UNIVERSITÀ DEGLI STUDI DI PADOVA

ICRC2019
Madison, WI, USA

INFN

Extreme blazars and their TeV gamma-ray emission: are they a unique population?

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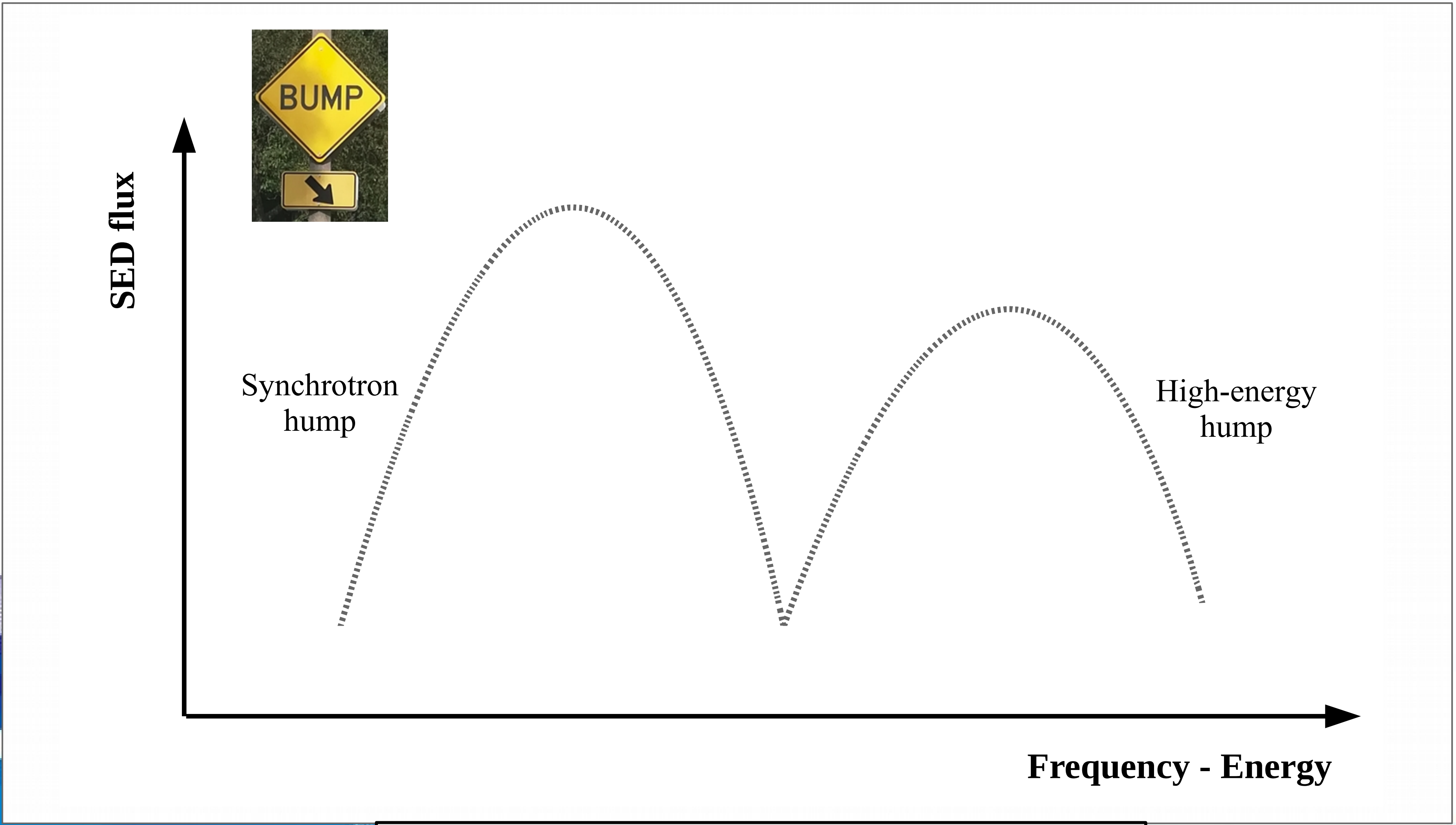
ICRC2019, Madison WI
July 29th, 2019

Overview

- Main **observational differences** in the broad-band SED of extreme blazars (EHBLs)
- A new **sample** of hard X-rays selected EHBLs
- Are we facing with a **population** of EHBLs?
- Looking for new TeV extreme blazars **candidates**

