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

Luca Foffano, Elisa Prandini,
Alberto Franceschini, Simona Paiano

eXtreme19, Padova
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Overview

- Main **observational differences** in the broad-band SEDs of 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

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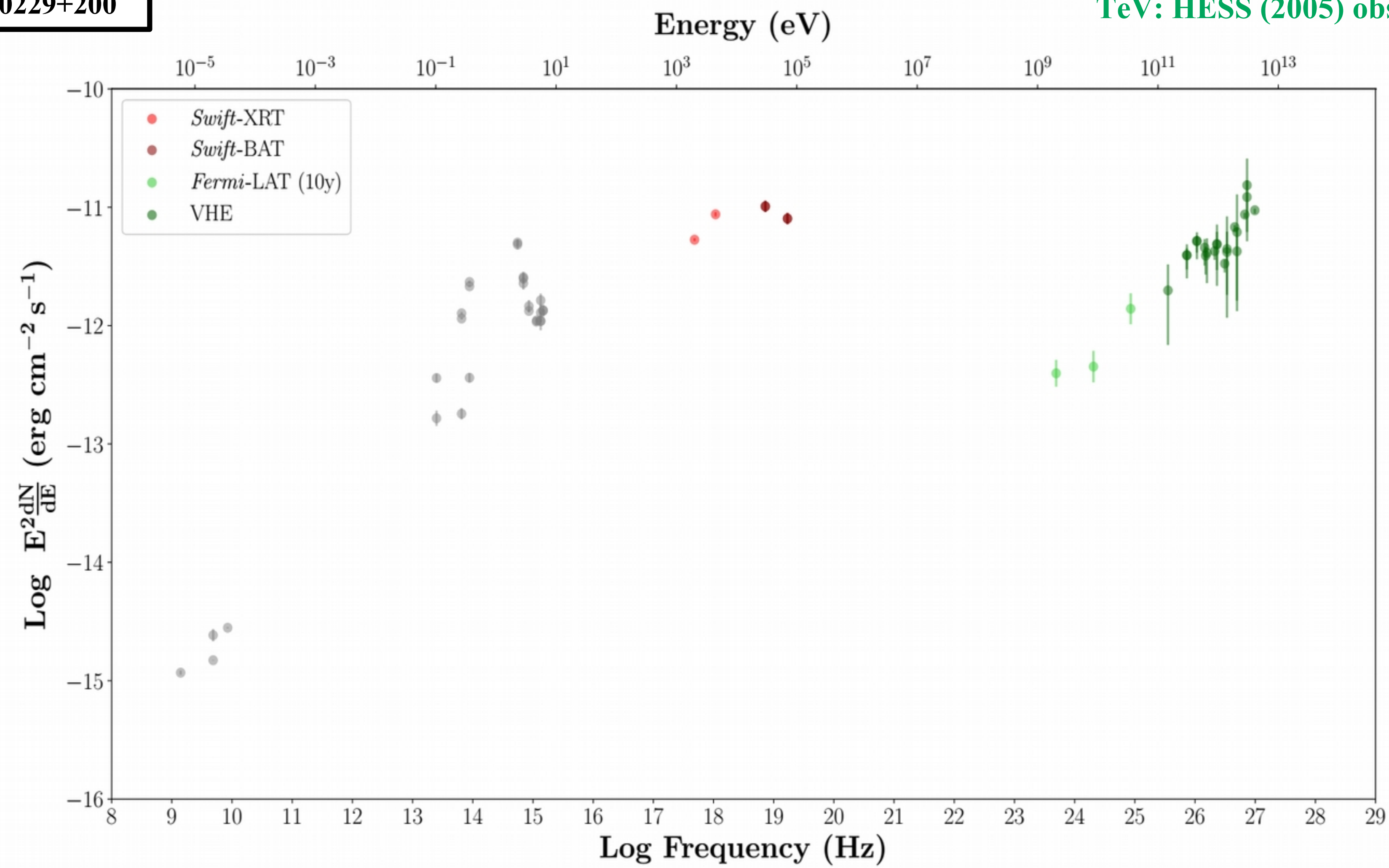
1ES 0229+200

TeV: HESS (2005) observations



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

Luca Foffano
University and INFN of Padova

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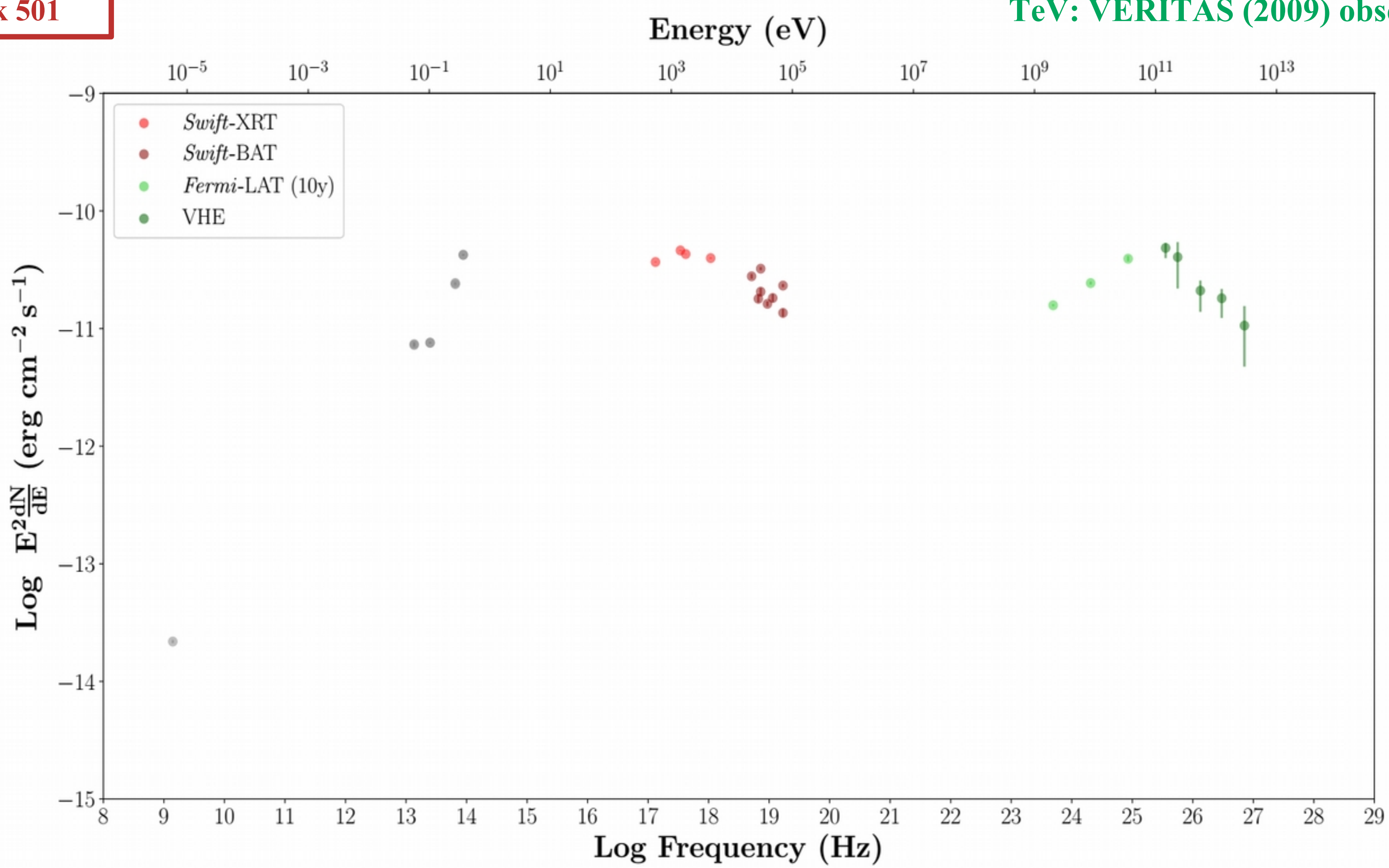
Mrk 501

