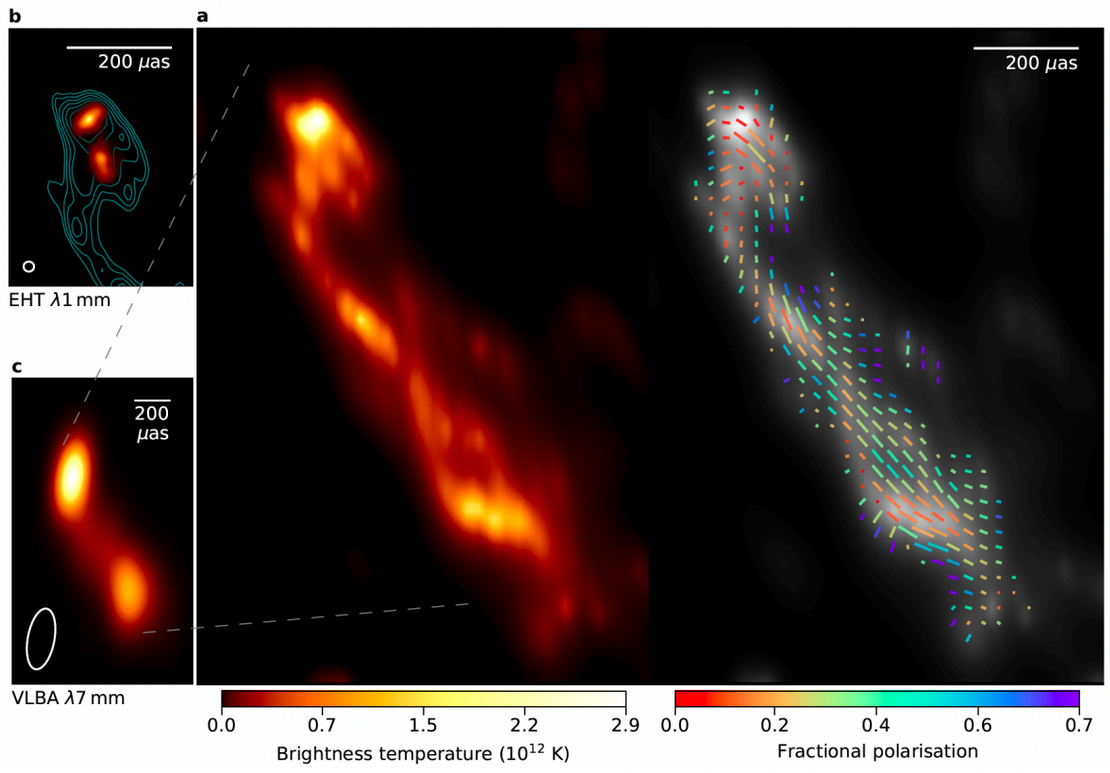
Marsher et al. 2021

Mkn 421 costant change of polarization angle



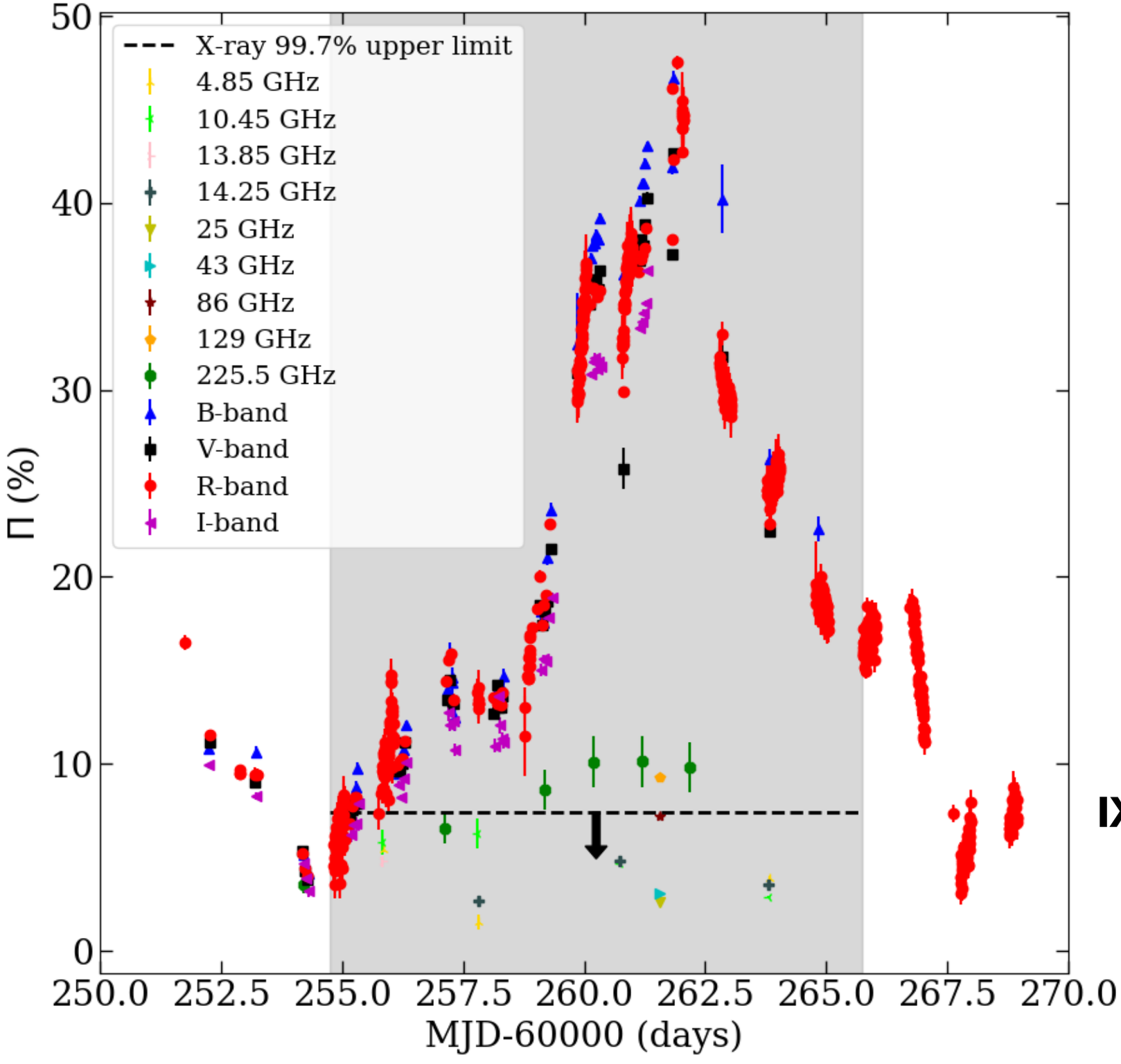
Di Gesu et al. 2023





3C279 Fuentes et al. 2023

BL Lac Optical Polarization “flare”
Nov. 2023



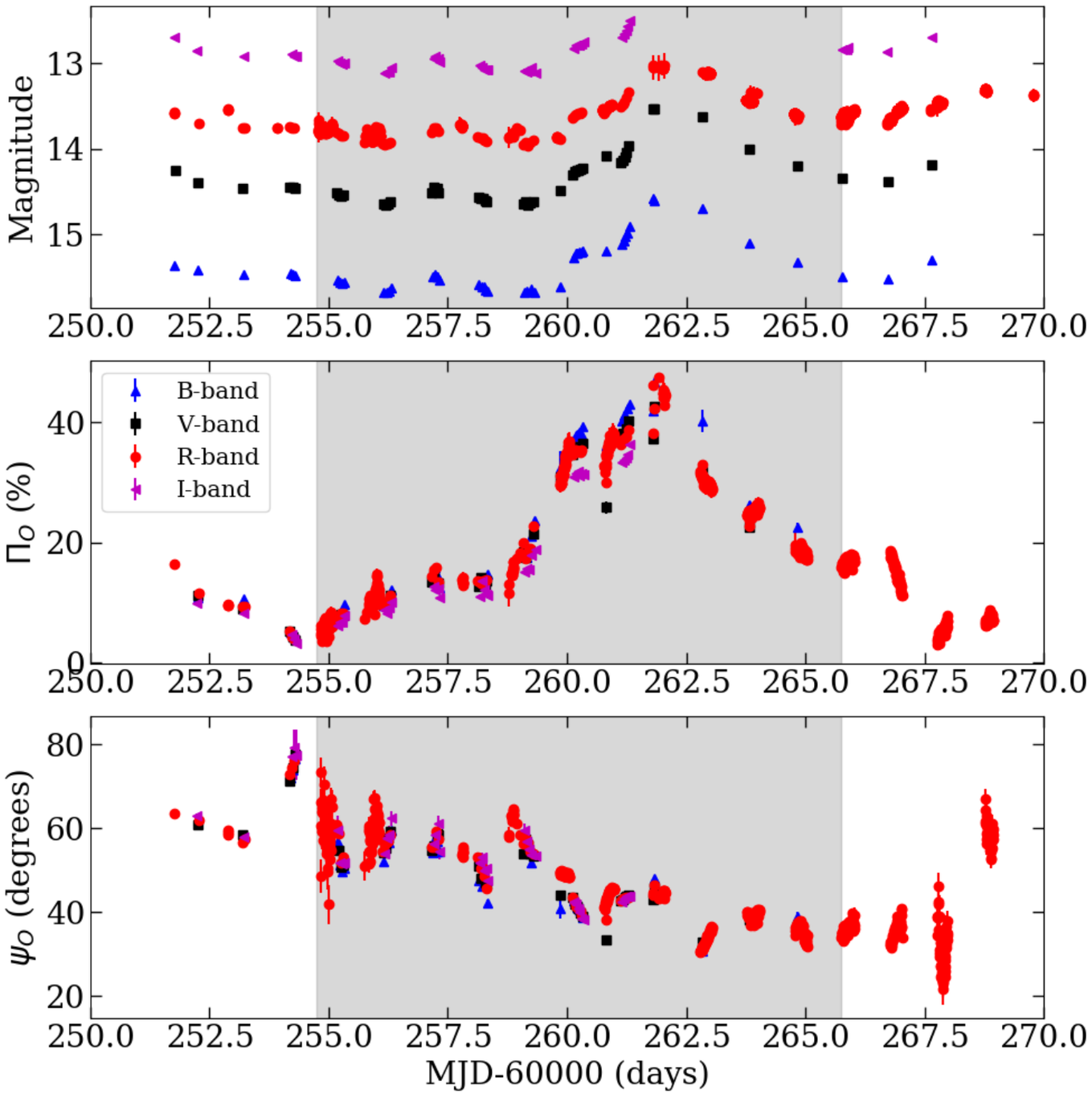
47% !

Beaming in conical jet depolarizes,
=> intrinsic >50% !

IXPE u.l.

Agudo et al. 2025

BL Lac Optical Polarization "flare"
Nov. 2023



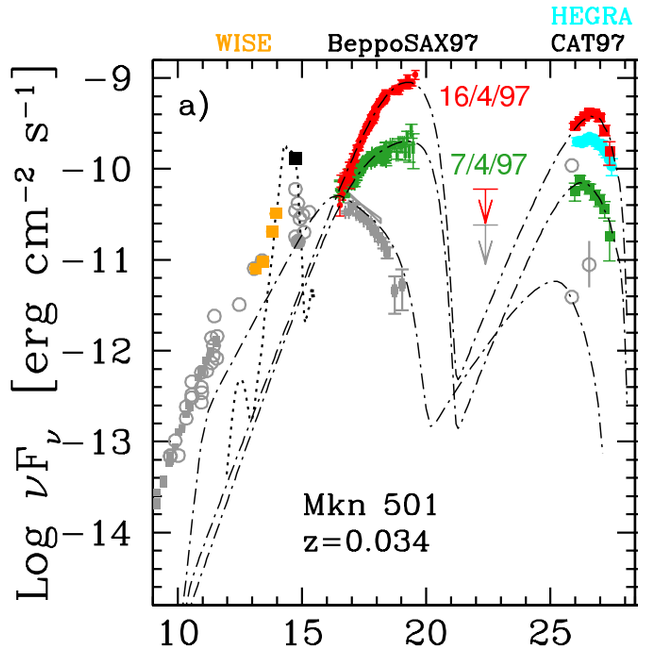
Flux ~3x variation

R ~7x10^{16} (δ/10) cm

(region size or travelled path)

1) Less magnetic turbulence ?
No Turb. Multi-Zone models ?