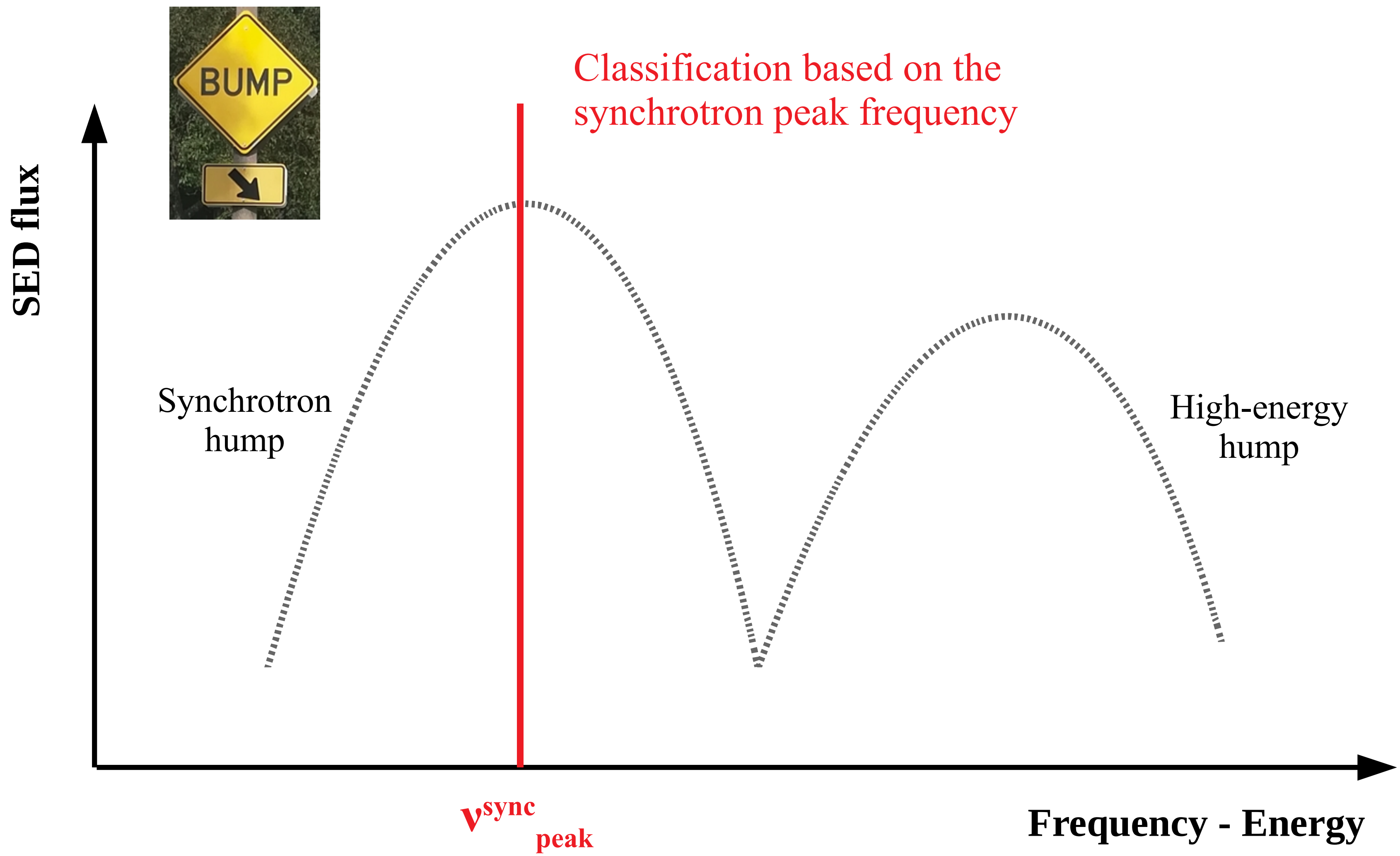
The idea

BL Lac objects



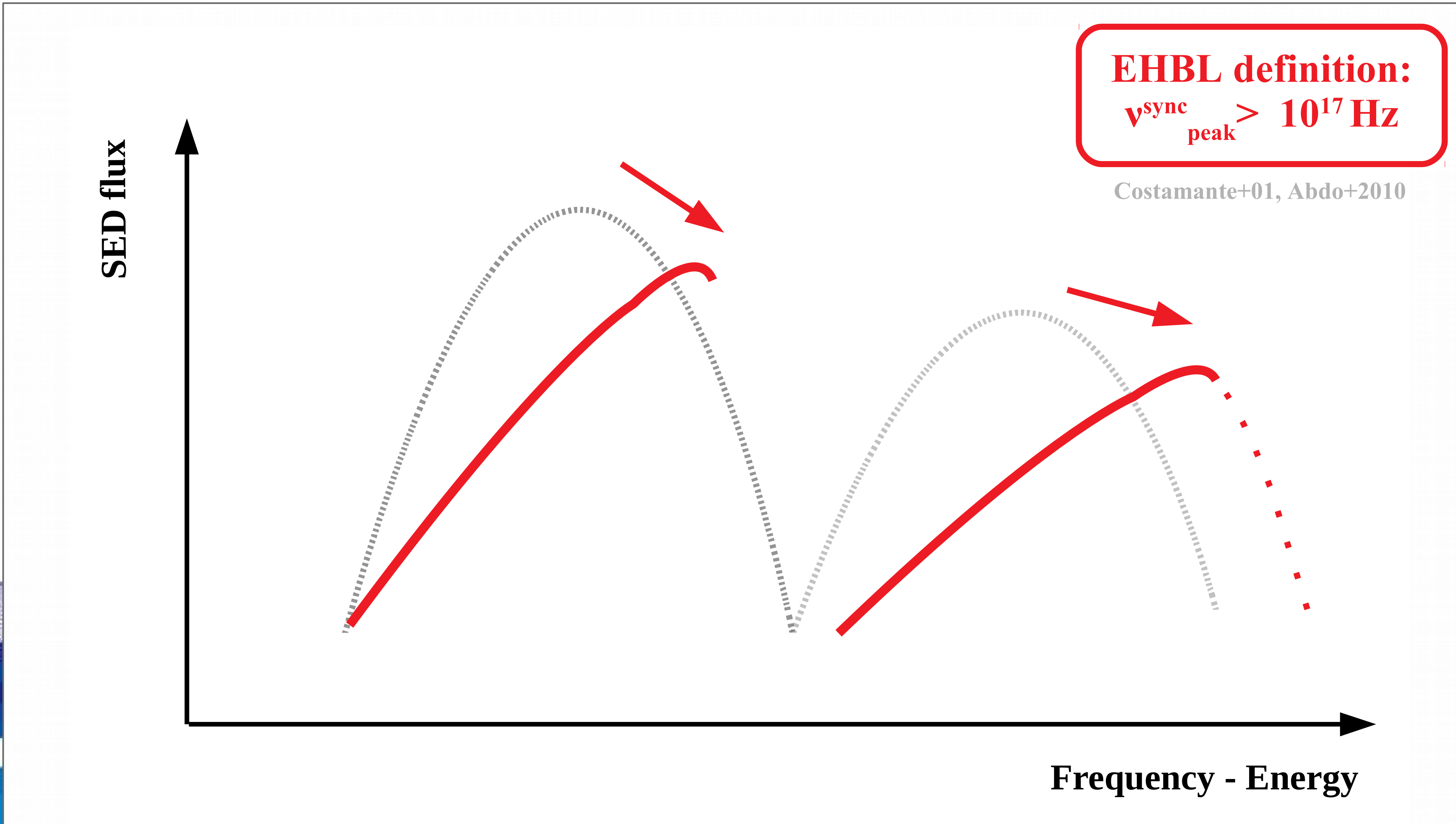
Sketch of HSP blazars spectral energy distribution (SED)

BL Lac objects



Sketch of HSP blazars spectral energy distribution (SED)

Extreme blazars



Sketch of extreme blazars (EHBL) spectral energy distribution

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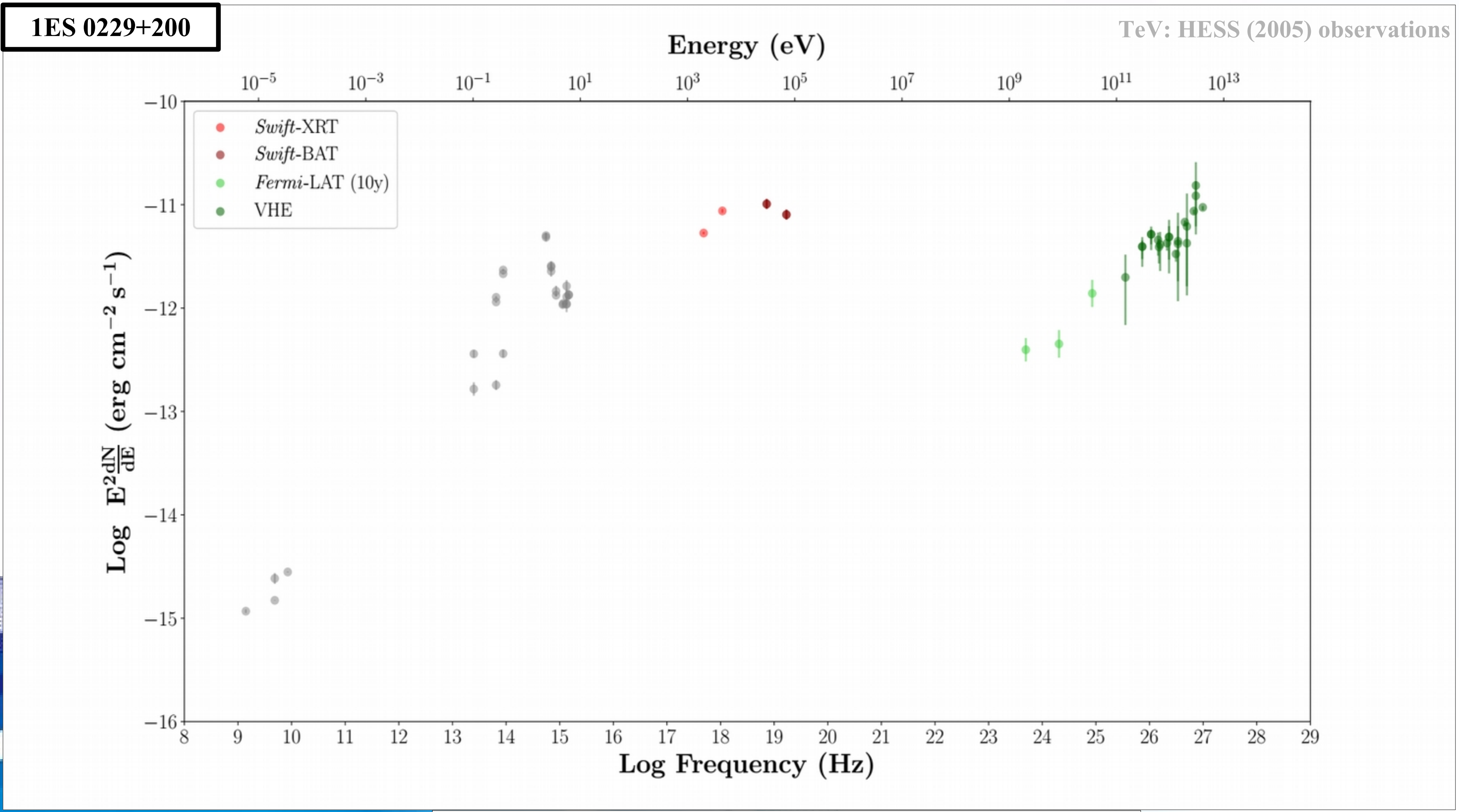
The archetypal extreme blazar