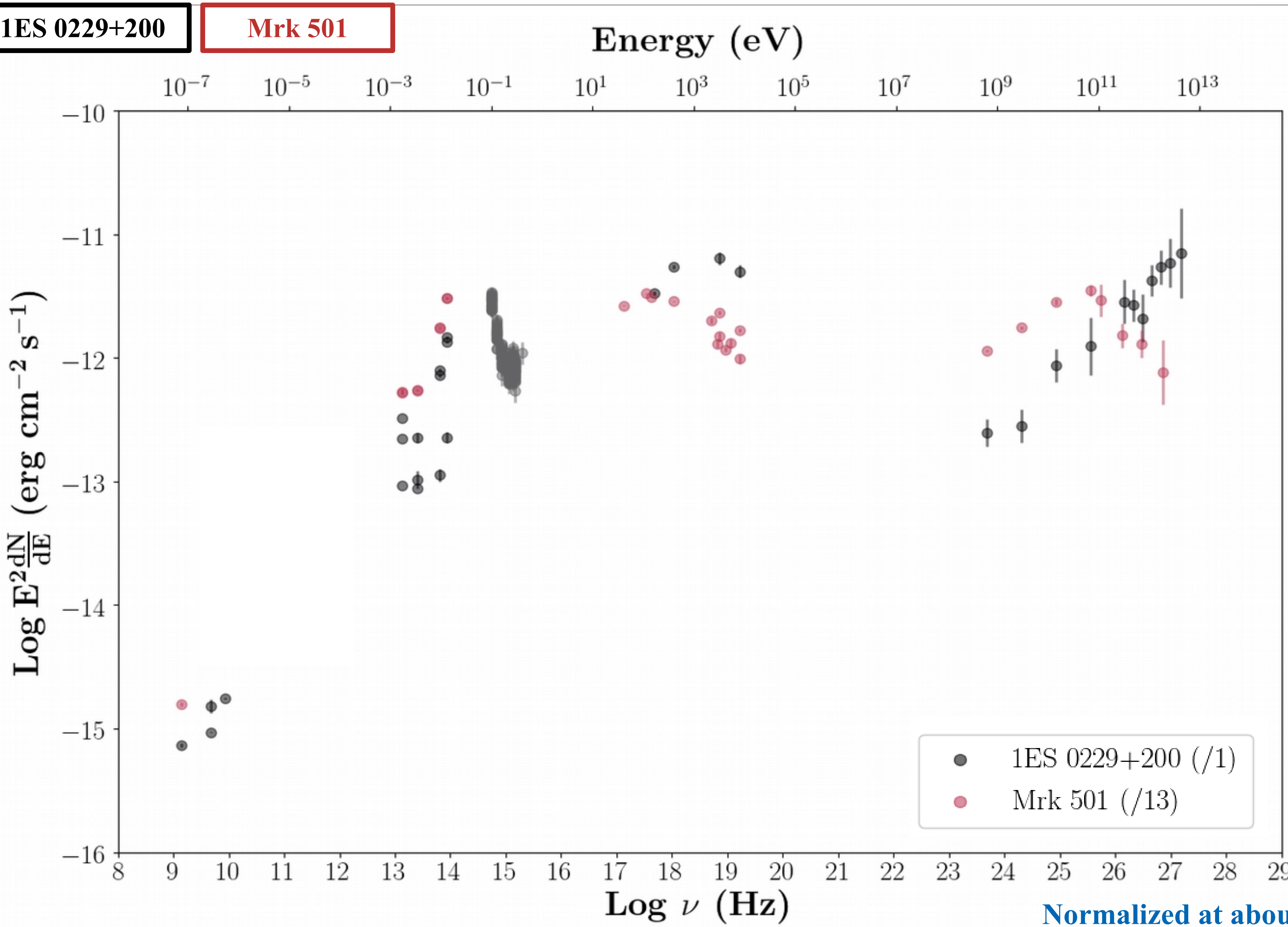
TeV: VERITAS (2009) observations



Mrk 501 broad band intrinsic SED archival data (SSDC)