2) IXPE could see up to 50% polarization in HBL-like flares



incidentally…

The Astrophysical Journal Letters, 985:L15 (18pp), 2025 May 20 https://doi.org/10.3847/2041-8213/adc572
© 2025. The Author(s). Published by the American Astronomical Society.
OPEN ACCESS

High Optical-to-X-Ray Polarization Ratio Reveals Compton Scattering in BL Lacertae's Jet

Iván Agudo[1], Ioannis Liodakis[2,3], Jorge Otero-Santos[1,4], Riccardo Middei[5,6,7], Alan Marscher[8], Svetlana Jorstad[8,9],

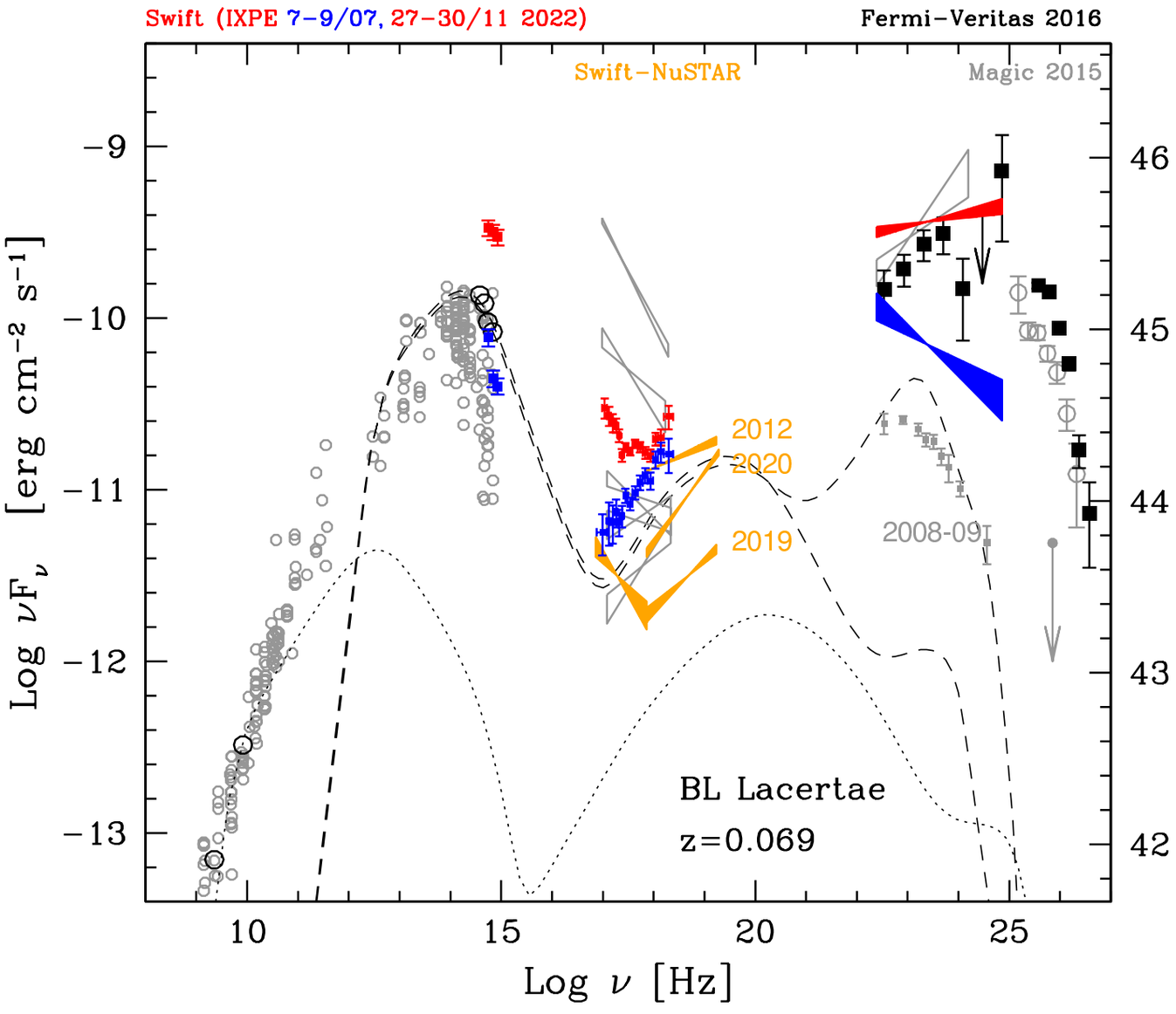
X-ray wavelengths. The observations caught an extraordinary event on 2023 November 10–18, when the degree of linear polarization of optical synchrotron radiation reached a record value of 47.5%. In stark contrast, the Imaging X-ray Polarimetry Explorer found that the X-ray (Compton scattering or hadron-induced) emission was polarized at less than 7.4% (3σ confidence level). We argue here that this observational result rules out a hadronic origin of the high-energy emission and strongly favors a leptonic (Compton scattering) origin, thereby breaking the degeneracy between hadronic and leptonic emission models for BL Lacertae and demonstrating the power of

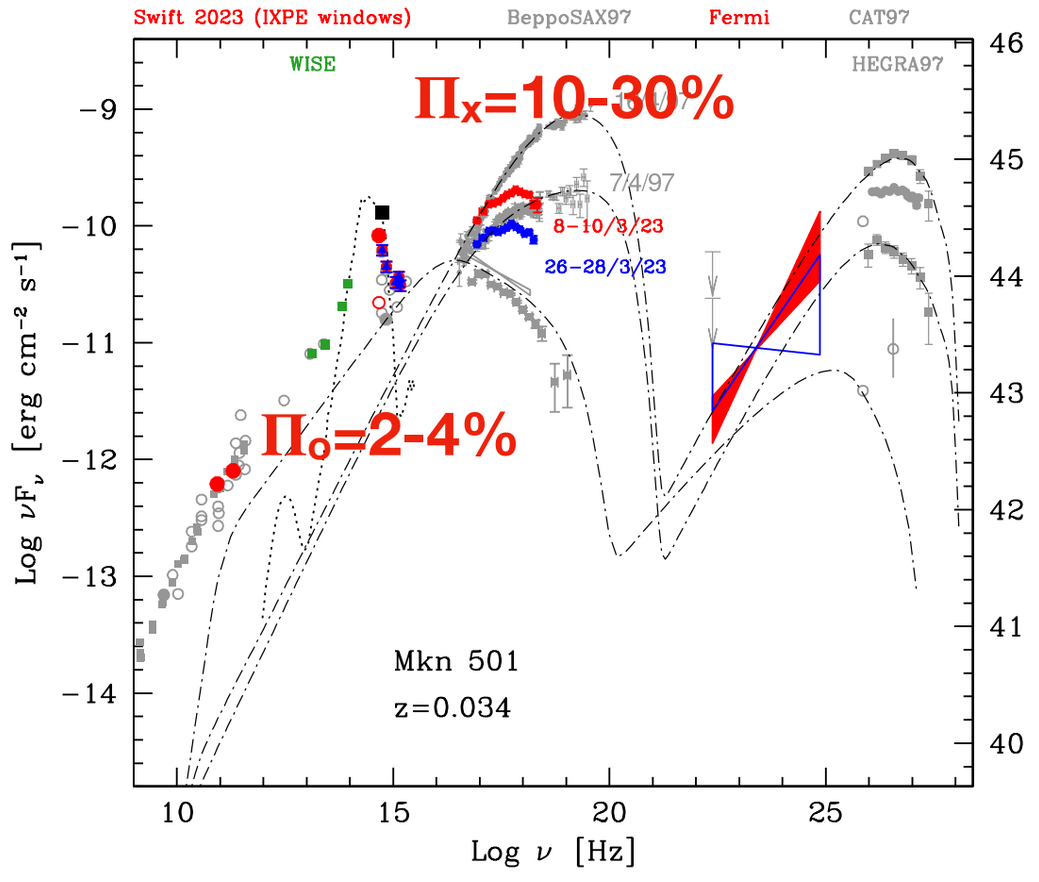
well…. NO, NOT AT ALL !

The point is: is gamma-ray *bump* produced by proton-synchr ?

$E_p > 10^{19}$ eV

E_p at X-rays are low energy ~10^{16}



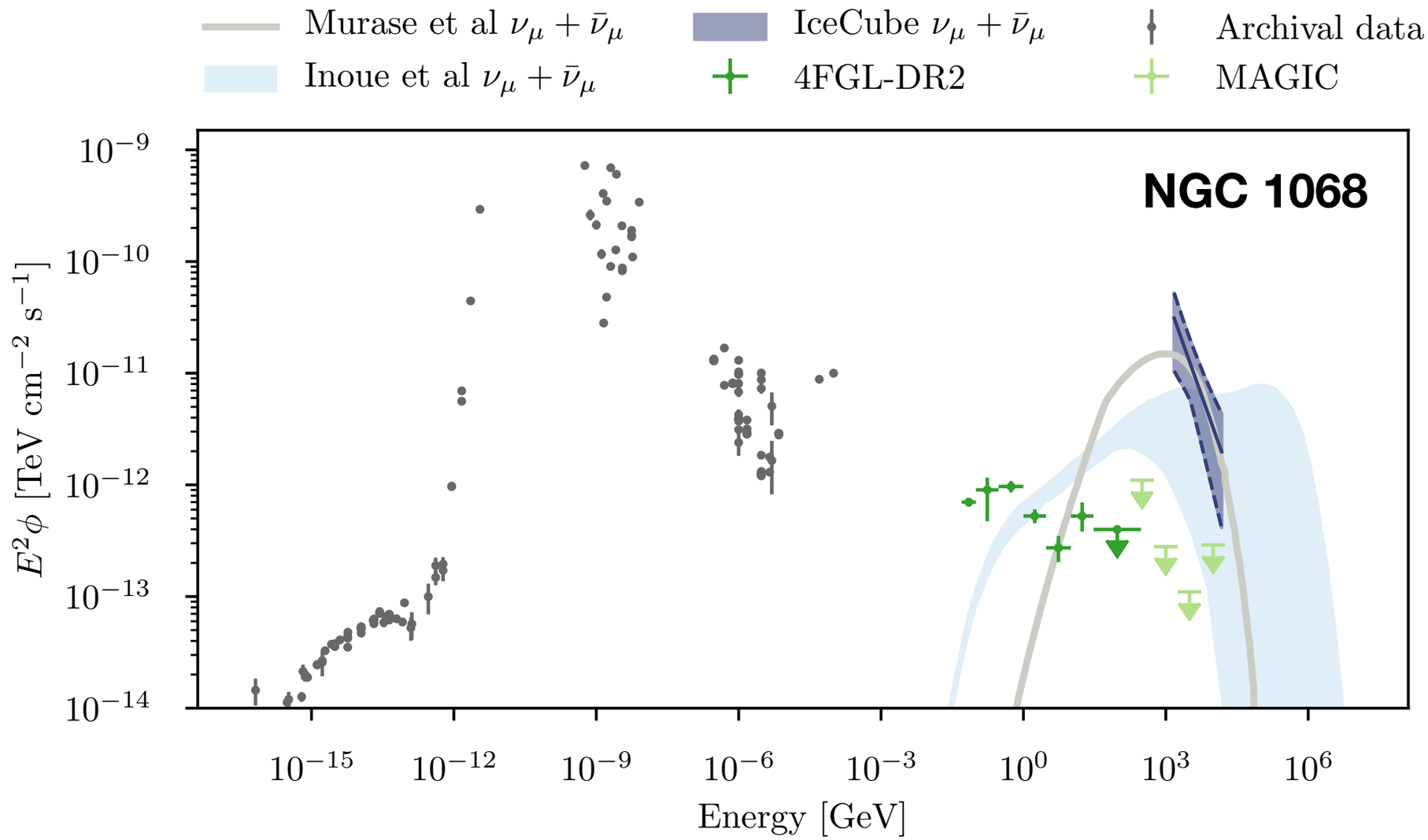


- **SED valley can be dominated by SSC even if gamma is proton-synchrotron**
- **Any depolarisation mechanisms at work in electrons (pol Opt << pol X) is $(m_p/m_e)^n$ times more effective for protons (slower cooling, larger radii)**
- **As for the electrons, low-energy p (X-ray) pol. can be << high-energy p (Gamma) pol.**