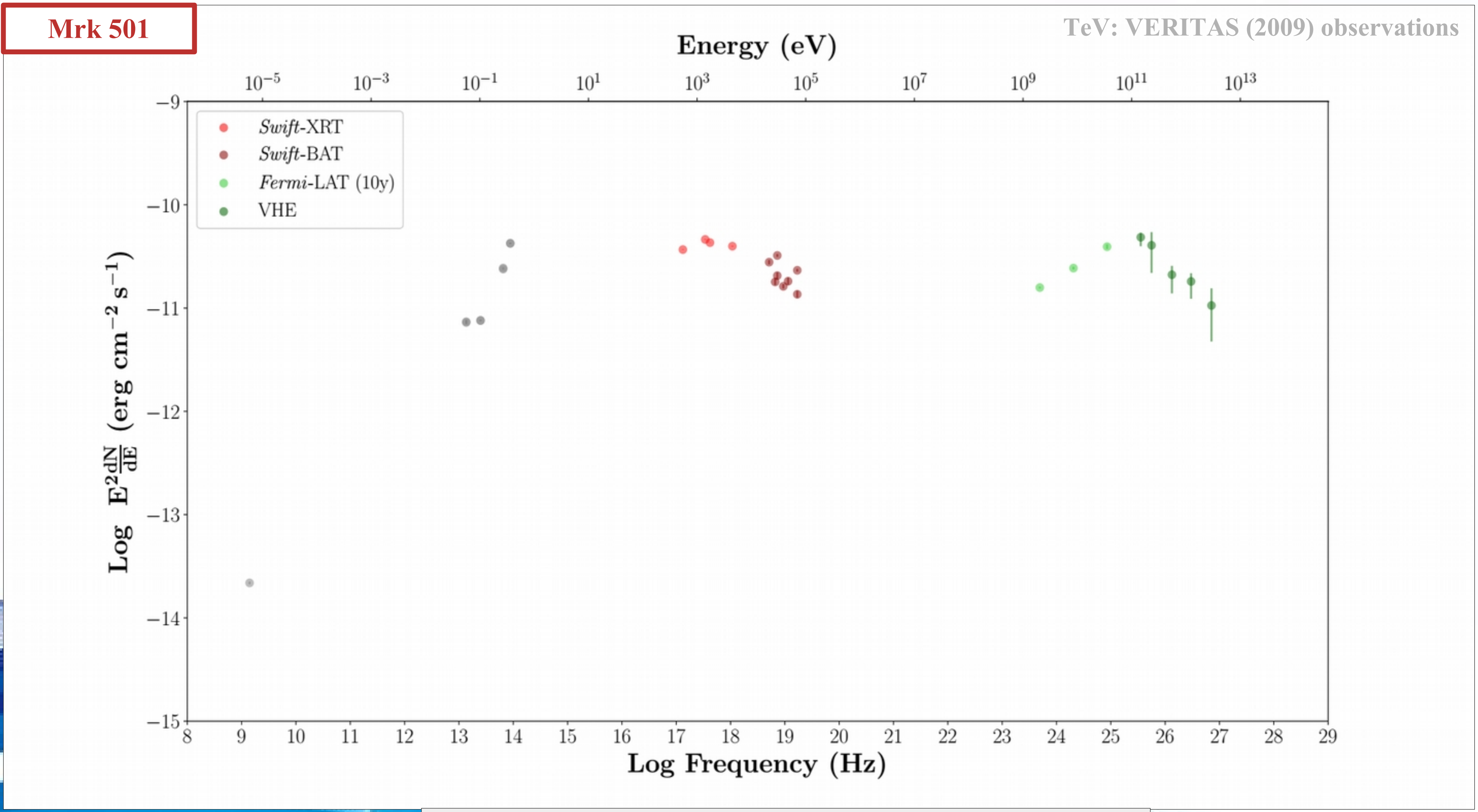
1ES 0229+200



1ES 0229+200 broad-band intrinsic SED
archival data (SSDC website)