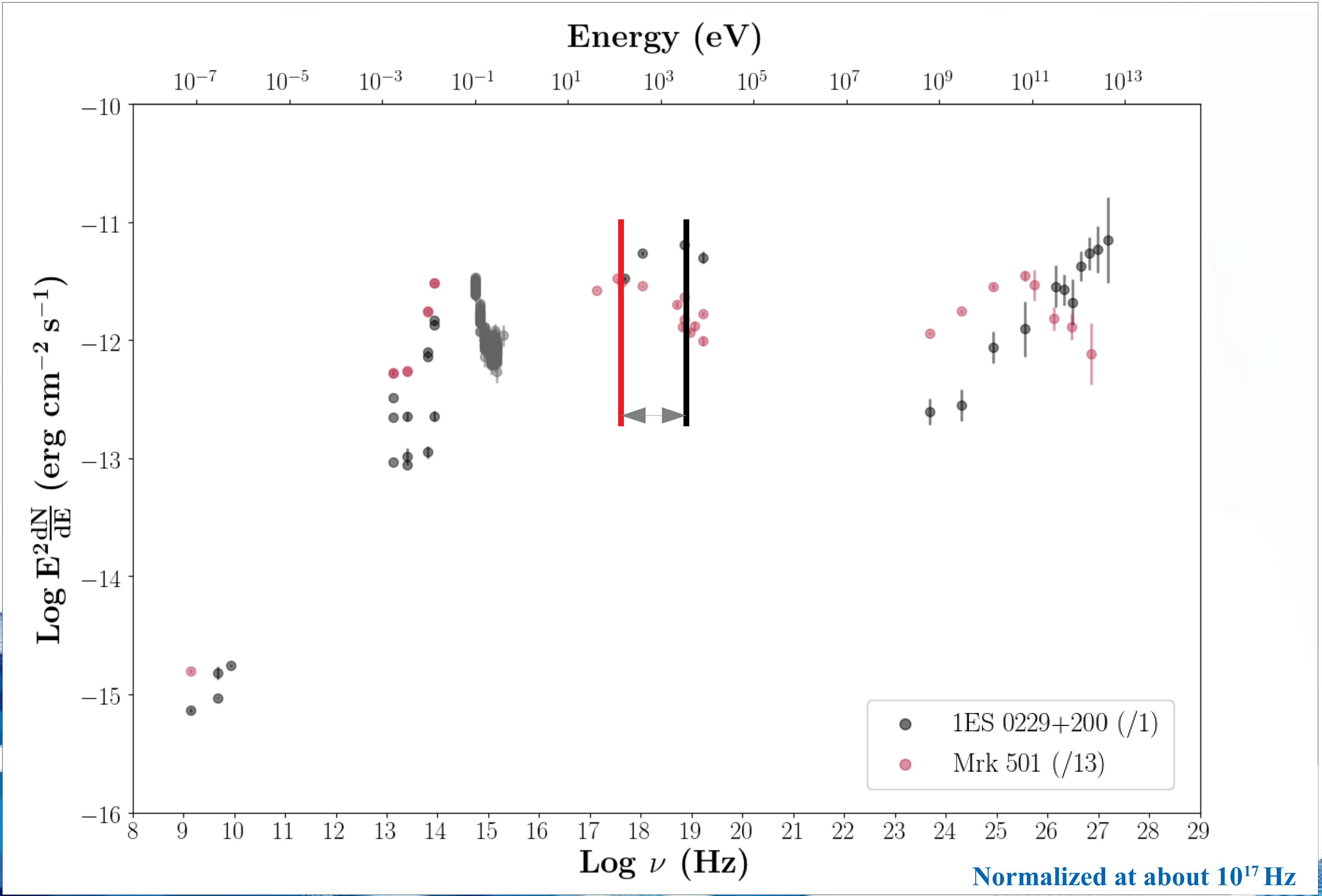
1ES 0229+200

Mrk 501

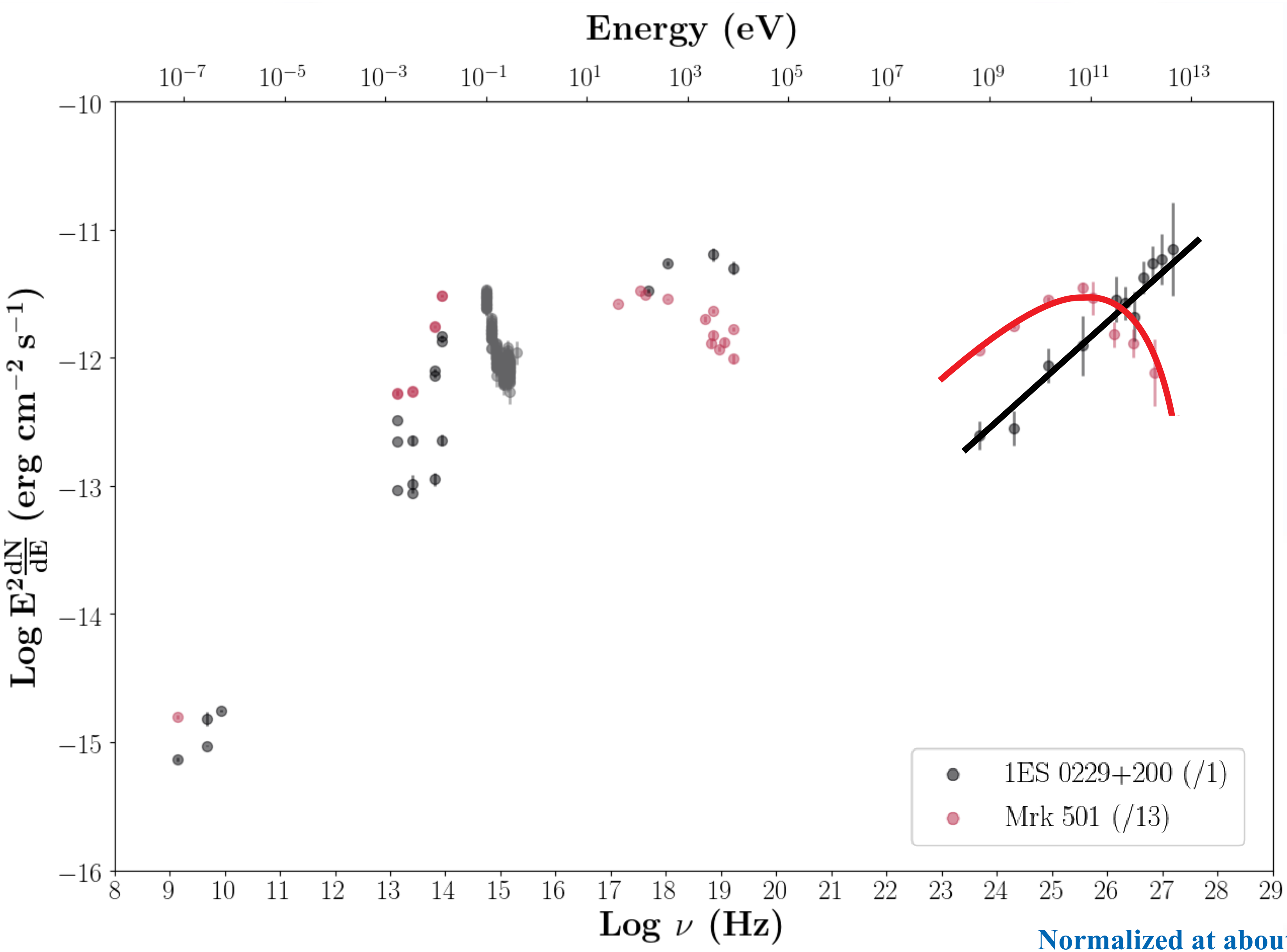


Normalized at about 10^{17} Hz

Comparison of 1ES 0229+200 + Mrk 501 broad band intrinsic SED archival data (SSDC)



Normalized at about 10^{17} Hz



Normalized at about 10^{17} Hz

So many differences...

- The most known EHBL are the **hard-TeV sources** (e.g. 1ES 0229+200):

  hard TeV spectrum, low TeV variability, only few sources

- There are a lot of EHBLs that are **not hard-TeV sources** (e.g. PKS 0548-322, 1ES 1426+428):

  decreasing spectrum at TeV energies

- Some HBLs show **EHBL-like behavior** when **flaring** (e.g. Mrk 501, 1ES 1218+304, 1ES 1959+650, 1ES 2344+514):

  decreasing spectrum at TeV energies, high TeV variability

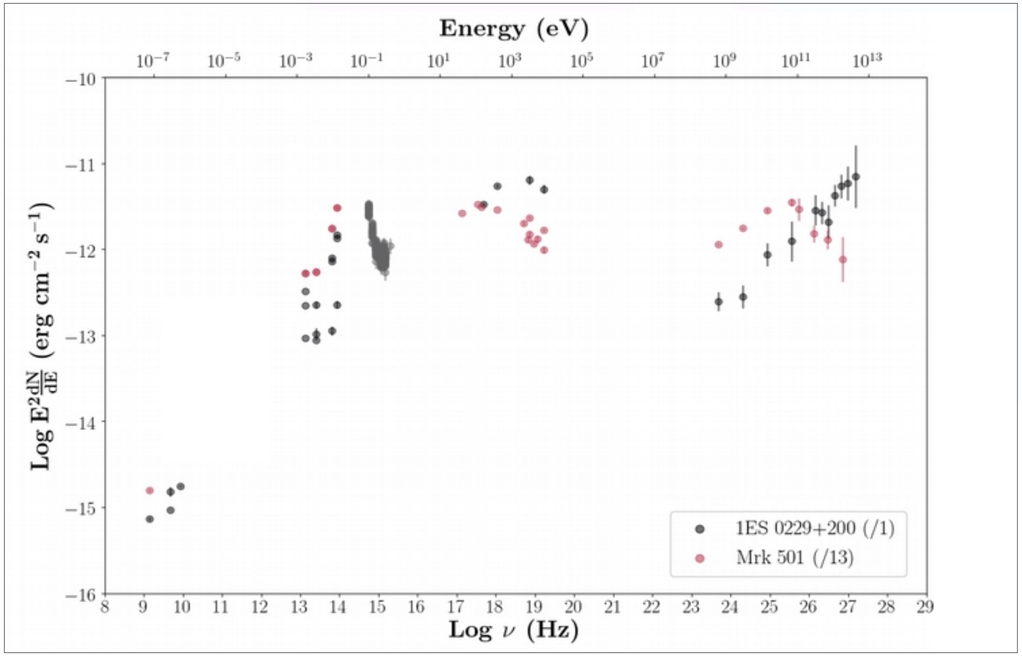
Is there a population of EHBLs behind these differences?