Counter-example: perfectly viable prot-synchr model in Tavecchio et al. 2025

F) Neutrinos: 2 warnings

Jets might not be the places of neutrino production
(see also talk by Martin Pohl at Gamma 2026 conf.,
hadronic corona model for NGC 4278 , LLAGN detected at VHE)

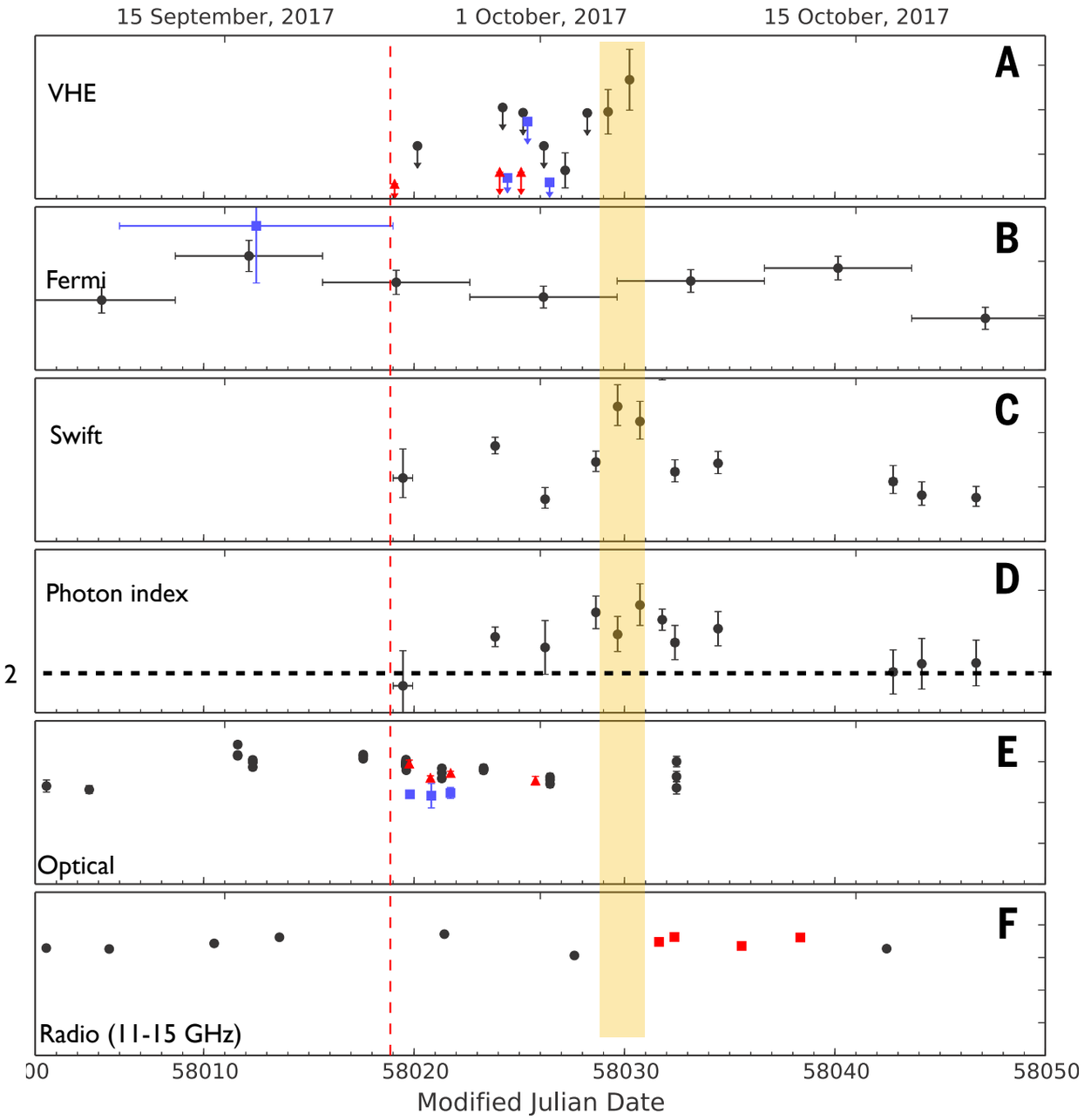


Problem is: for pγ to work, photon density makes regione opaque

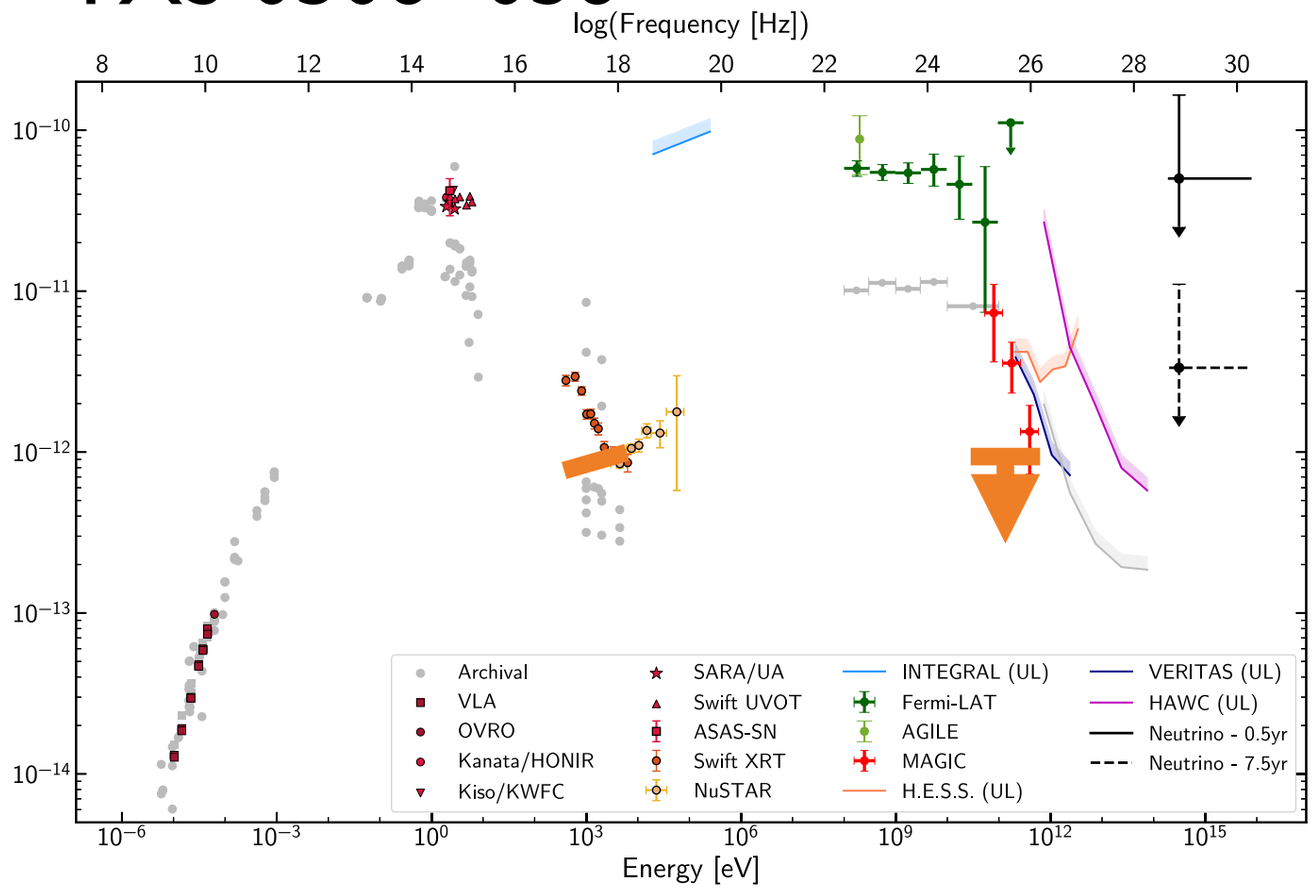
1) Beware of “simple” correlations with gamma-rays

(look out for different variability timescales)