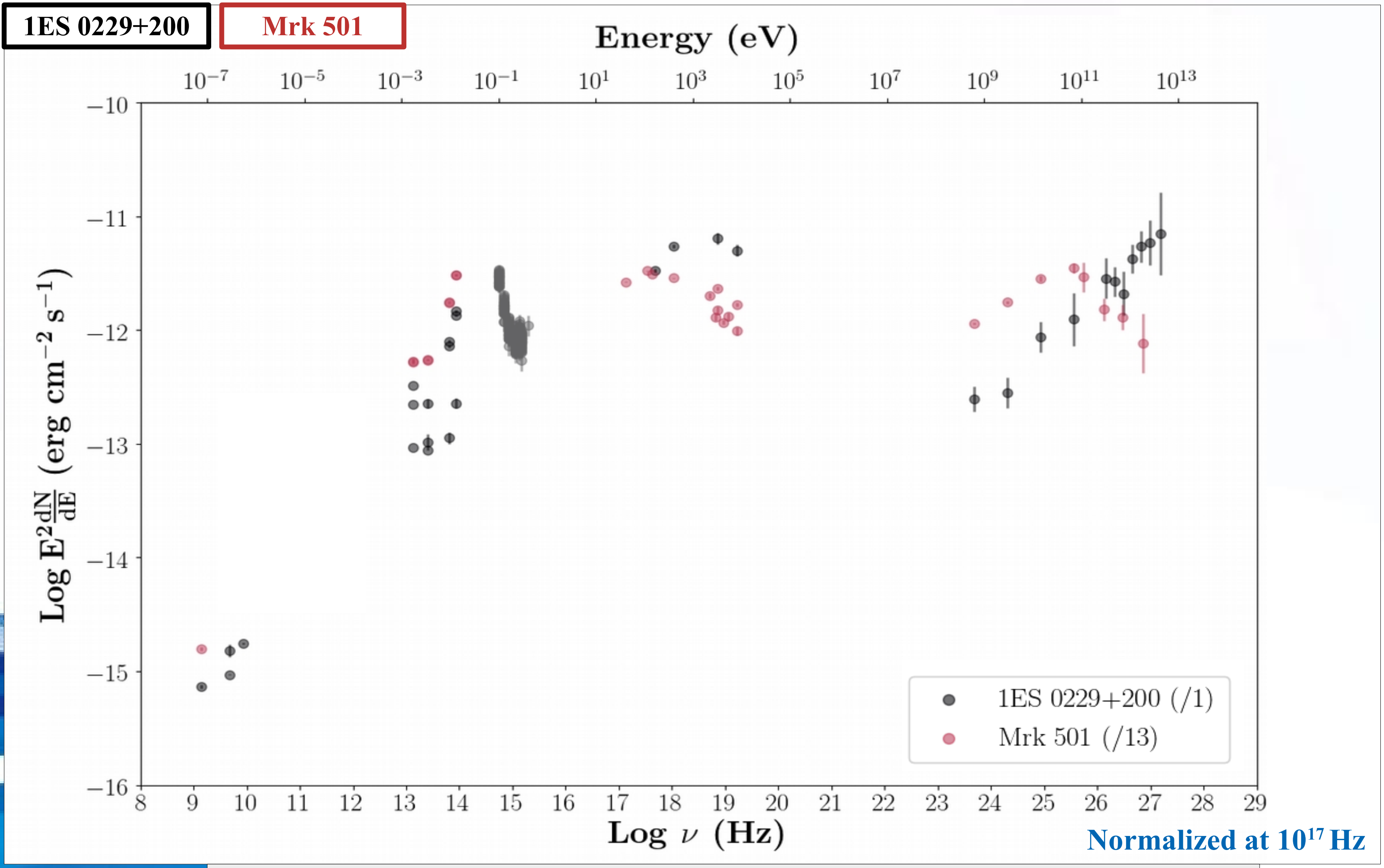
Another extreme blazar

Mrk 501

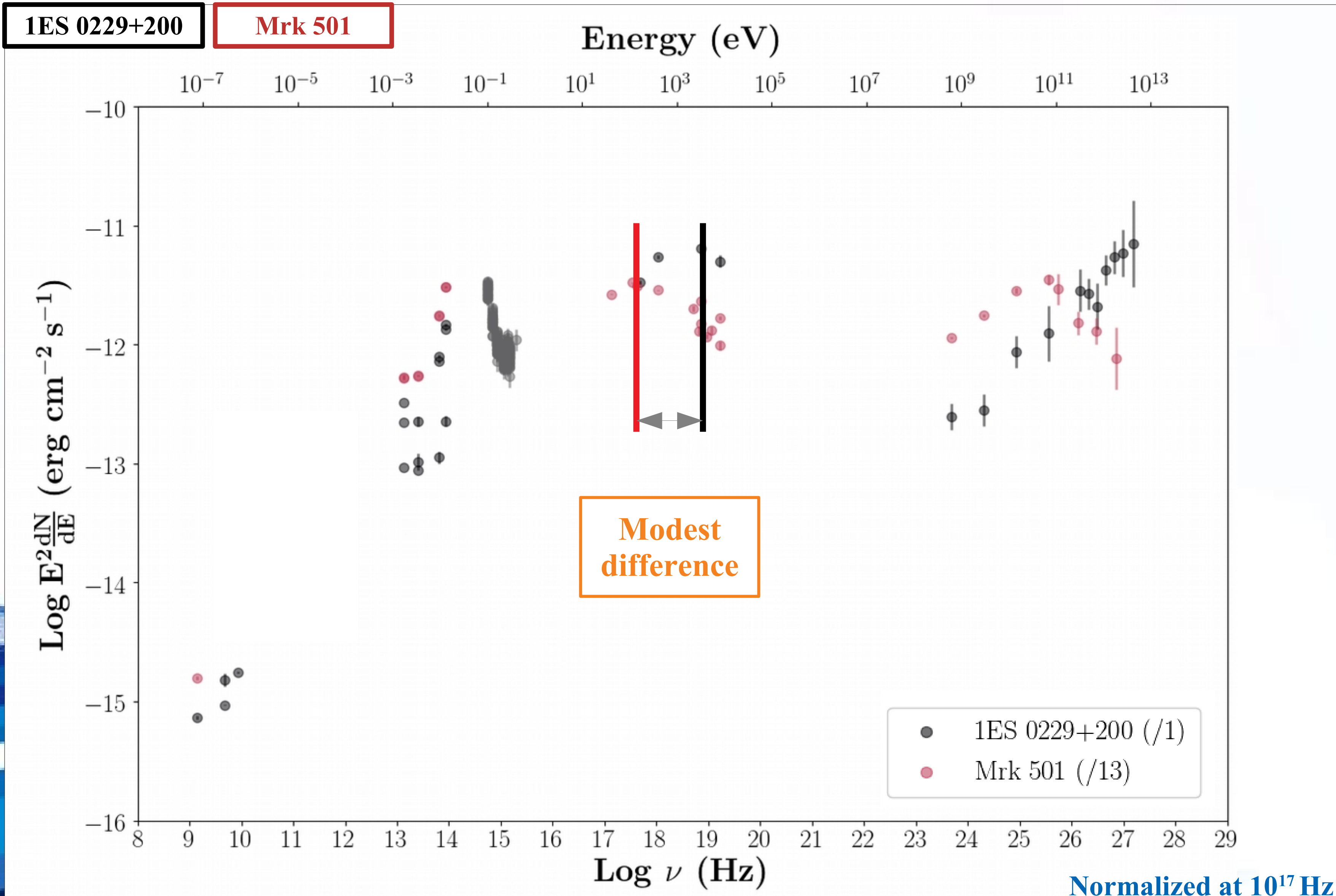


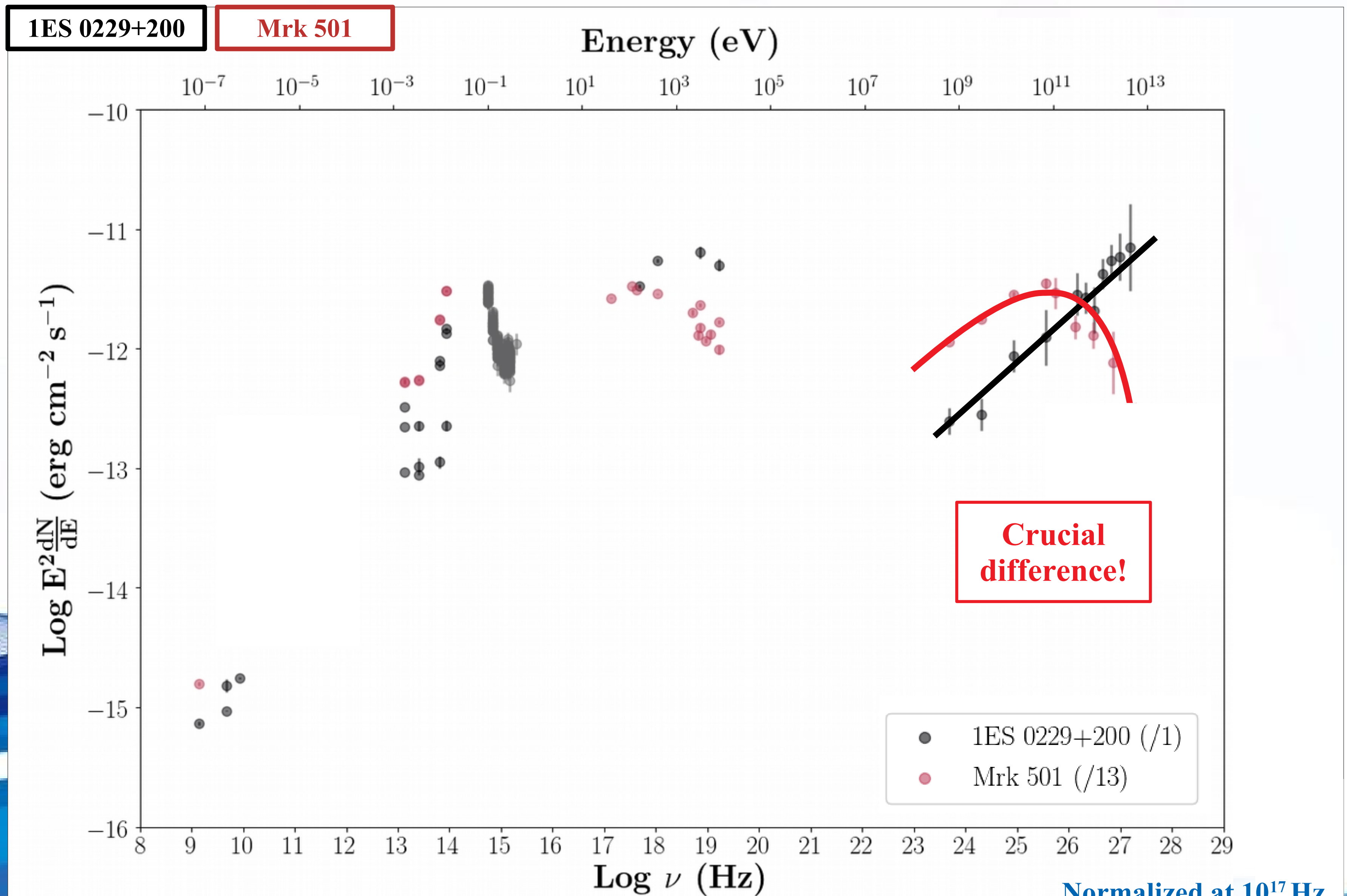
Mrk 501 broad-band intrinsic SED
archival data (SSDC website)