A new sample of hard X-ray selected EHBLs

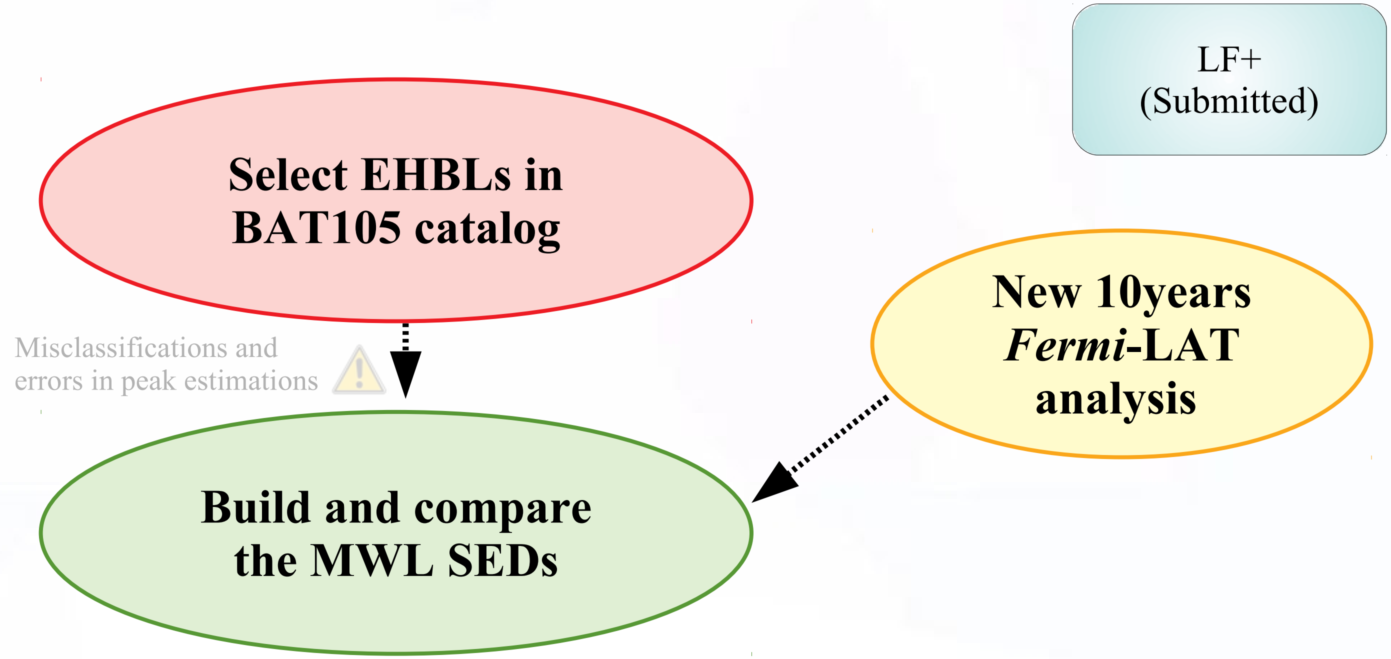
Luca Foffano
University and INFN of Padova

The idea

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



The project


LF+
(Submitted)
Select EHBLs in BAT105 catalog
Misclassifications and errors in peak estimations
New 10years *Fermi*-LAT analysis
Build and compare the MWL SEDs

The project

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Select EHBLs in BAT105 catalog

Misclassifications and errors in peak estimations

New 10years *Fermi*-LAT analysis

Sample of 32 EHBLs

Build and compare the MWL SEDs

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

Sample of TeV-detected sources

#	*Swift*-BAT name	Counterpart	Log $\nu_{\rm peak}^{\rm sync}$ (Hz)
1	SWIFT J0232.8+2020	1ES 0229+200	18.5 $\pm$ 0.2
2	SWIFT J1136.7+6738	RX J1136.5+6737	18.2 $\pm$ 0.6
3	SWIFT J1428.7+4234	1ES 1426+428	18.0 $\pm$ 0.2
4	SWIFT J1221.3+3012	1ES 1218+304	17.9 $\pm$ 0.2
5	SWIFT J0036.0+5951	1ES 0033+595	17.9 $\pm$ 0.2
6	SWIFT J0710.3+5908	3FGL J0710.3+5908	17.8 $\pm$ 0.2
7	SWIFT J0550.7-3212A	PKS 0548-322	17.8 $\pm$ 0.2
8	SWIFT J2346.8+5143	1ES 2344+514	17.7 $\pm$ 0.4
9	SWIFT J1654.0+3946	Mrk 501	17.7 $\pm$ 0.2
10	SWIFT J0349.2-1159	1ES 0347-121	17.7 $\pm$ 0.4
11	SWIFT J1103.5-2329	1ES 1101-232	17.7 $\pm$ 0.2
12	SWIFT J2359.0-3038	H 2356-309	17.6 $\pm$ 0.2
13	SWIFT J0507.7+6732	1ES 0502+675	17.5 $\pm$ 0.2
14	SWIFT J1959.6+6507	1ES 1959+650	17.4 $\pm$ 0.2
15	SWIFT J0136.5+3906	B 30133+388	17.4 $\pm$ 0.2
16	SWIFT J2009.6-4851	PKS 2005-489	17.0 $\pm$ 0.9
17	SWIFT J2056.8+4939	RX J2056.6+4940	17.0 $\pm$ 0.9
18	SWIFT J1104.4+3812	Mrk 421	17.0 $\pm$ 0.3