IceCube-170922A



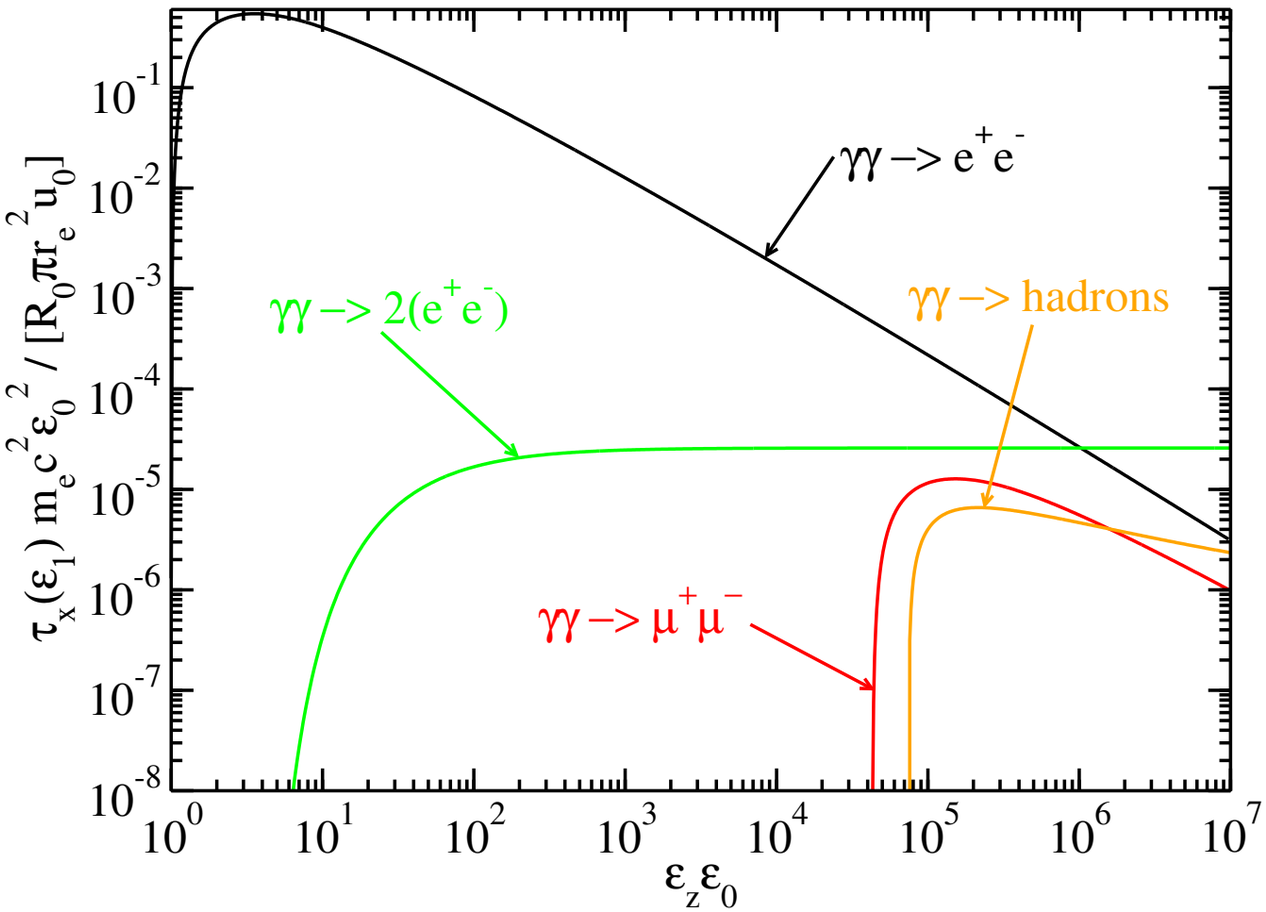
TXS 0506+056

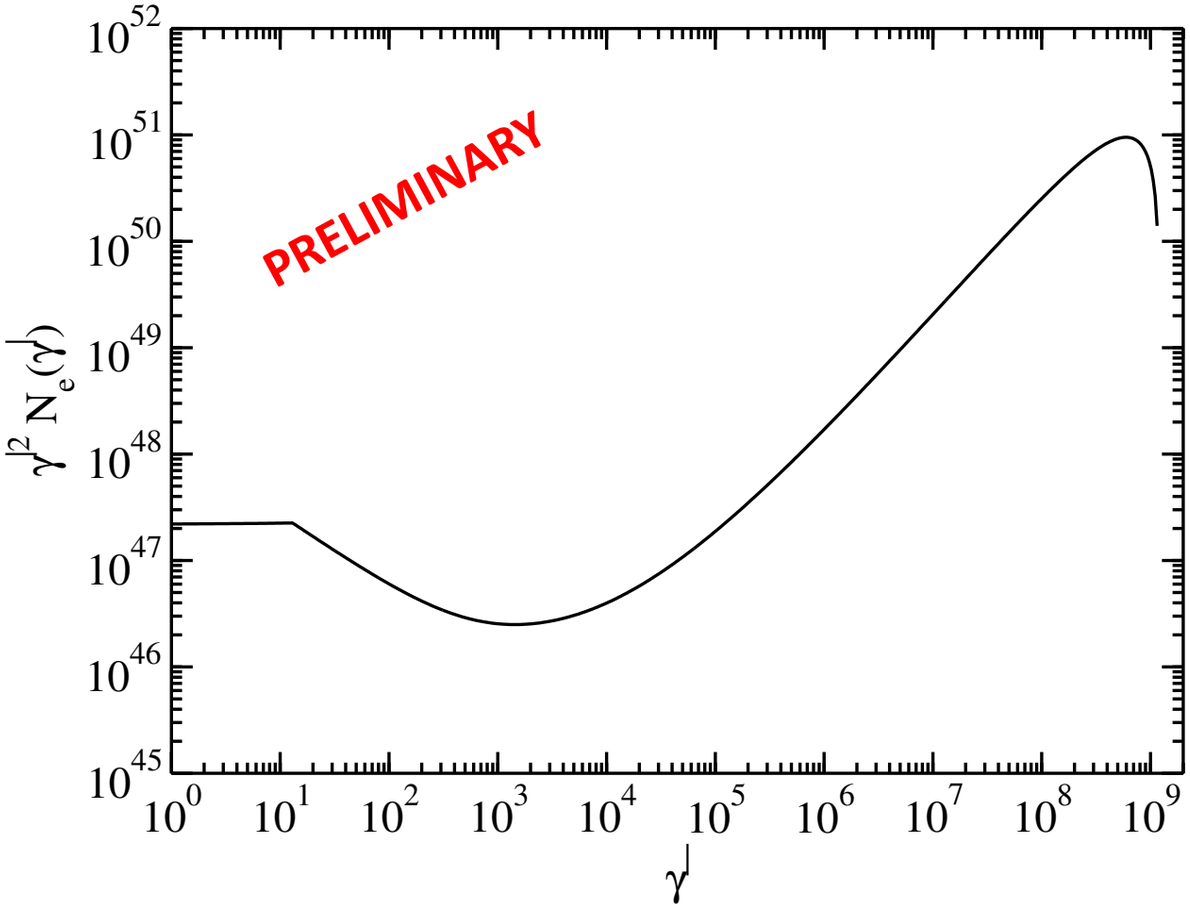


2) Also purely leptonic models can produce neutrinos !

(Justin Finke, Heidelberg Gamma 2026 conf.)

e.g. Pair Muon production





Electron distribution after energy losses.
Electrons injected as ~$\gamma^{-1.9}$ between 13 and 10^9

2) Also purely leptonic models can produce neutrinos !

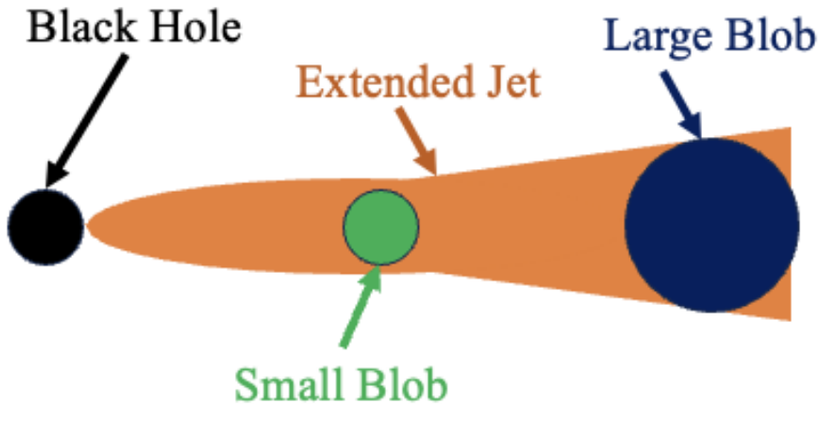
(Justin Finke, Heidelberg Gamma 2026 conf.)

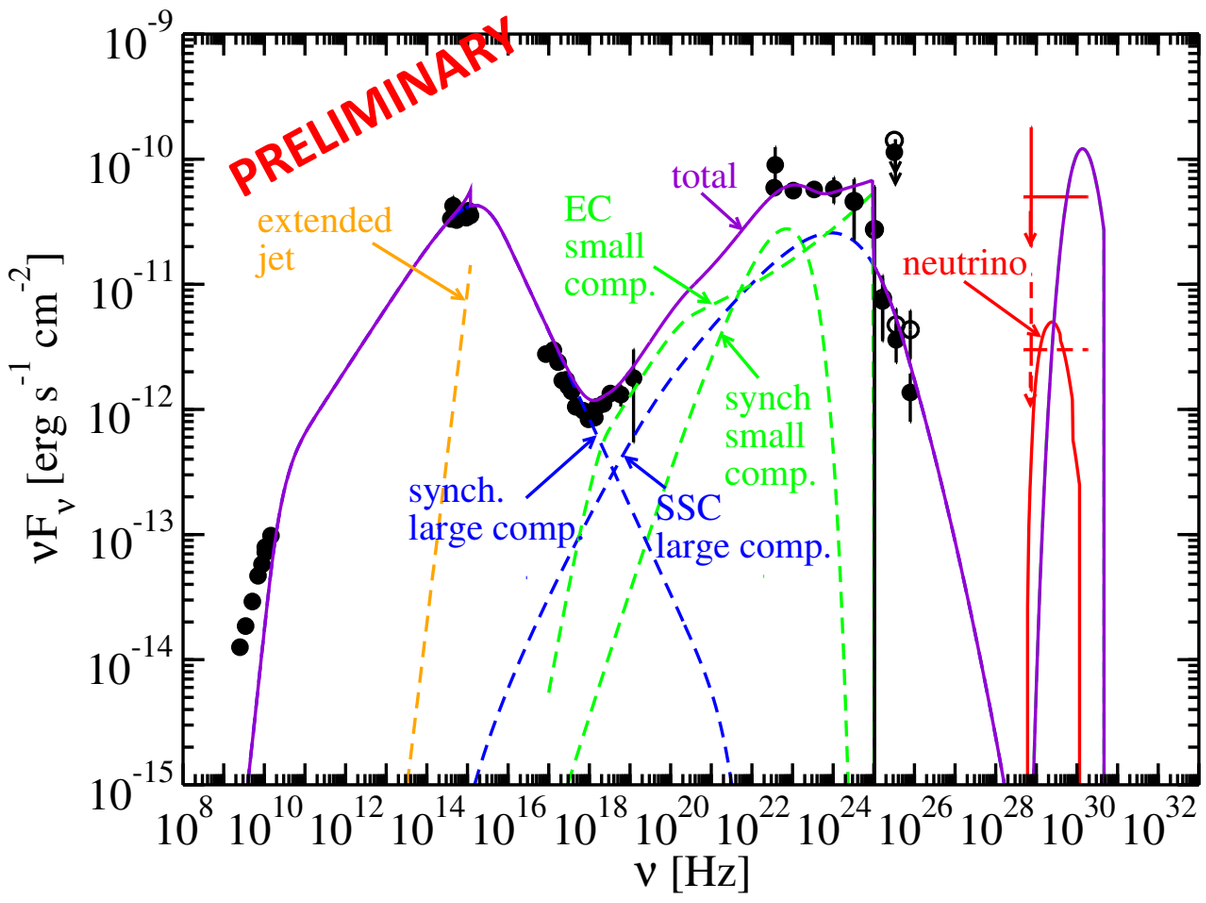
Leptonic model can completely explain SED, including neutrinos.

Can produce *higher* neutrino flux than some lepto-hadronic models

Total jet power (4.4 x 10^{46} erg/s) less than Eddington luminosity for 10^9 M_{Sun} black hole

Disadvantages: More free parameters than lepto-hadronic models (21 versus 16)
Requires hard radiation field for acceleration of electrons to very high energies ($\gamma=10^9$)





TXS 0506+056 (data from Aartsen et al. 2018)

Finke & Razzaque 2026 (submitted)

In Summary :

How the jet is launched ? Blandford-Znajek, but… **Boh ?**

What powers the jet ? **Spin BH via B (pushed by accretion), probably…**

Why only a few % produce powerful relativistic jets ? **Boh ?**

What particle acceleration mechanism ? **many …** (shocks, shear, B-reconnection, Fermi II, neutron converter…)

Particles, mechanism and location of gamma-ray emission ? **Boh ?**
(p or e ? synchrotron, IC or photo-meson ? mostly far from BH, SSC there)

What determines the difference in SED between FSRQ/BLLacs, LSP and HSP ?
Boh ?
Not the cooling on BLR

after 30+ years, a bit depressing…

What now ?

It’s not data what is missing… more imagination !

Lots of data/campaigns, and unique for quite some time given loss of SWIFT !

- SWIFT 2.0, NOW ! ASAP !