Extreme blazars - comparison



Comparison of broad-band intrinsic SEDs
archival data (SSDC website)


1ES 0229+200
Mrk 501
Energy (eV)
10^{-7} 10^{-5} 10^{-3} 10^{-1} 10^{1} 10^{3} 10^{5} 10^{7} 10^{9} 10^{11} 10^{13}
Log $E^2\frac{dN}{dE}$ (erg cm^{-2} s^{-1})
−10 −11 −12 −13 −14 −15 −16
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Log ν (Hz)
Modest difference
1ES 0229+200 (/1)
Mrk 501 (/13)
Normalized at 10^{17} Hz



Normalized at 10^{17} Hz

A new sample of hard X-ray selected EHBLs

The idea

- **Find** a sample of good **EHBL representatives**
- **Compare** the broad-band **SEDs**
- **Study** the most important spectral **differences**:
  - Spectral properties in **X-rays** and **HE**
  - Relation between **HE** and **VHE** spectra
  - Relation between the **synchrotron peaks**

The project

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In this work, we consider only archival data (except for *Fermi*-LAT) and low-state activity of the sources

Select EHBLs in *Swift*-BAT 105 months catalogue

Misclassifications and errors in peak estimations

New 10years *Fermi*-LAT analysis

Build and compare the MWL SEDs

Sample of 32 EHBLs

TeV gamma-ray detected EHBLs

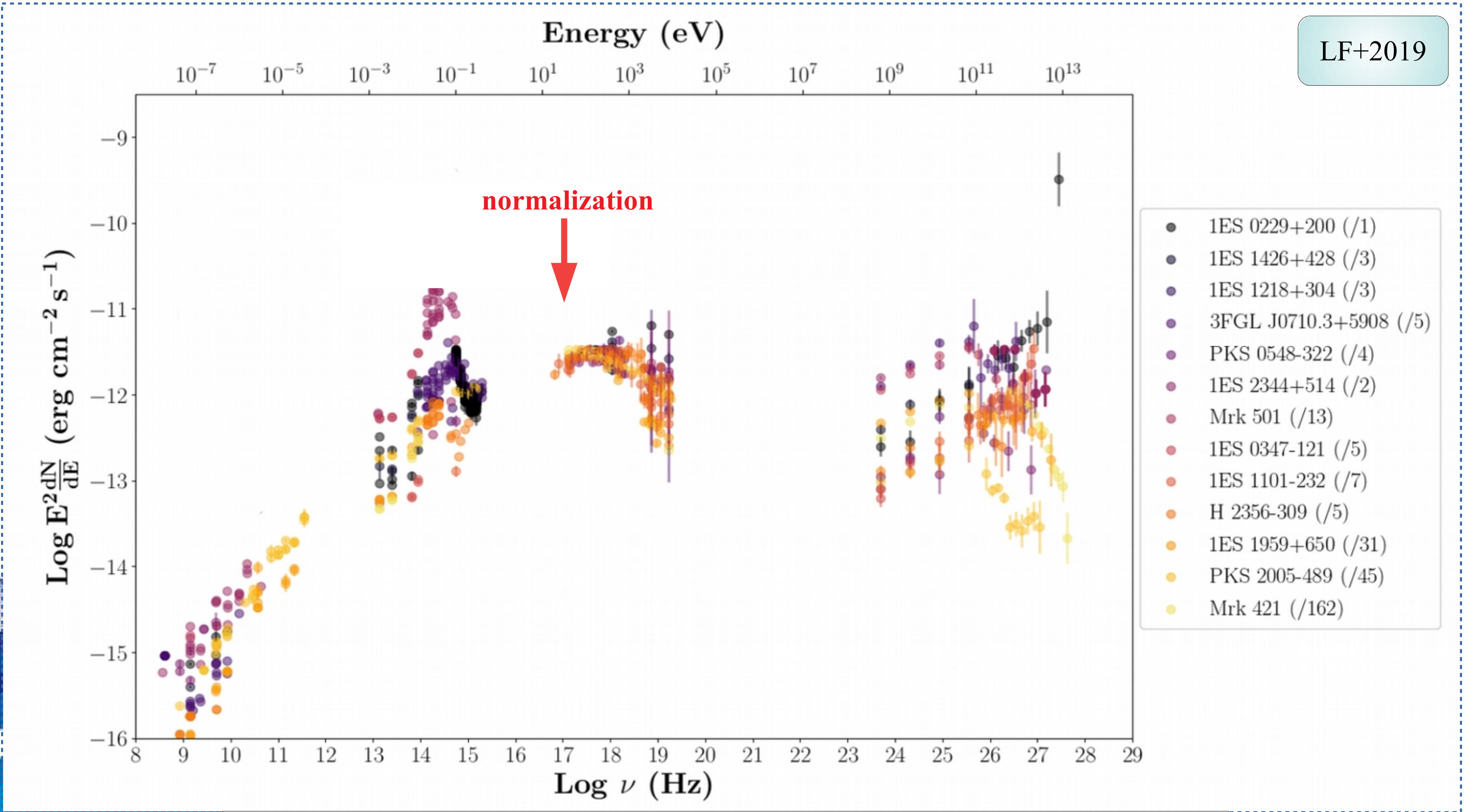
TeV gamma-ray undetected EHBLs

Study and compare the SEDs at TeV energies

Extrapolations to VHE

TeV gamma-ray detected EHBLs

Comparing the SEDs



Superimposition of all the SEDs with normalization at 10^{17} Hz
EBL deabsorbed data (Franceschini+17)

Comparing the SEDs in gamma rays

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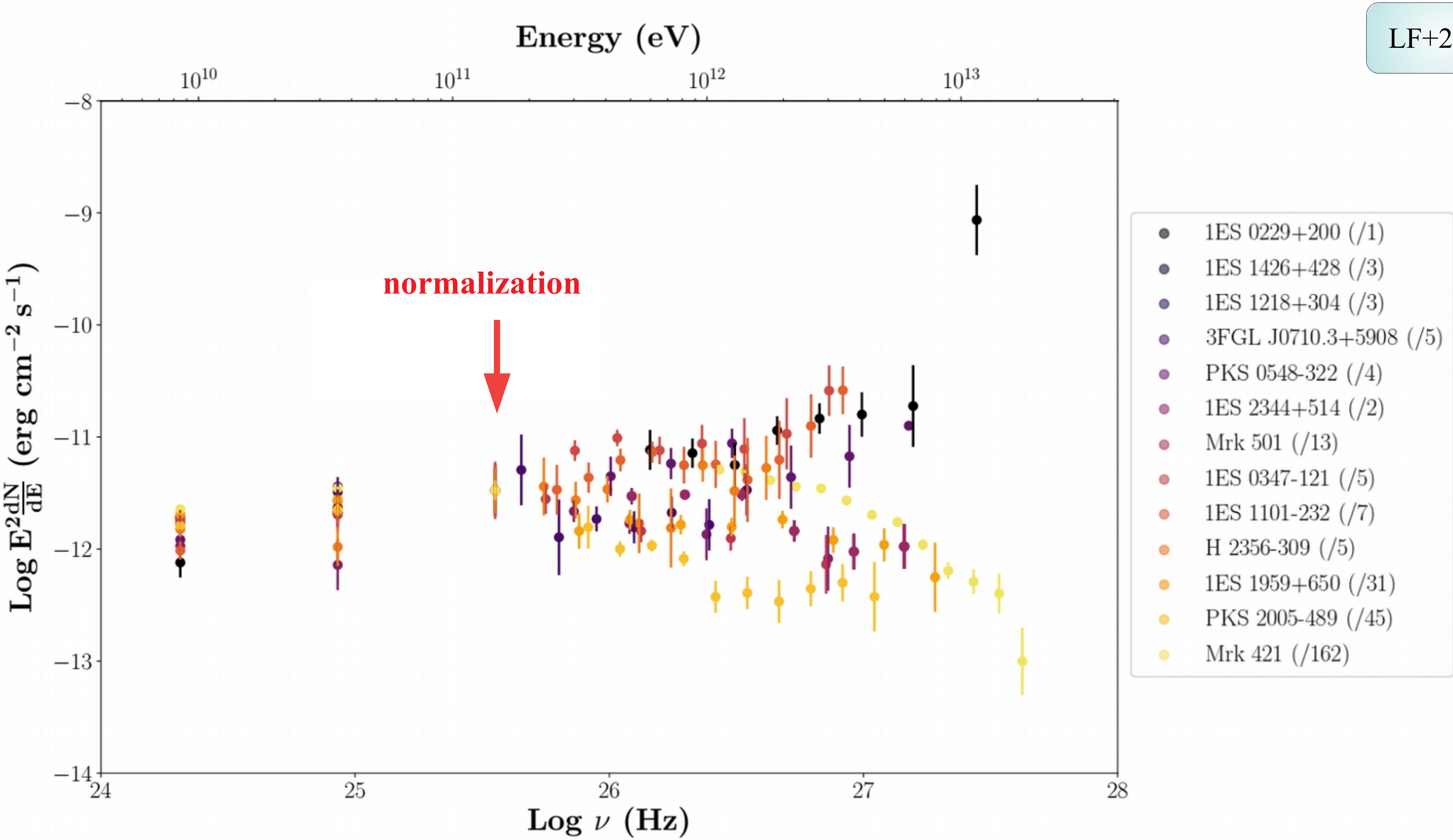