Sample of 18 TeV gamma-ray detected EHBLs

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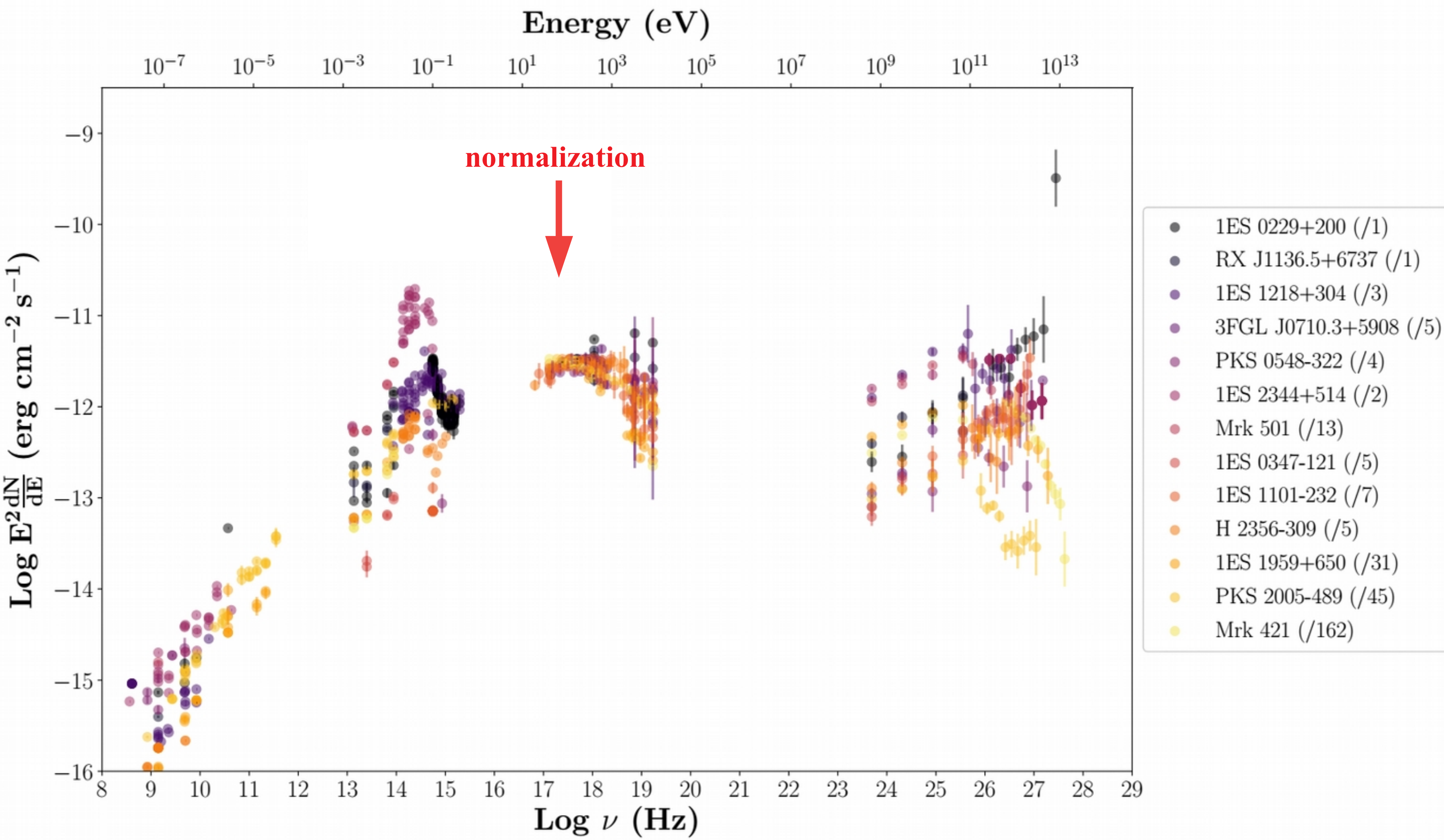
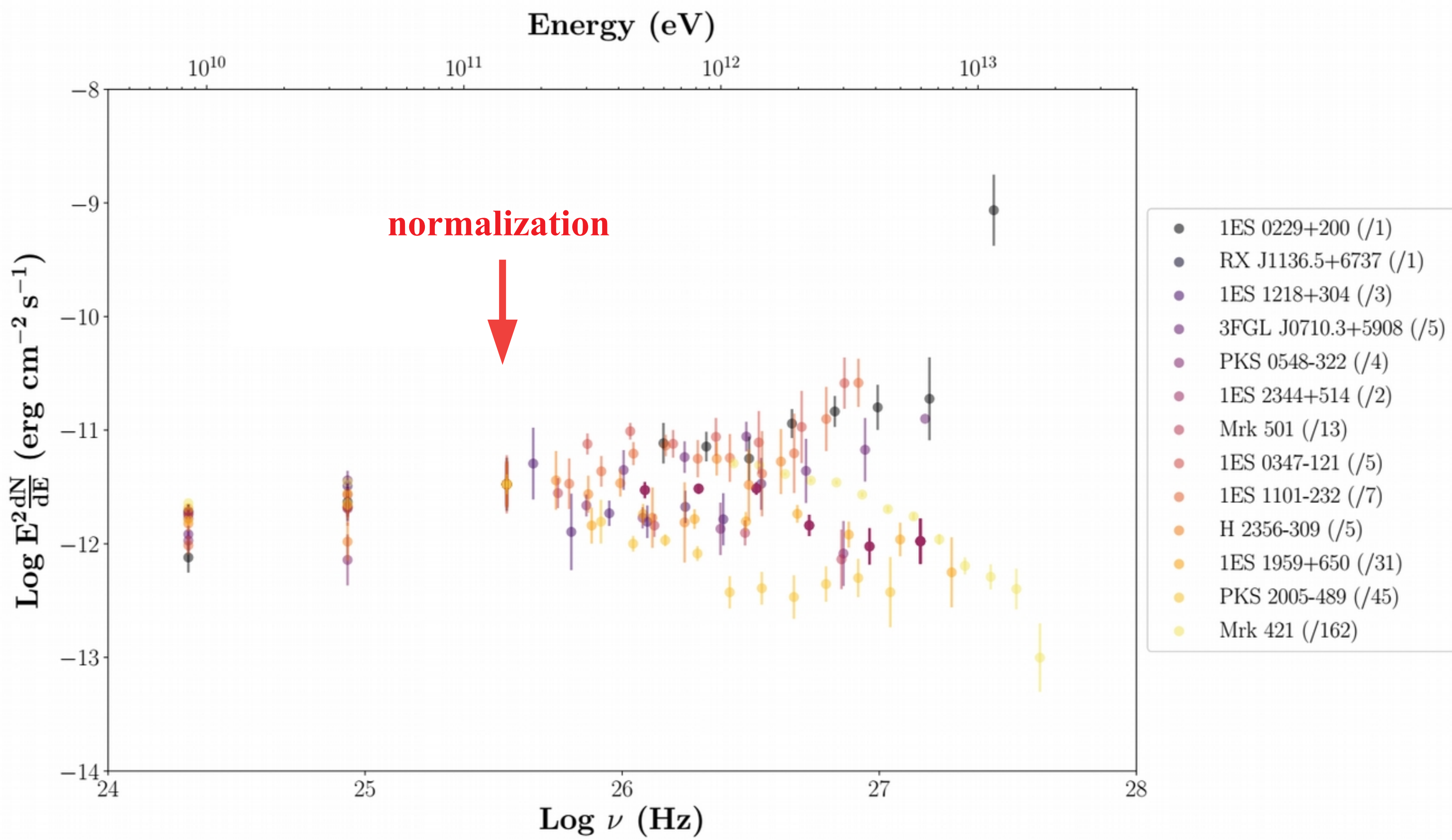
Comparing the SEDs



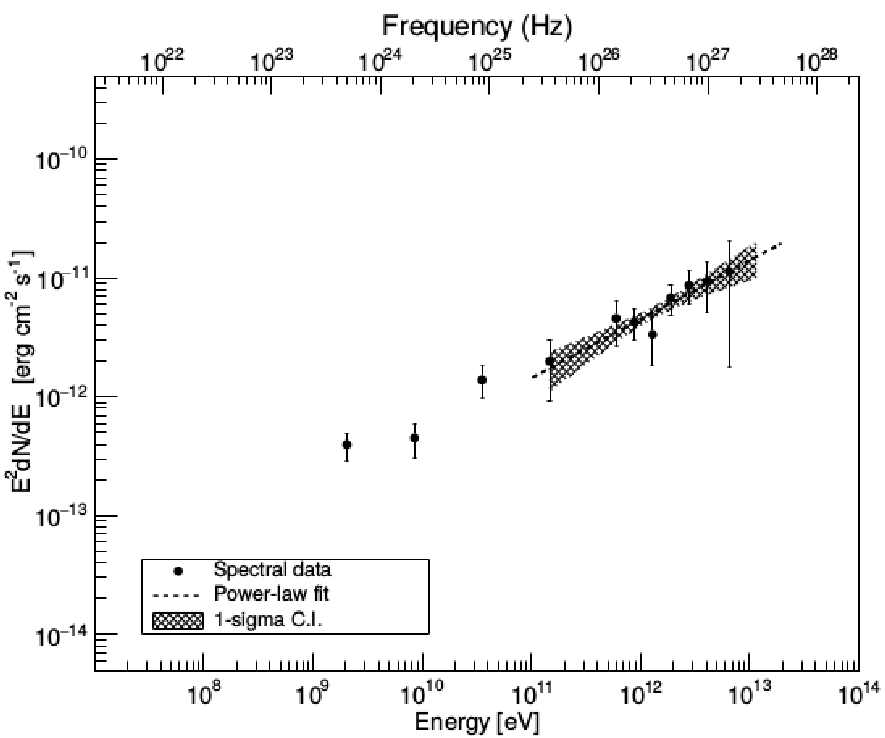
Superimposition of all the SEDs with normalization at 10^{17} Hz
EBL deabsorbed data (Franceschini + 17)