- Gamma-ray Polarimetry (MeV may be ok (COSI), GeV better)

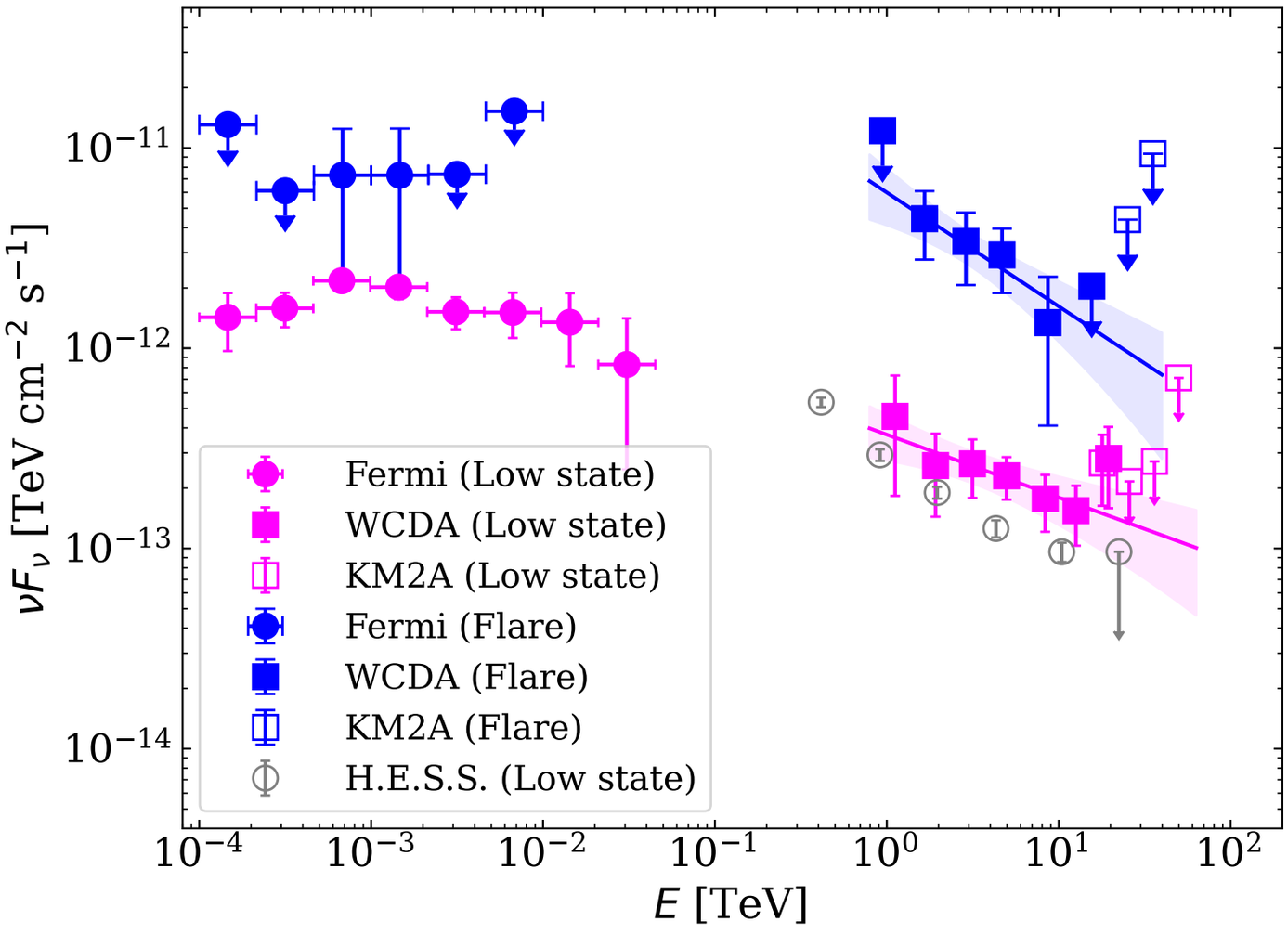
- **High-z Universe AGN**

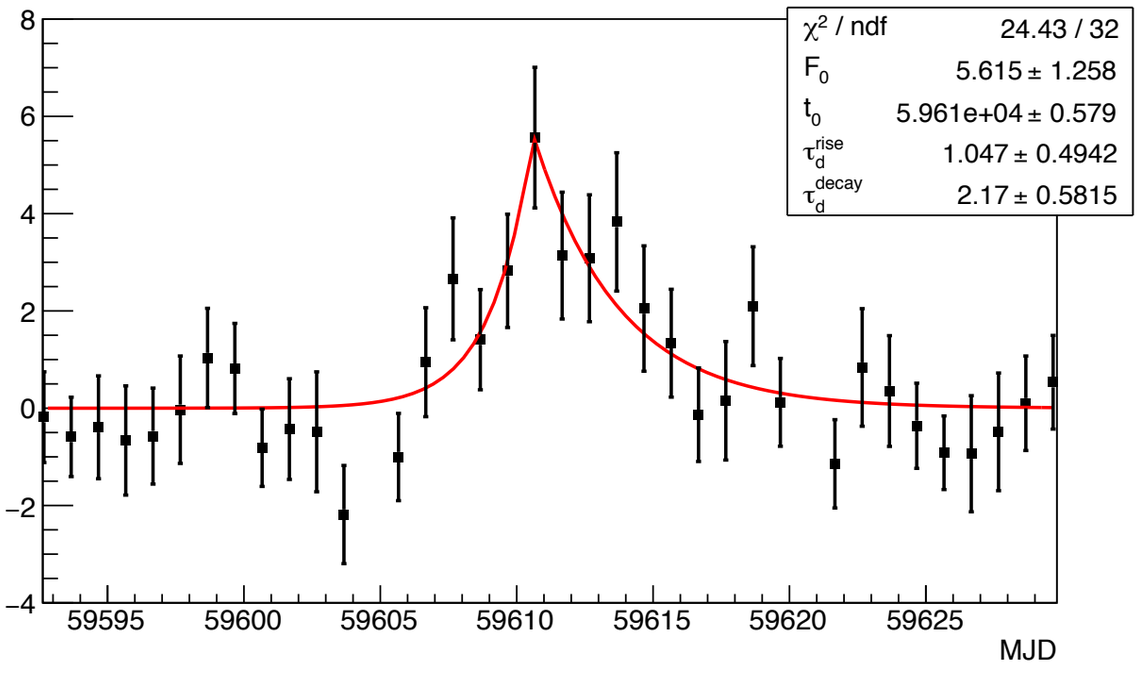
- X-ray interferometry

- Study Galactic BH-jet systems (microQSO go above 100 TeV !)
(study cats to understand tigers…)

back up slides

M 87





up to ~20 TeV !

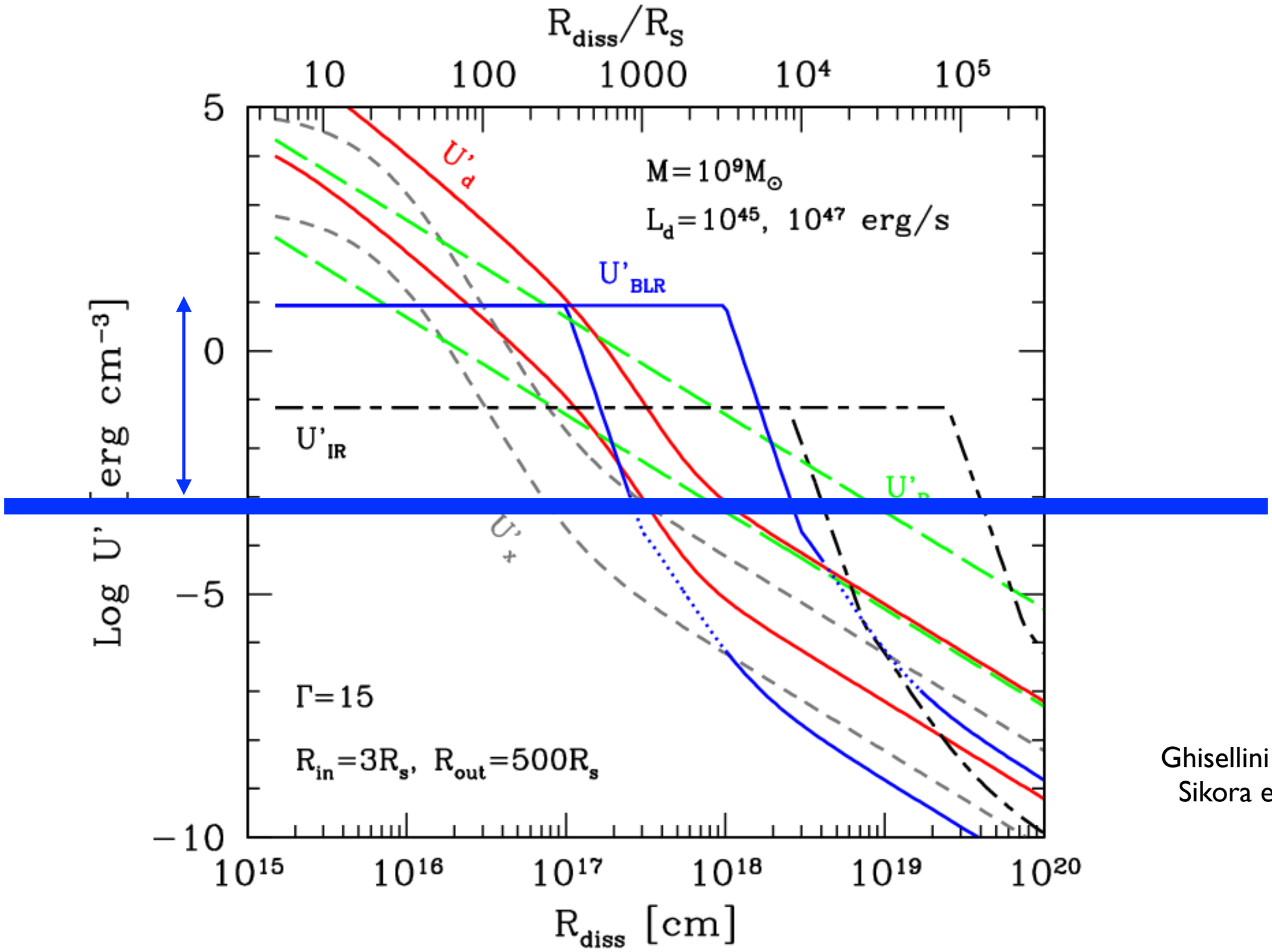
Cao et al. (LHAASO) 2024

Alternatives?

to reduce absorption but staying within the BLR ?