Focus on the TeV gamma-ray band with normalization at about 100 GeV

TeV gamma-ray slopes

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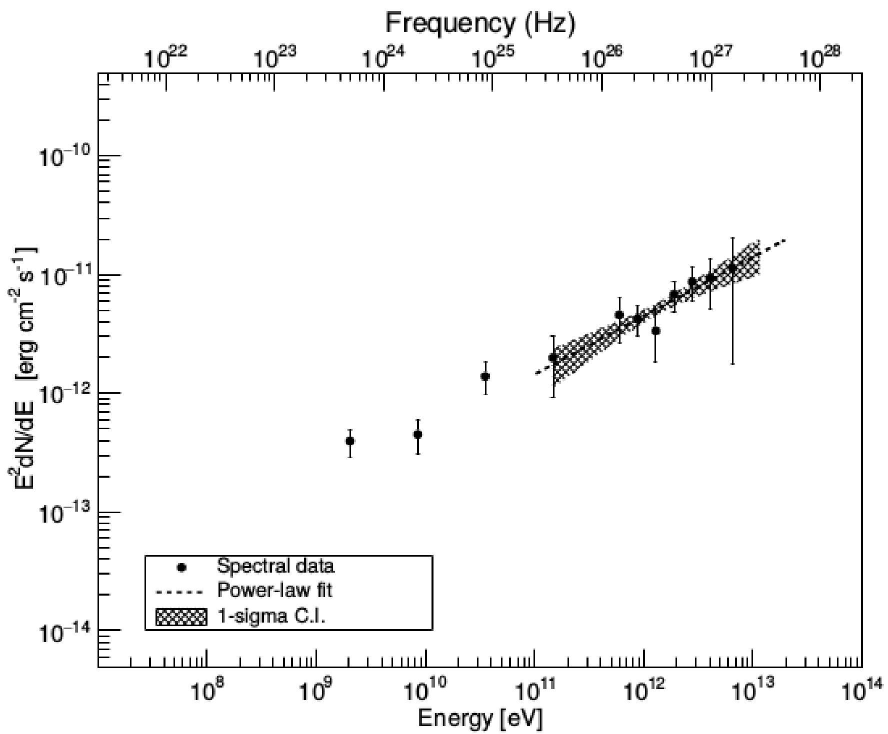
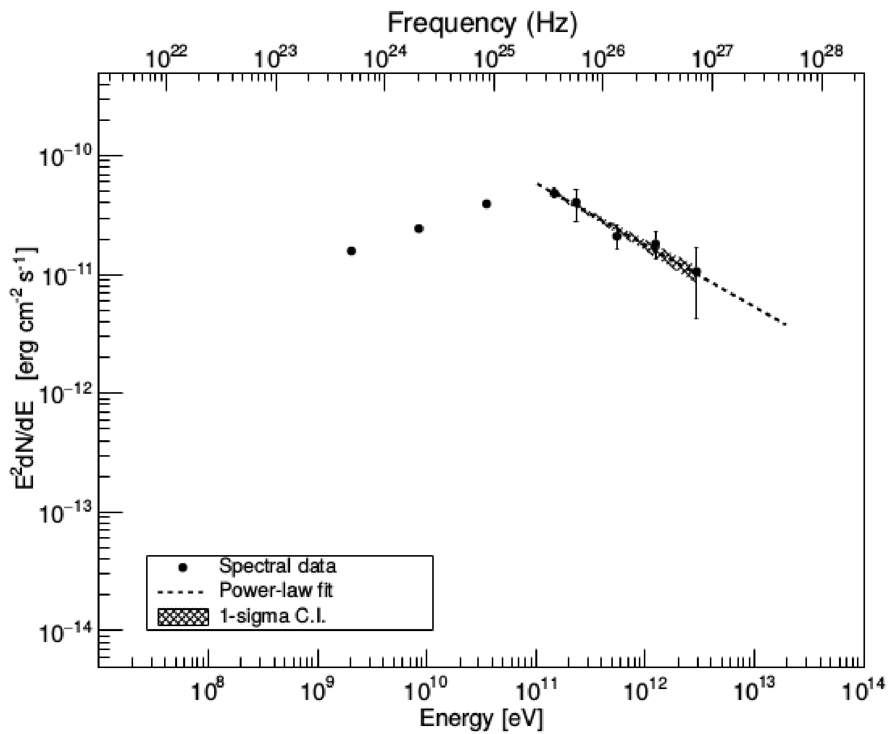