Comparing the SEDs in gamma rays

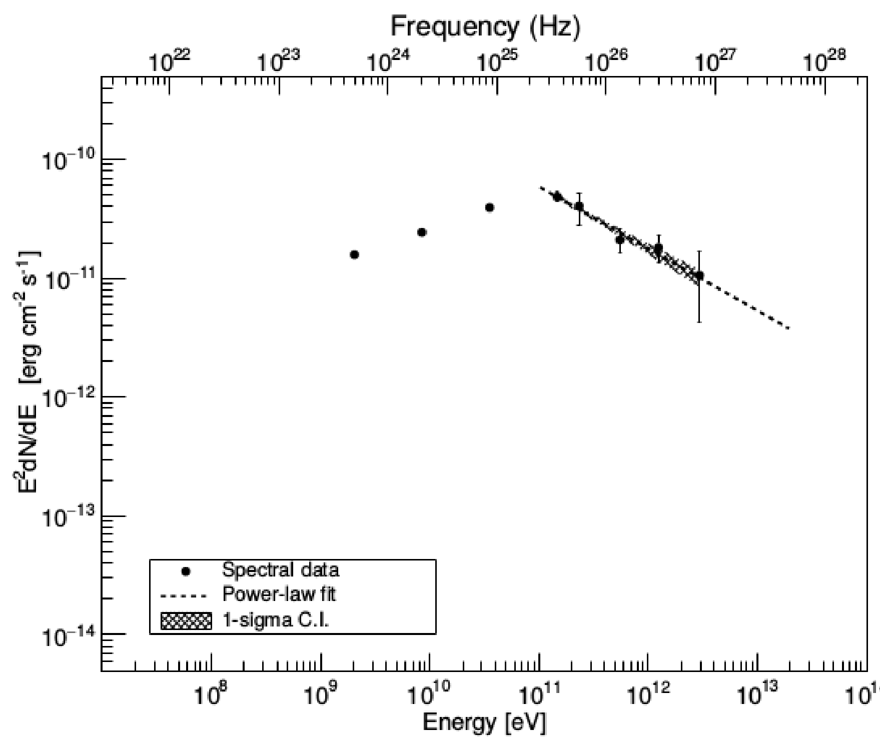


Focus on the TeV gamma-ray band with normalization at about 100 GeV

TeV gamma-ray slopes

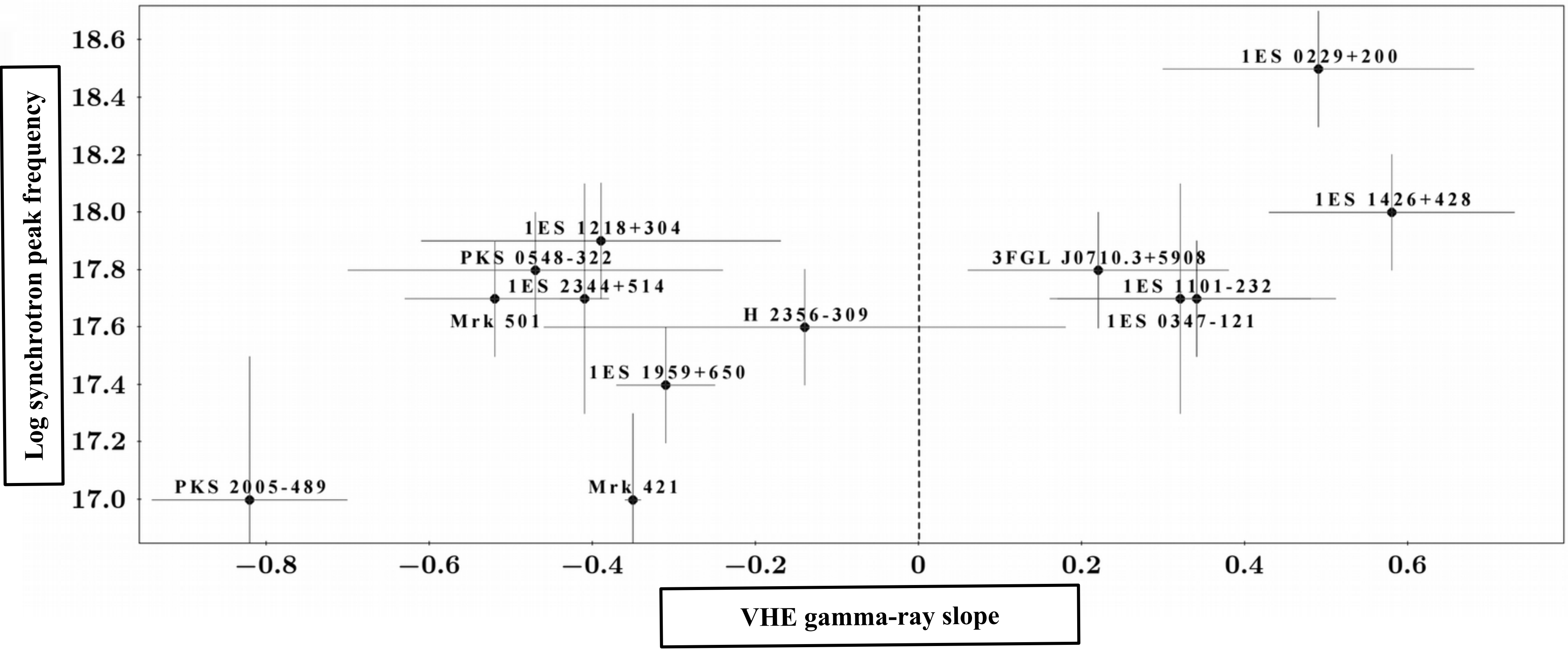


1ES 0229+200

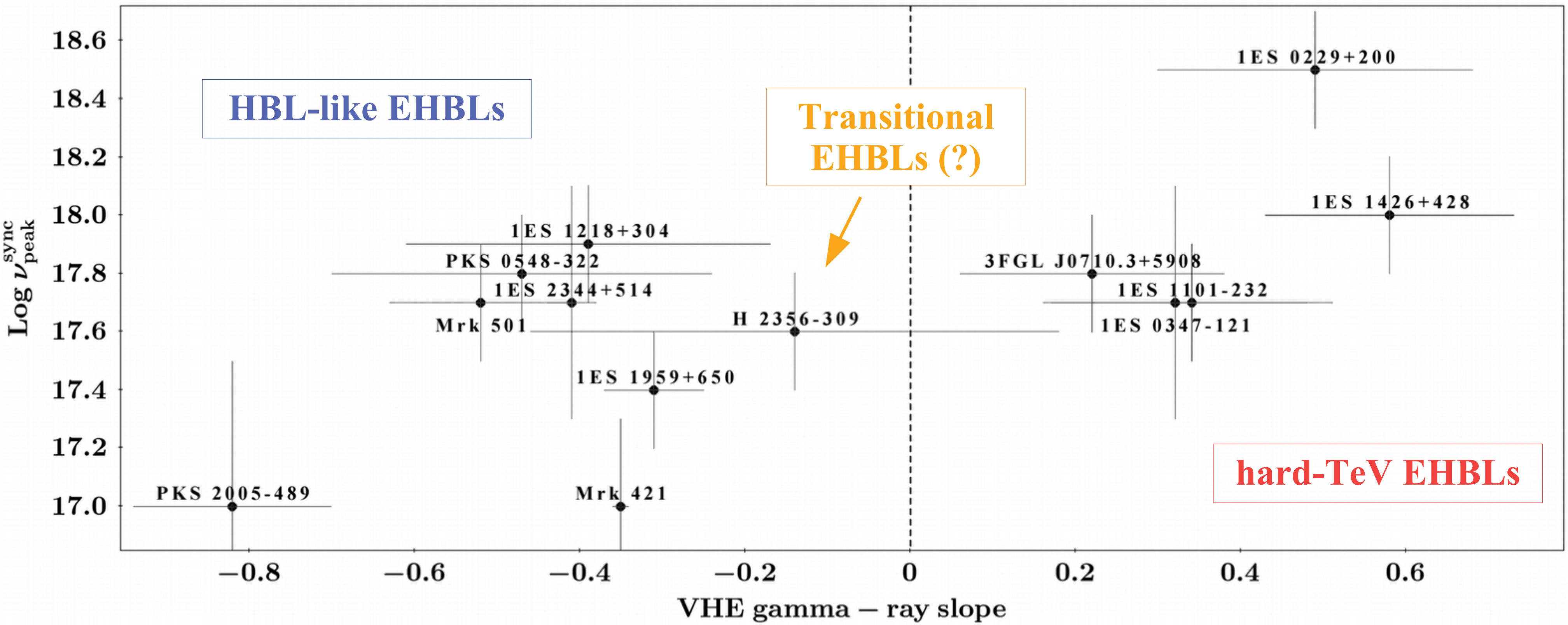


Mrk 501

Synchrotron peak frequency vs TeV gamma-ray slope



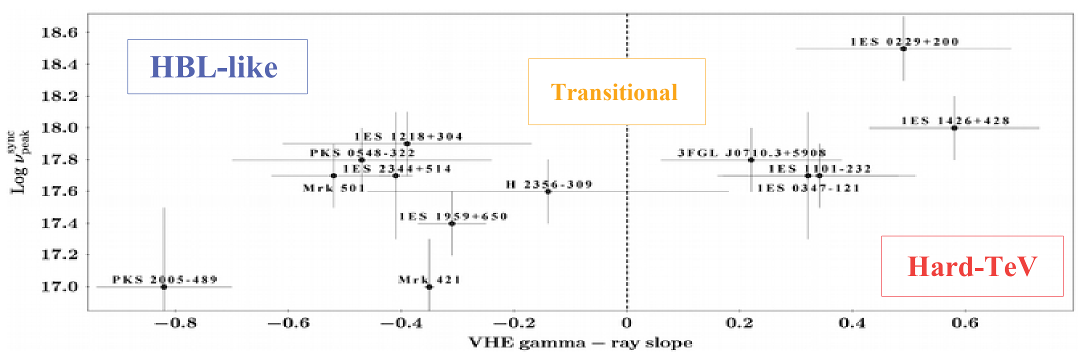
Synchrotron peak frequency vs TeV gamma-ray slope



Synchrotron peak frequency vs TeV gamma-ray slope

We find at least **three types** of EHBLs