1. *Much larger BLR (~100x)* $\tau \propto 1/R_{\rm BLR}$
2. *Shift $\gamma\gamma$ threshold by selecting angles ("Flattened BLR")*

1. Energy density U_{BLR} goes down 10^{-4}



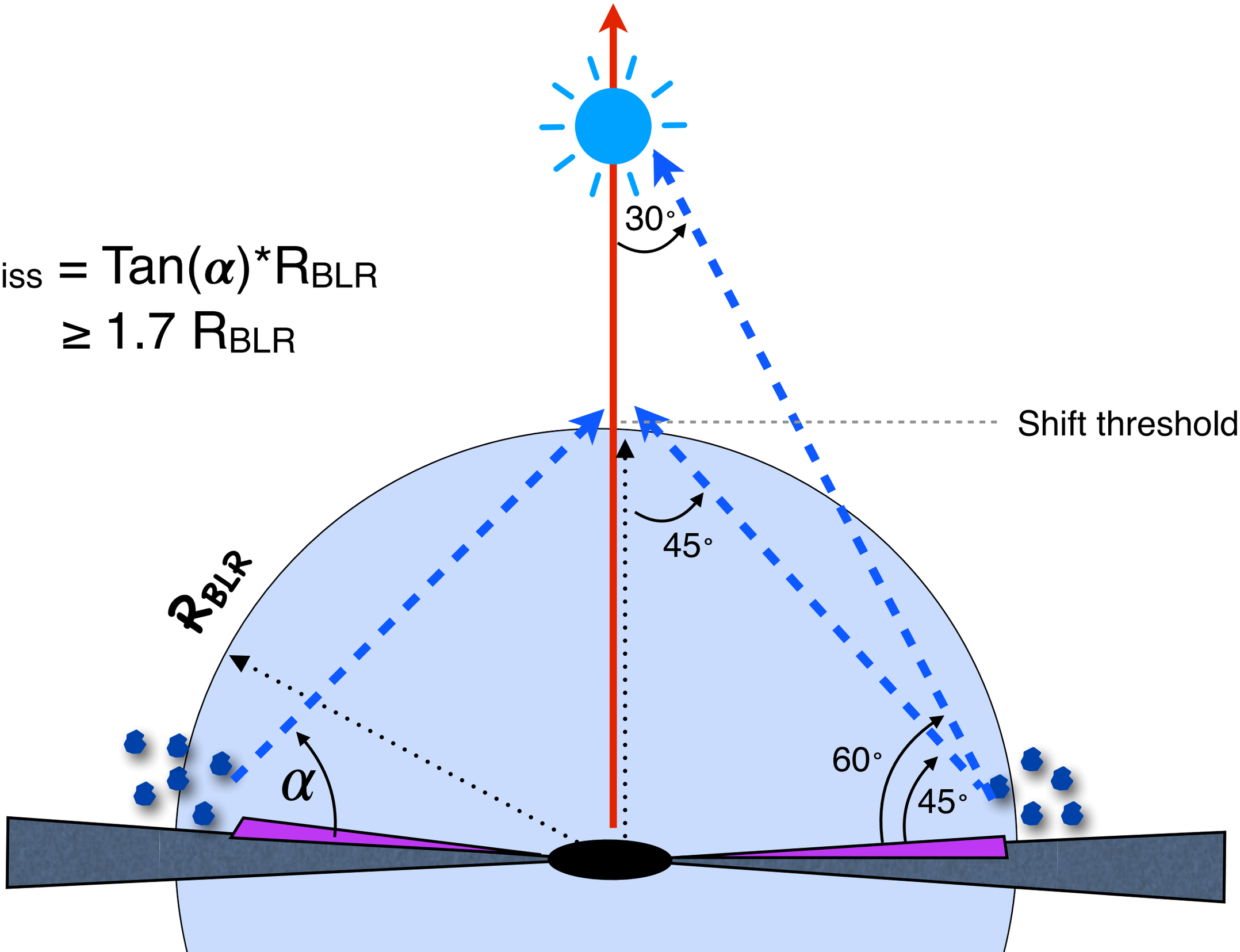
Ghisellini et al. 2009
Sikora et al. 2009

U_{BLR} ***becomes lower than any other radiation field***
—> EC(BLR) disfavoured

2. Shift threshold 5x (to ~100 GeV) —> $\vartheta \leq$ 30 deg

$R_{diss} = Tan(\alpha)*R_{BLR}$

$\geq 1.7\ R_{BLR}$



Alternatives?

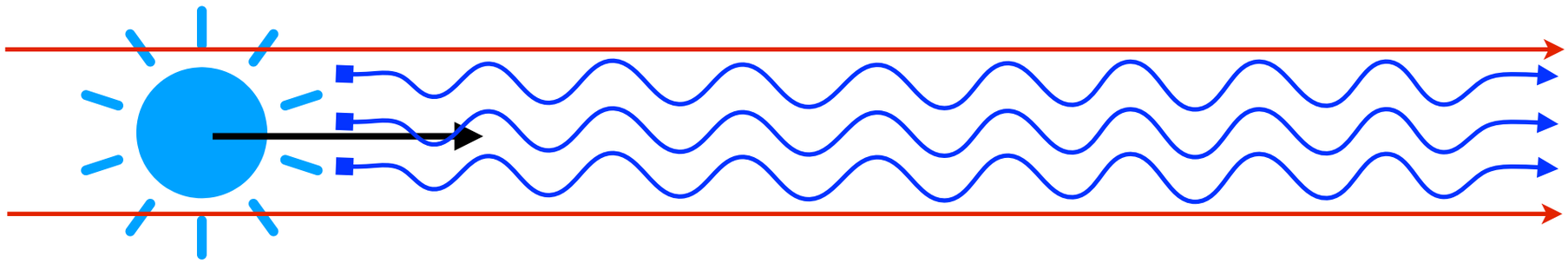
to reduce absorption but staying within the BLR ?

1. *Much larger BLR (~100x)* $\tau \propto 1/R_{\rm BLR}$
2. *Shift $\gamma\gamma$ threshold by selecting angles ("Flattened BLR")*