1ES 0229+200



Mrk 501

Synchrotron peak frequency vs TeV gamma-ray slope

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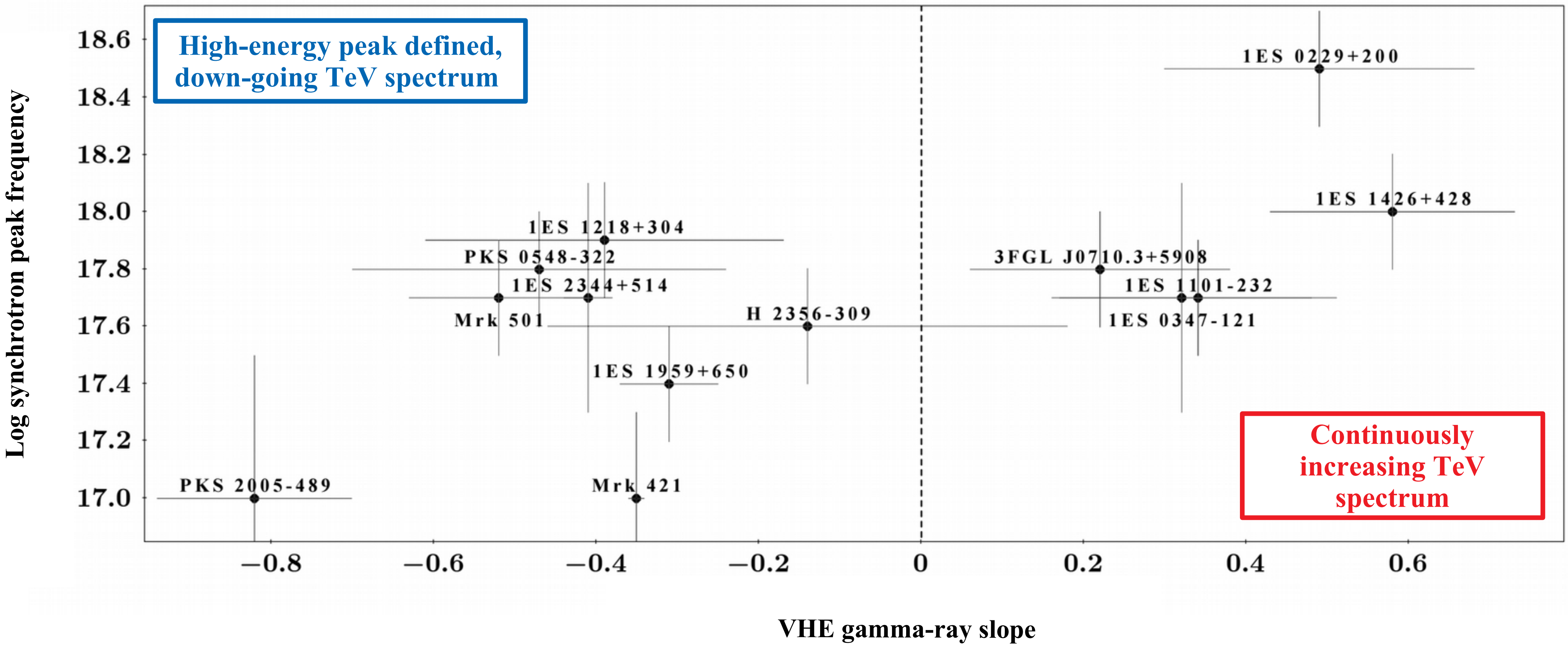

Synchrotron peak frequency vs TeV gamma-ray slope

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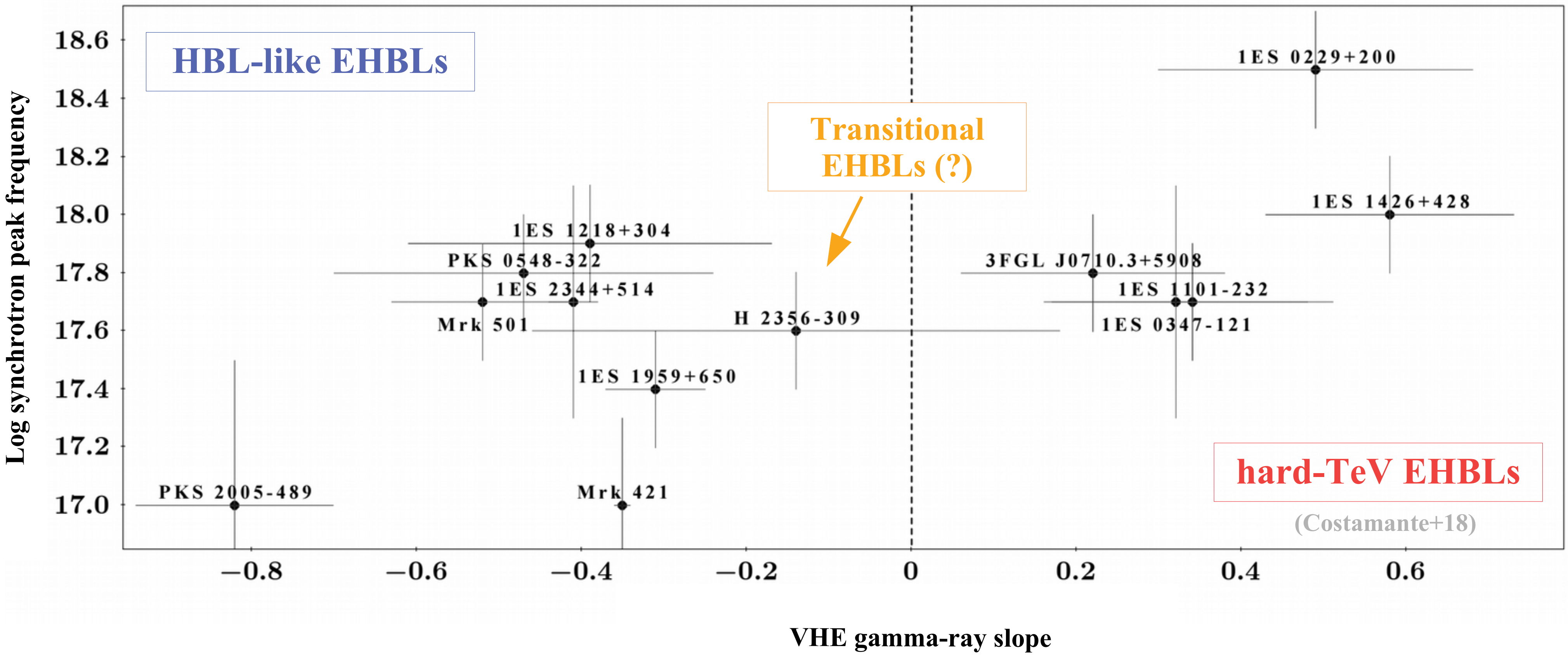

So many differences...

"hard-TeV" sources

→ The most known EHBL
→ e.g. 1ES 0229+200 – the archetypal EHBL
→ **hard-TeV** spectrum, **low TeV variability**
→ only few sources

Non hard-TeV sources ("Transitional")

→ a lot of sources
→ e.g. PKS 0548-322
→ decreasing spectrum at TeV energies

"HBL-like" extreme blazars

→ EHBL behaviour only when **flaring**
→ several sources, some of them not yet recognized as EHBLs
→ e.g. Mrk 501, 1ES 1218+304, 1ES 1959+650, 1ES 2344+514
→ **decreasing TeV** gamma-ray spectrum, high TeV variability

Is there a population of EHBLs behind these differences?

TeV gamma-ray undetected EHBLs

Next candidates for Cherenkov telescopes?

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#	*Swift*-BAT name	Counterpart	Log ν_{peak}^{sync} (Hz)
1	SWIFT J2251.8-3210	1RXS J225146.9-320614	18.3 ± 0.3
2	SWIFT J0733.9+5156	3FGL J0733.5+5153	18.3 ± 0.2
3	SWIFT J0244.8-5829	BZB J0244-5819	18.2 ± 0.3
4	SWIFT J0709.3-1527	PKS 0706-15	18.0 ± 0.2
5	SWIFT J0156.5-5303	RBS 259	18.0 ± 0.2
6	SWIFT J0353.4-6830	PKS 0352-686	18.0 ± 0.2
7	SWIFT J0122.9+3420	1ES 0120+340	17.7 ± 0.2
8	SWIFT J1417.7+2539	BZB J1417+2543	17.7 ± 0.2
9	SWIFT J0640.3-1286	TXS 0637-128	17.7 ± 0.2
10	SWIFT J2246.7-5208	RBS 1895	17.6 ± 0.2
11	SWIFT J0213.7+5147	1RXS J021417.8+514457	17.6 ± 0.2
12	SWIFT J1031.5+5051	1ES 1028+511	17.5 ± 0.2
13	SWIFT J0930.1+4987	1ES 0927+500	17.4 ± 0.4
14	SWIFT J0326.0-5633	1RXS J032521.8-56354	17.4 ± 0.2