- **HBL-like** objects → Their IC peak is clearly distinguishable below the TeV band
  - Probably characterized by higher flux variability (e.g. Mrk 501) with respect to hard-TeV
- **Transitional** objects → Their IC peak probably peaks in the 1-10 TeV band
  - Moderate flux variability?
- **Hard-TeV** objects → Their IC peak goes above about 10 TeV
  - Generally characterized by low flux variability



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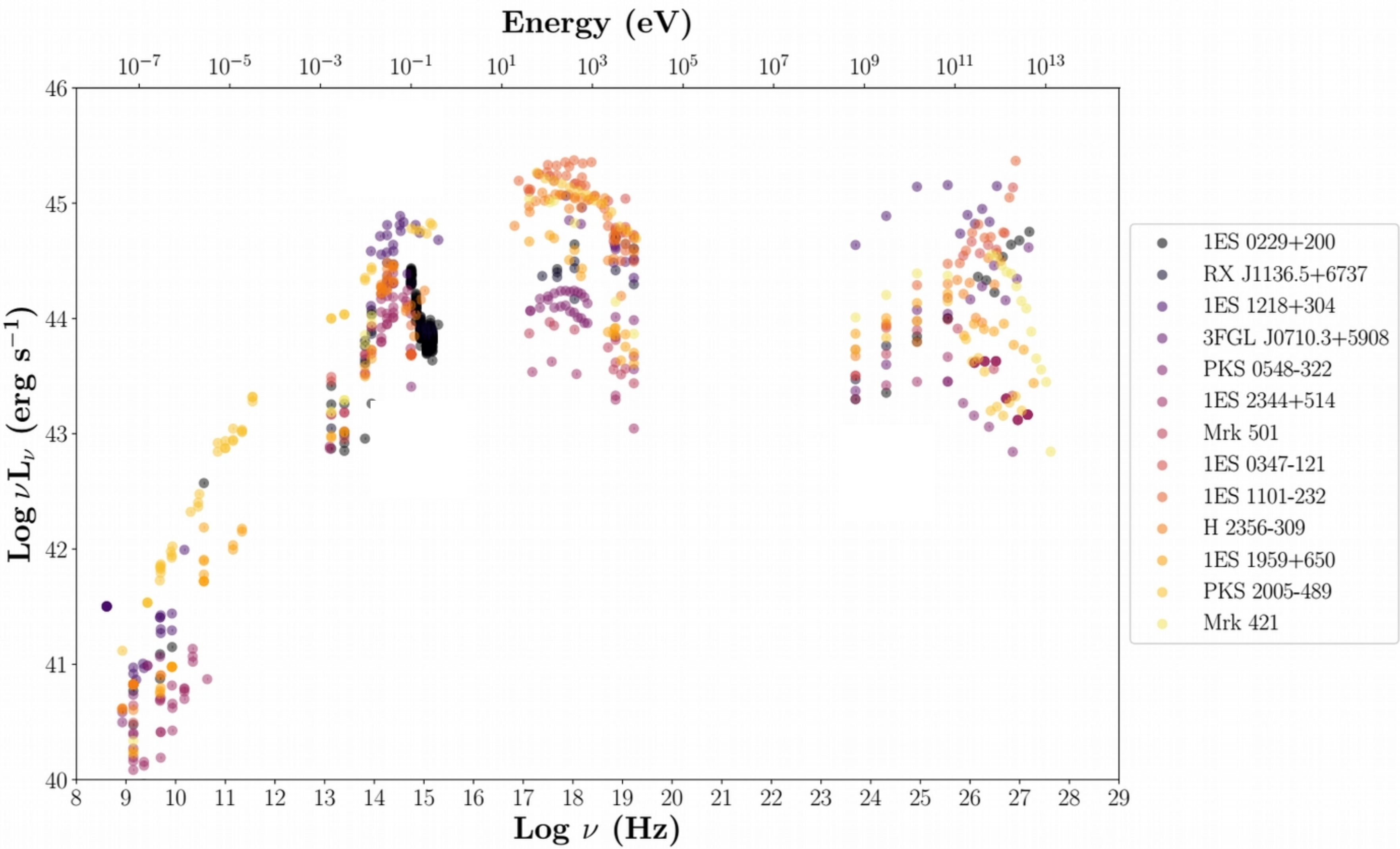
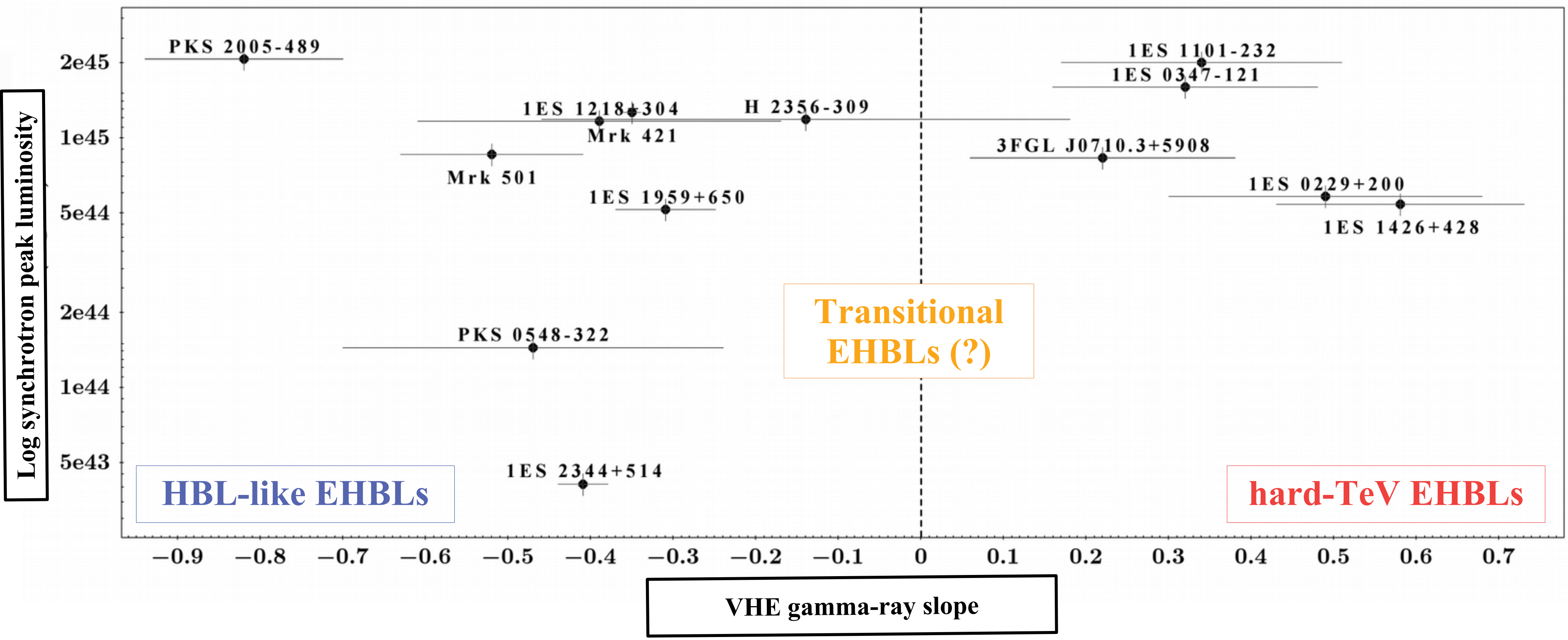
Luminosity