Both do NOT keep EC(BLR) viable

BLR $\tau \equiv \tau(\ell, E)$

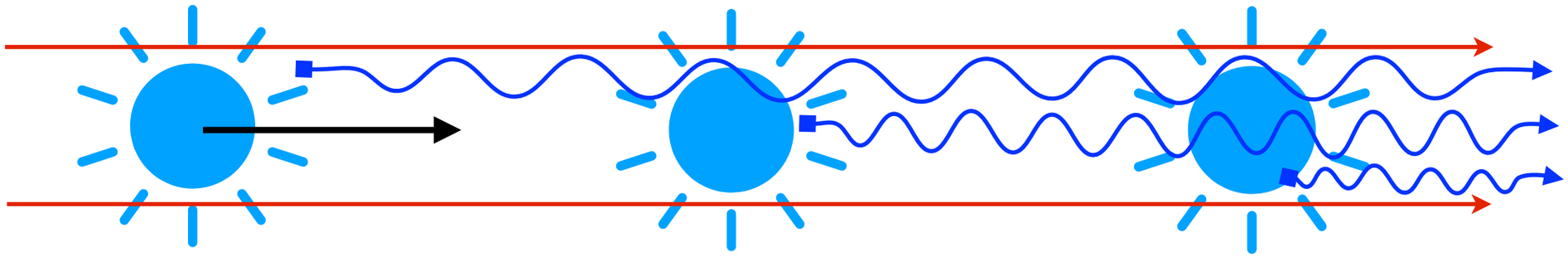
Localized



$e^{-\tau}$

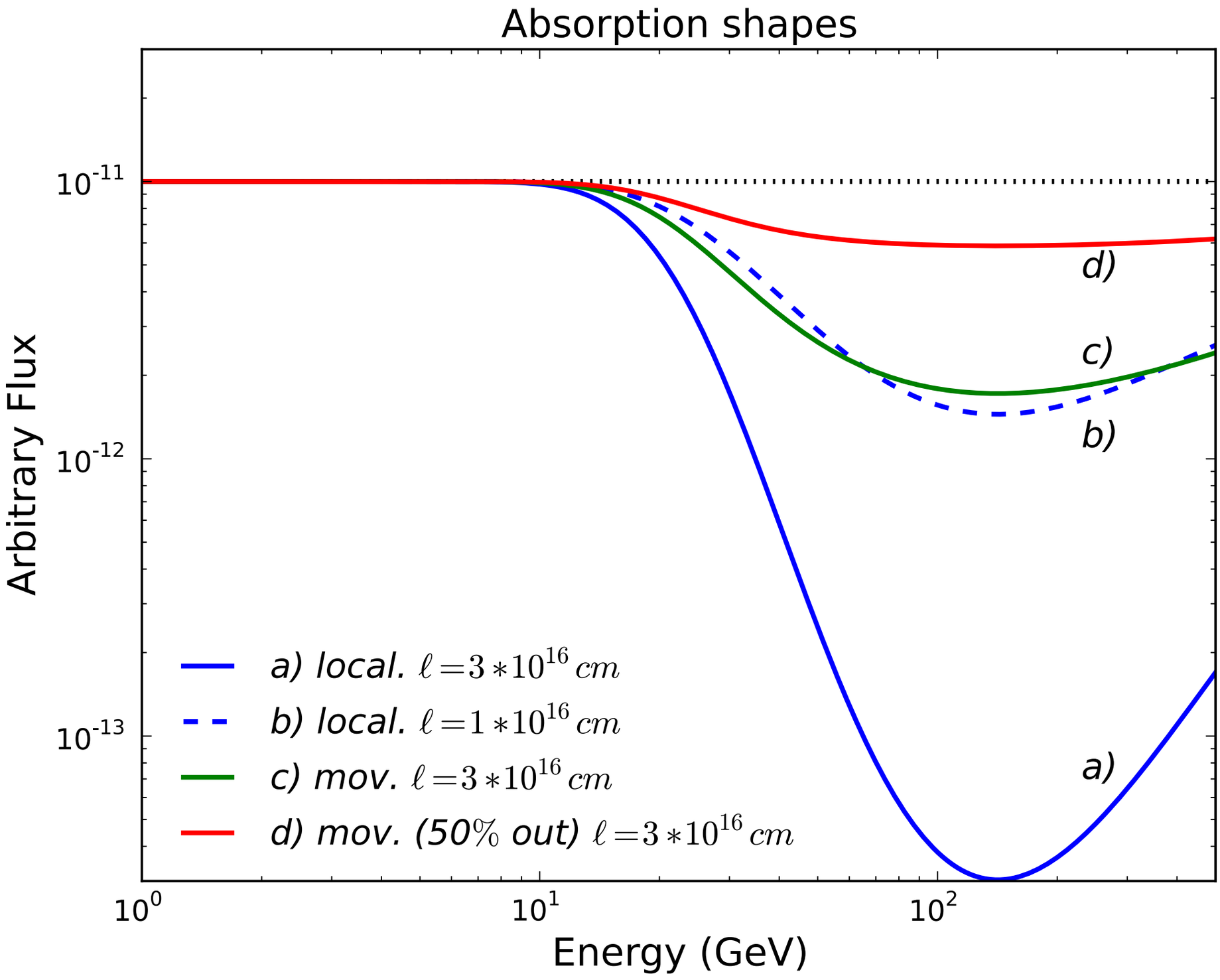
distance ℓ

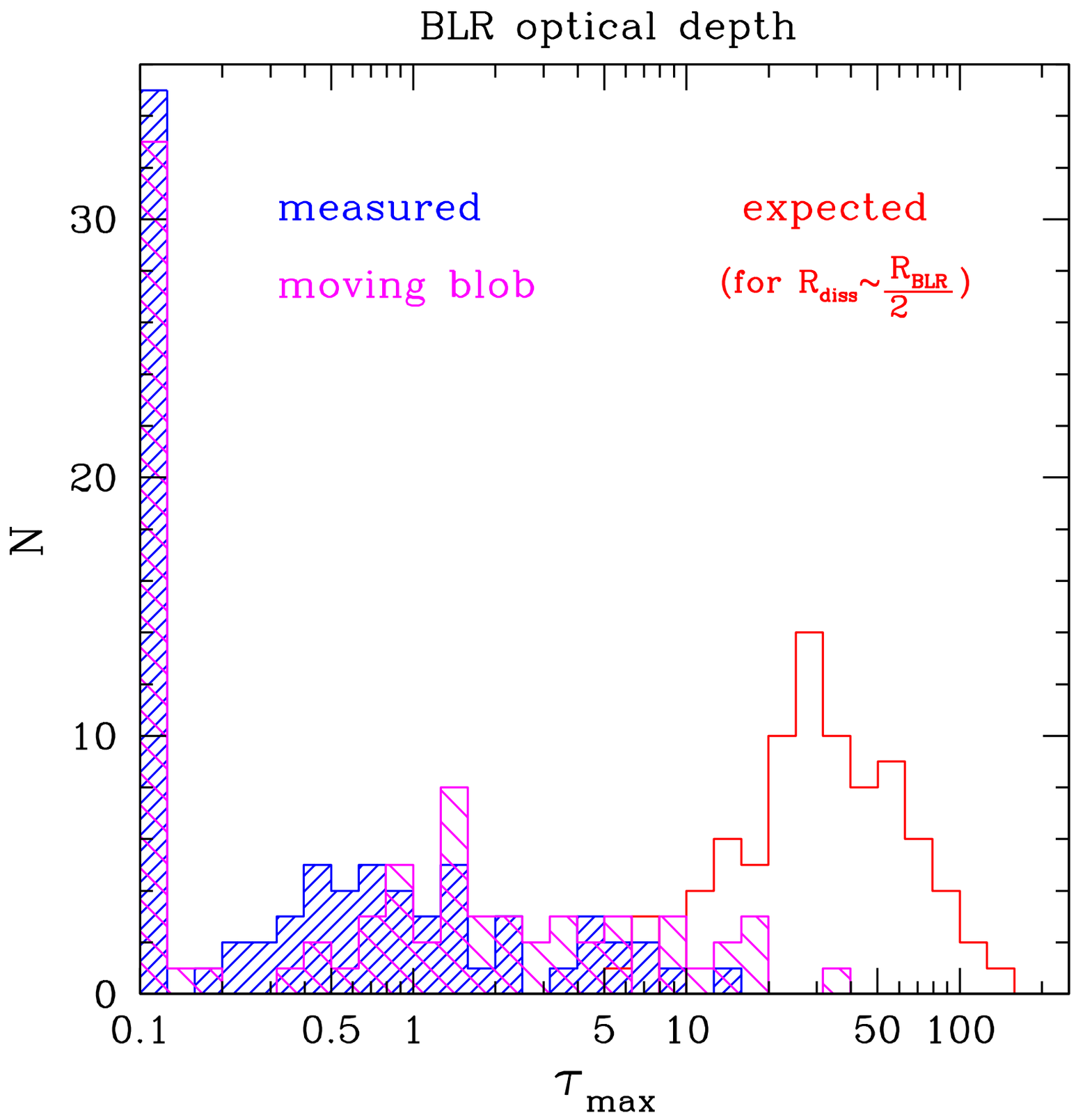
Moving



$$\frac{(1-e^{-\tau})}{\tau}$$

We can gain a factor ~3 in path length

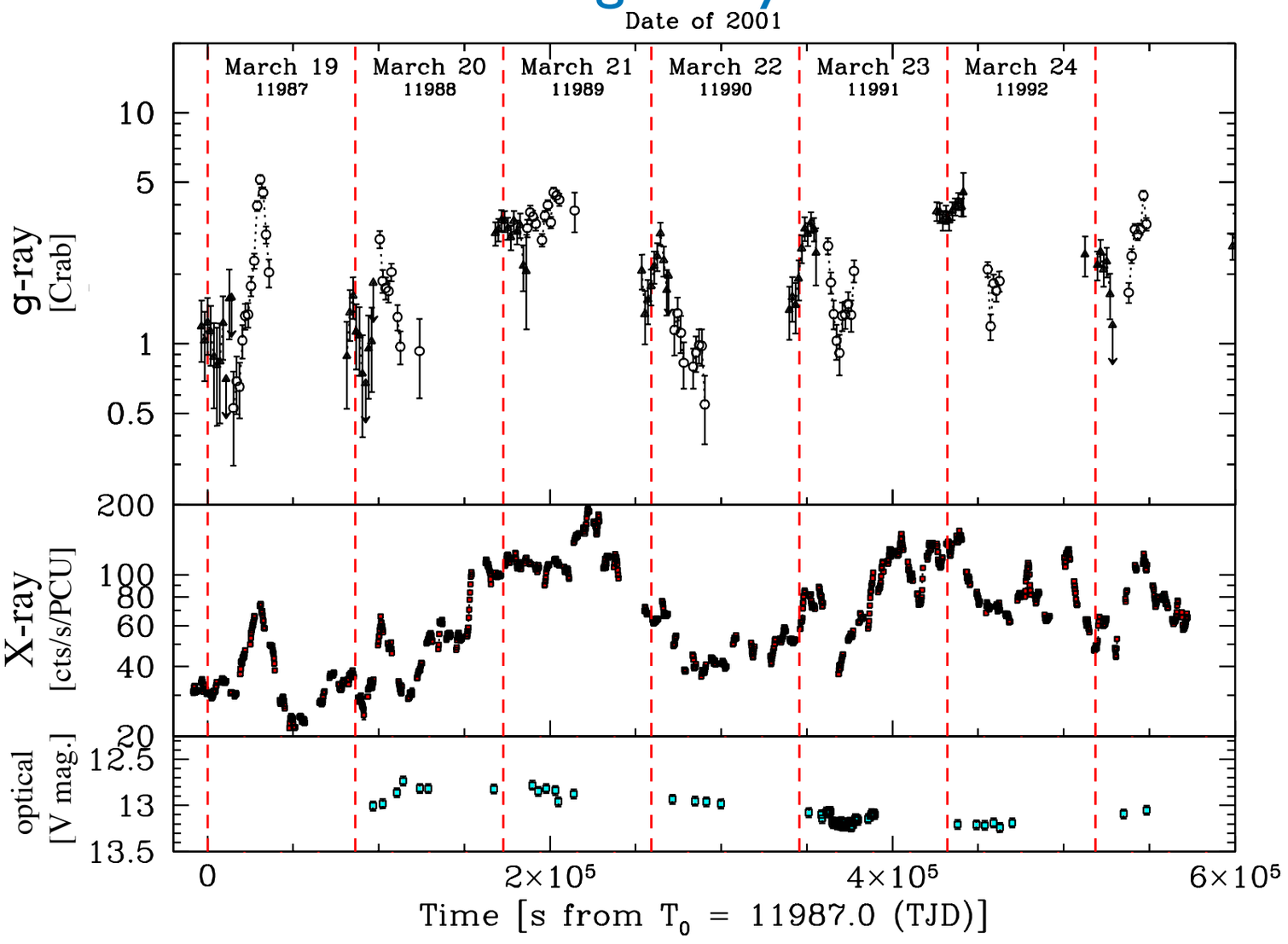




It does **NOT** *change the main result*

In flares X-ray - TeV correlation(s)

Mkn 421: strong X-ray-TeV correlation



Fossati et al. 2000

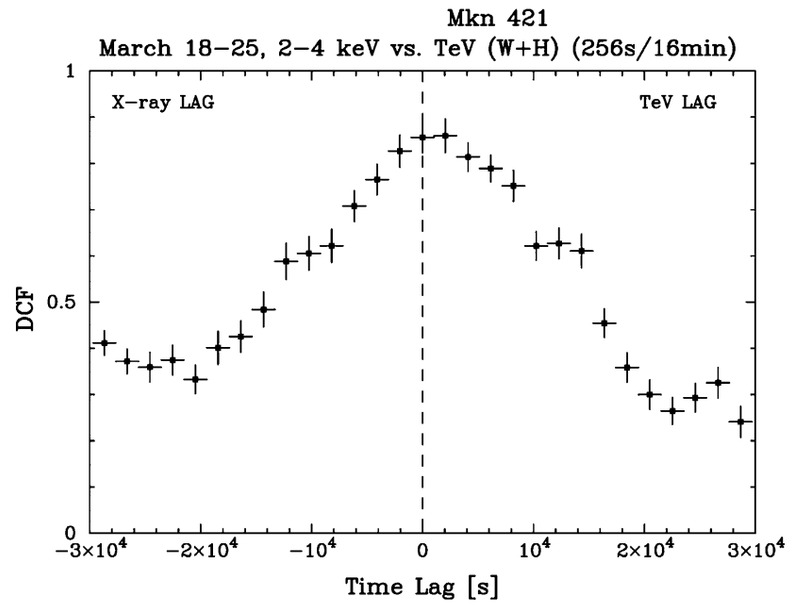
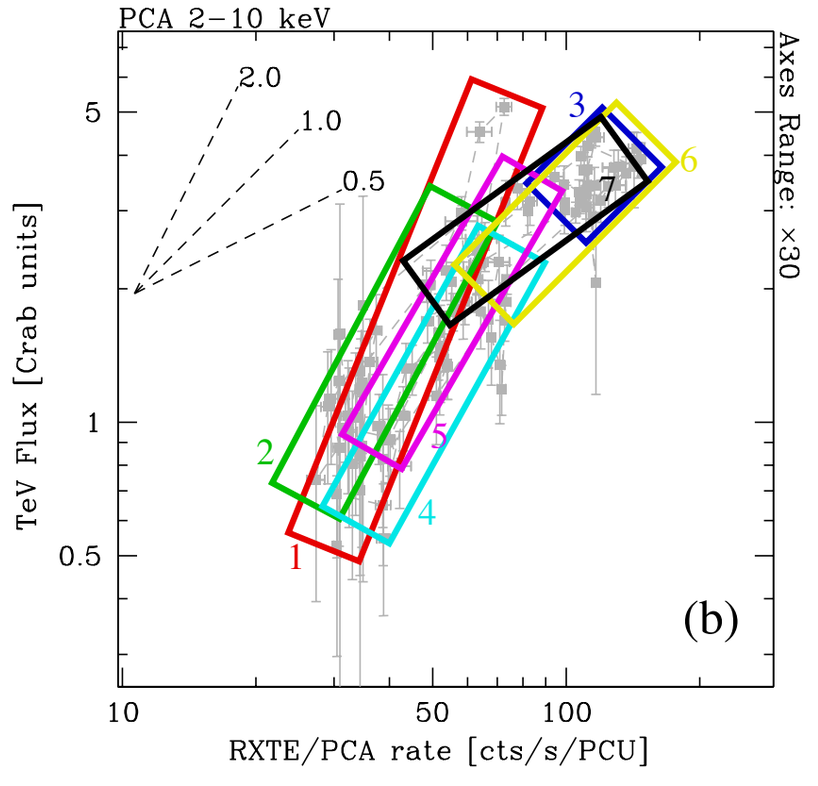


Fig. 2. Cross correlation between the X-ray (2–4 keV) and the TeV light curves for the whole campaign (computed over 2048 s bins, from X-ray data on 256 s bins, and TeV data on ∼750 s bins).