Sample of 14 TeV gamma-ray undetected EHBLs

Detectability by Cherenkov telescopes

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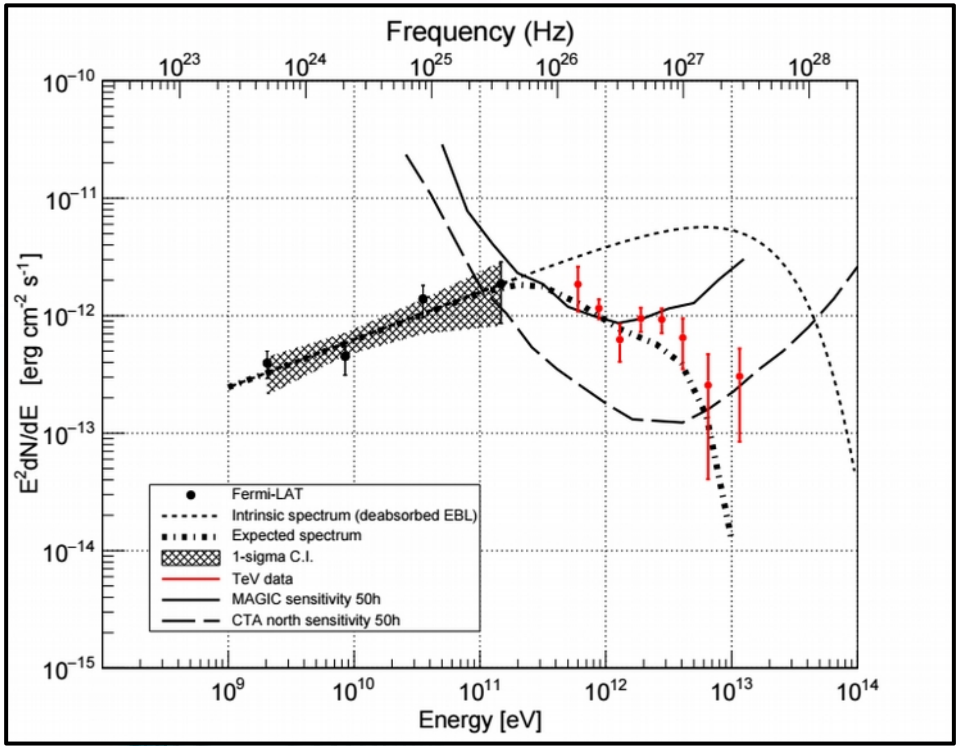
- The HE gamma ray data should be on the rising part of the high-energy hump → **power-law** is a good approximation
- The **high-energy peak** can be approximated by adding a **cut-off** at $E_{cut\text{-}off}$

BUT

- **Redshift** is crucial due to EBL absorption
- The expected **cut-off** is very important



→ We consider all available redshifts
→ We apply a (very) **conservative cut-off at 1 TeV**

Example: in 1ES 0229+200, the extrapolation works only if considering a $E_{cut\text{-}off}$ = 12 TeV

Looking for new TeV EHBL candidates

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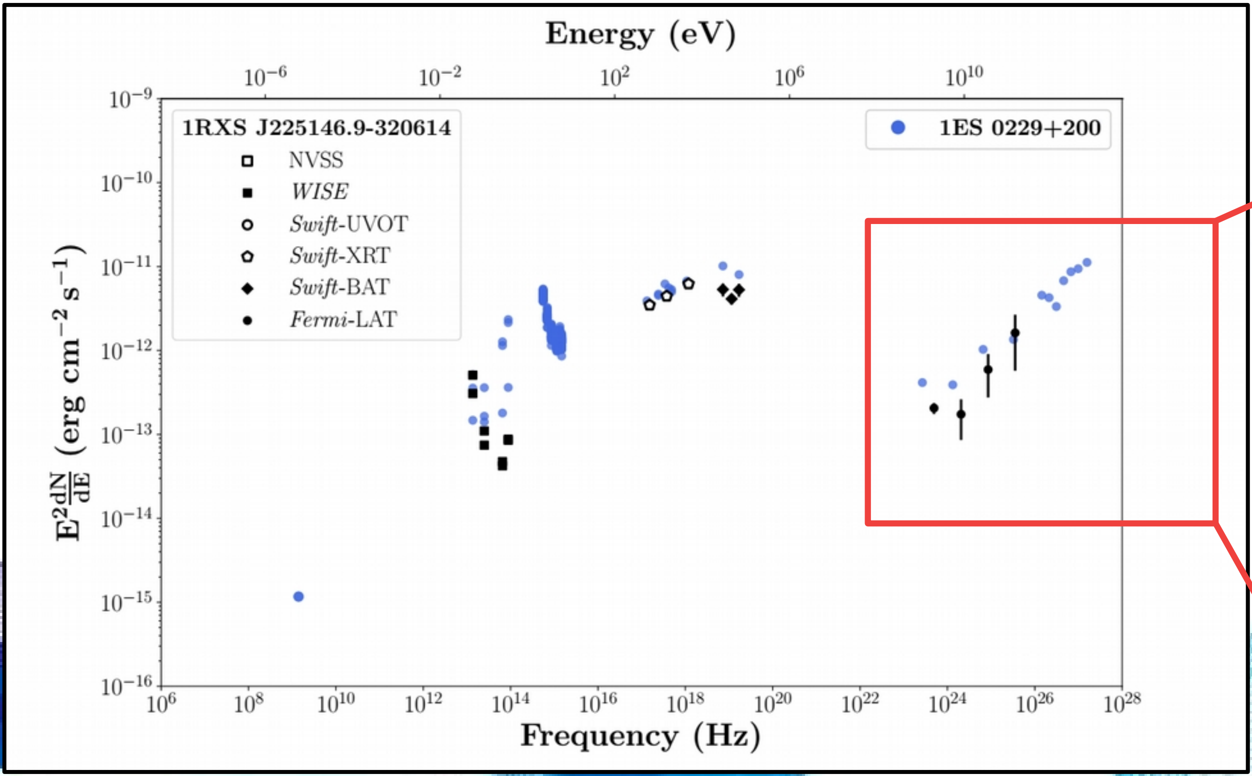

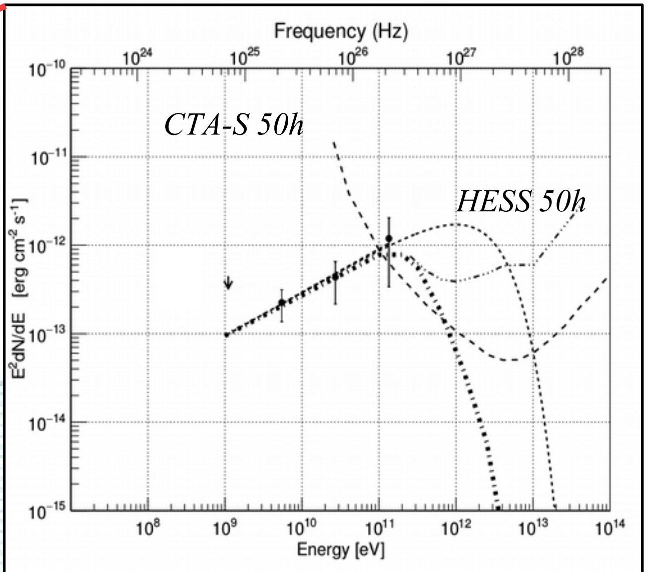

(f) 1RXS J225146.9–320614 with $z = 0.246$.

Power-law + cut-off extrapolations
on EBL deabsorbed data (Franceschini+17)

Conclusions

Take home message

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- **Extreme blazars** are a new category of blazars with extreme spectral properties

- We study a **sample of 32 EHBLs** in the *Swift*-BAT 105-months catalogue
- We find hints of **sub-classification**
- We **find new TeV EHBL candidates** to be observed with Cherenkov telescopes

- New **simultaneous MWL observations** would be crucial, especially at TeV gamma rays

- Next steps: **interpretation** of the results in term of jet emission models

See several talks and posters, e.g.:
- Prandini Elisa – GAI5a – MAGIC TeV gamma-ray detection of new EHBLs
- Orel Gueta – GAI5d – variability of EHBLs
- Arbet-Engels Axel – GAI5f – New data on 1ES 2344+514
- Foffano Luca – PS2-57 – MAGIC TeV gamma-ray detection the EHBL PGC 2402248

Thank you!