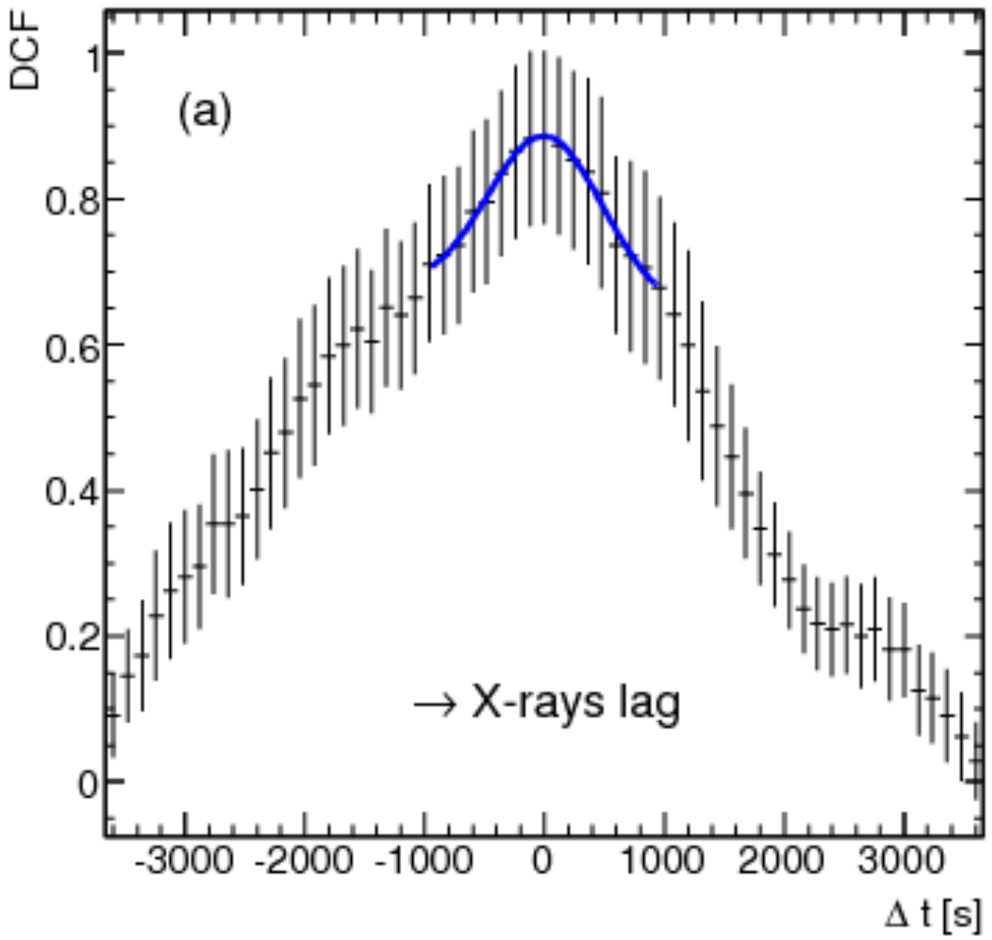


=> same population of electrons

PKS 2155-304 in July 2006

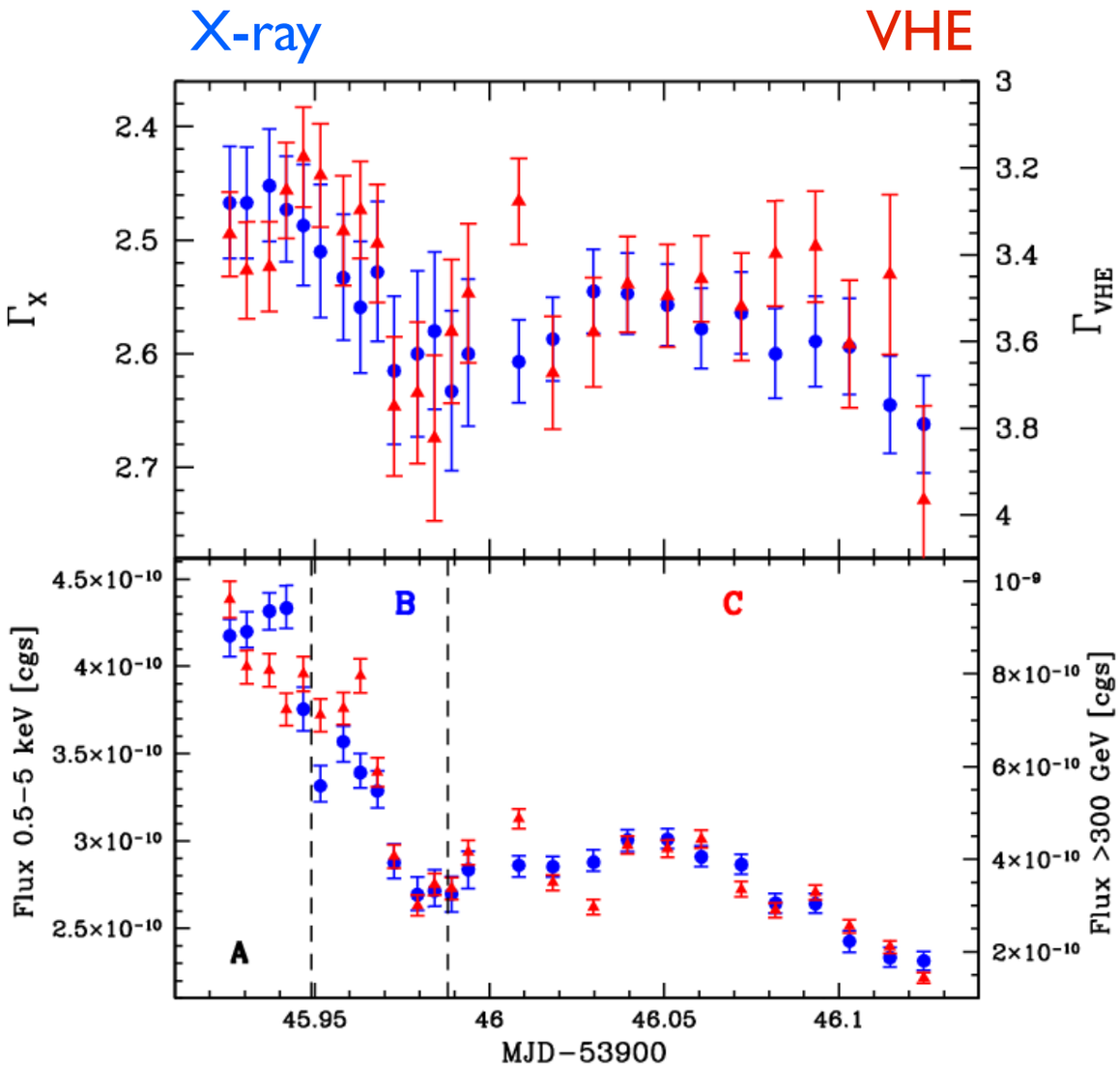
Strong and strict correlation in time & spectrum

DCF X-TeV



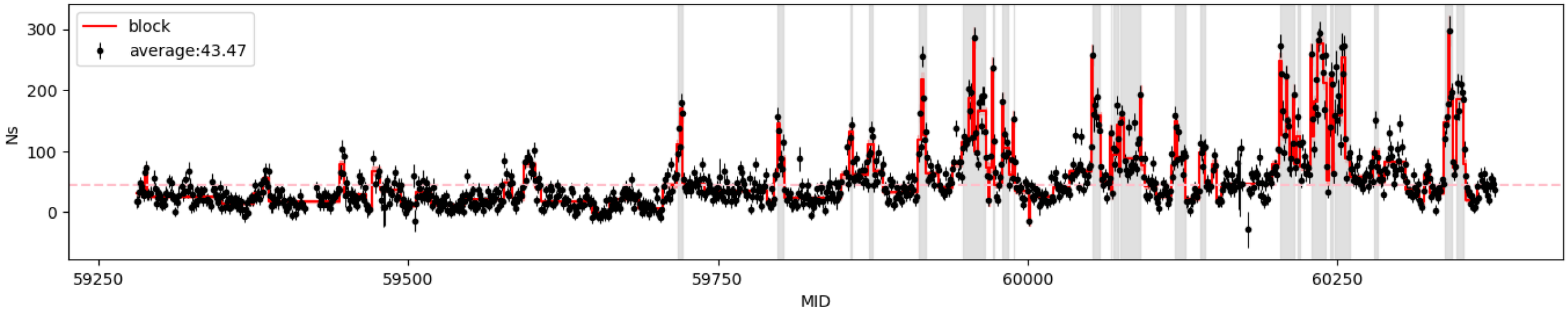
95% upper limit on lags: ~ 200s

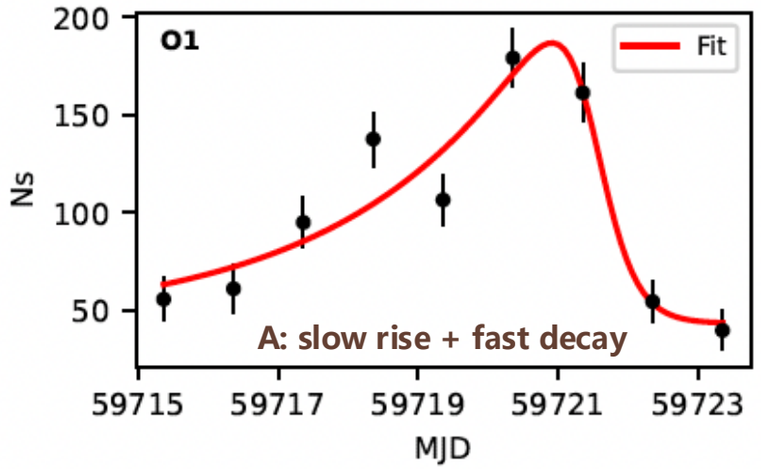
Time-resolved spectroscopy, 7-14 min bins

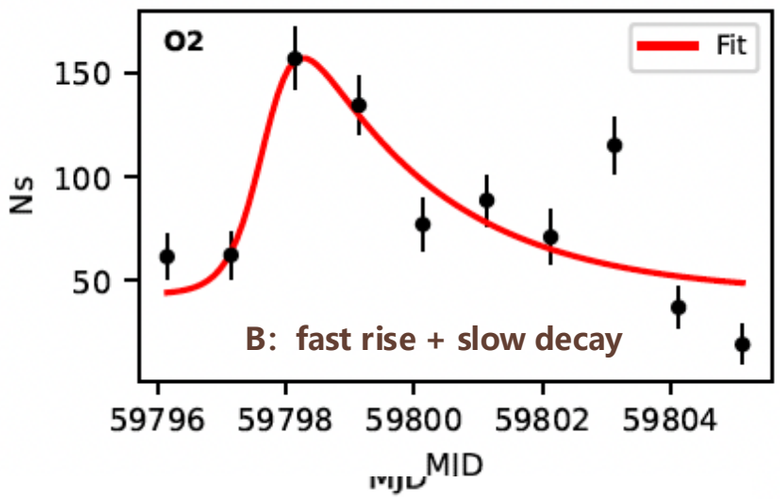


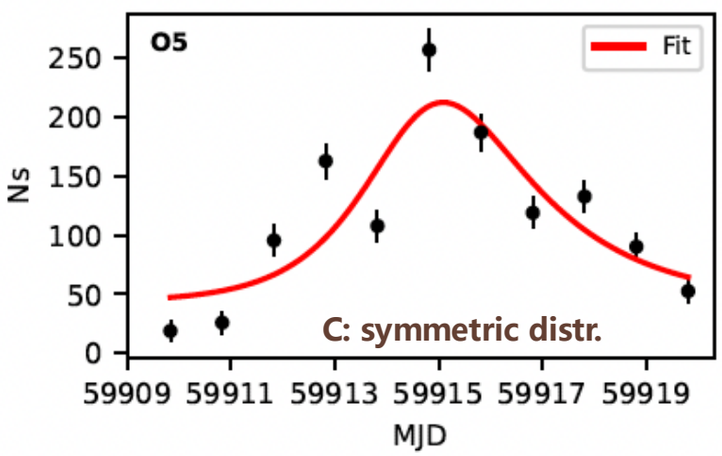
Aharonian et al. (HESS coll.) 2009

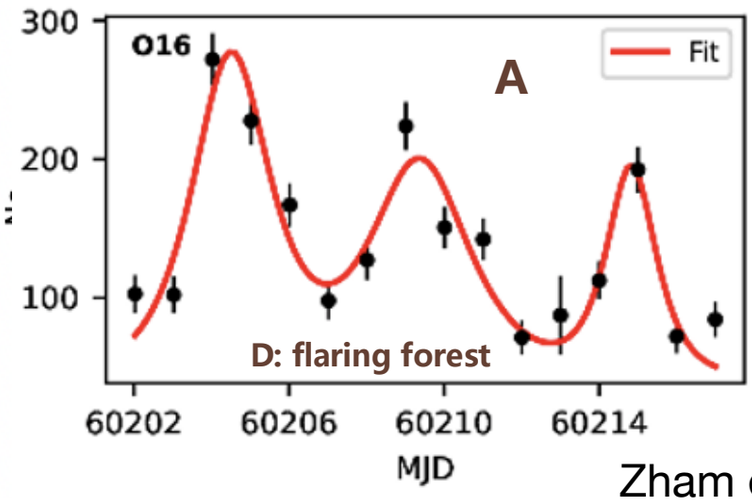
Mrk 421 Daily Light curve @ LHAASO-WCDA: 20210308 - 20240308











Zham et al. (Heidelberg2026),
LHAASO Collab. 2026