Synchrotron peak luminosity vs TeV gamma-ray slope



TeV gamma-ray undetected EHBLs

Next candidates for Cherenkov telescopes?

#	*Swift*-BAT name	Counterpart	Log $\nu_{\mathrm{peak}}^{\mathrm{sync}}$ (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

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Detectability by Cherenkov telescopes

- The HE gamma ray data should be on the rising part of the IC hump → **Power-law** is a good approximation
- The **IC peak** can be approximated 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**

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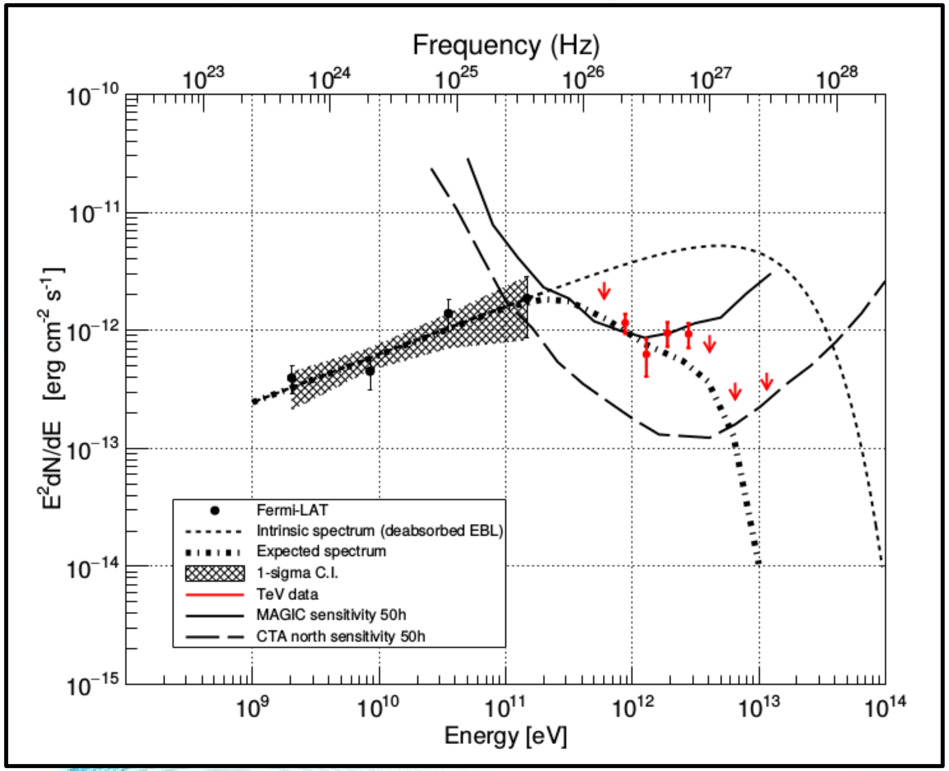

Example: in 1ES 0229+200 the extrapolation works only if considering a $E_{cut\text{-}off}$ = 12 TeV

Looking for new TeV EHBL candidates

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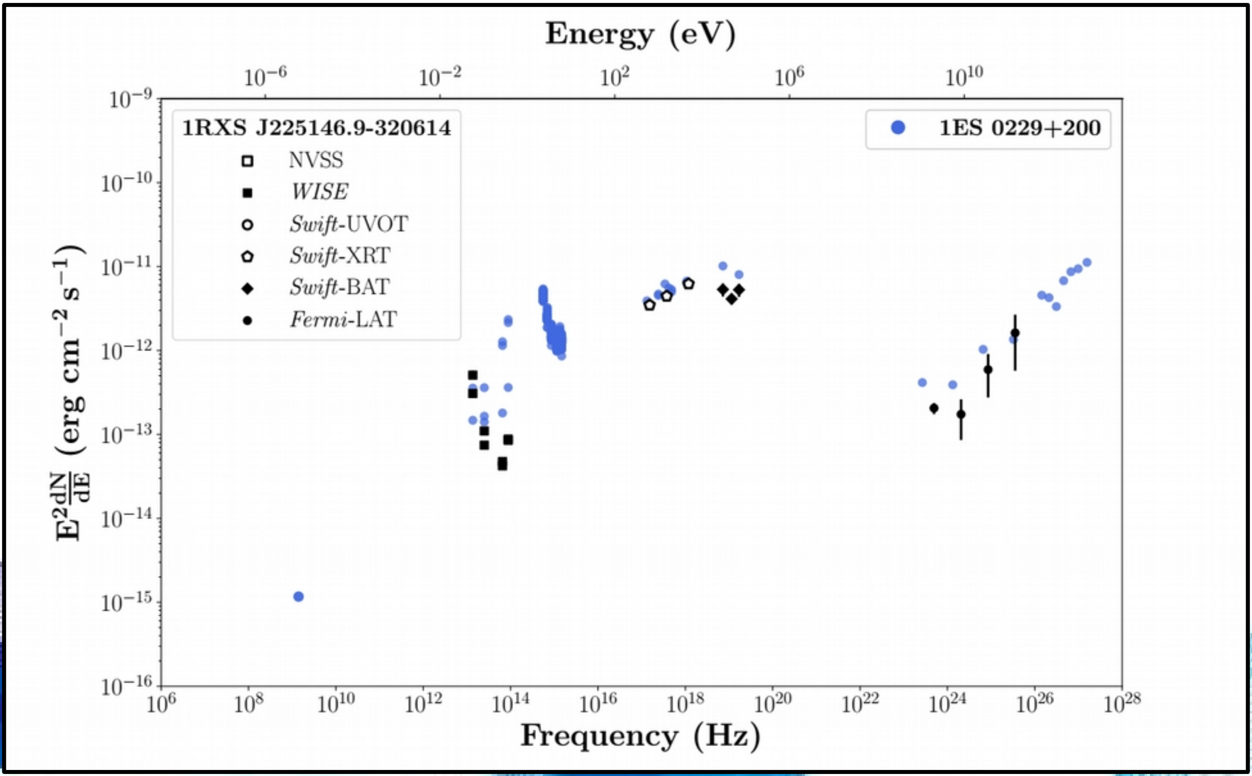
(Submitted)



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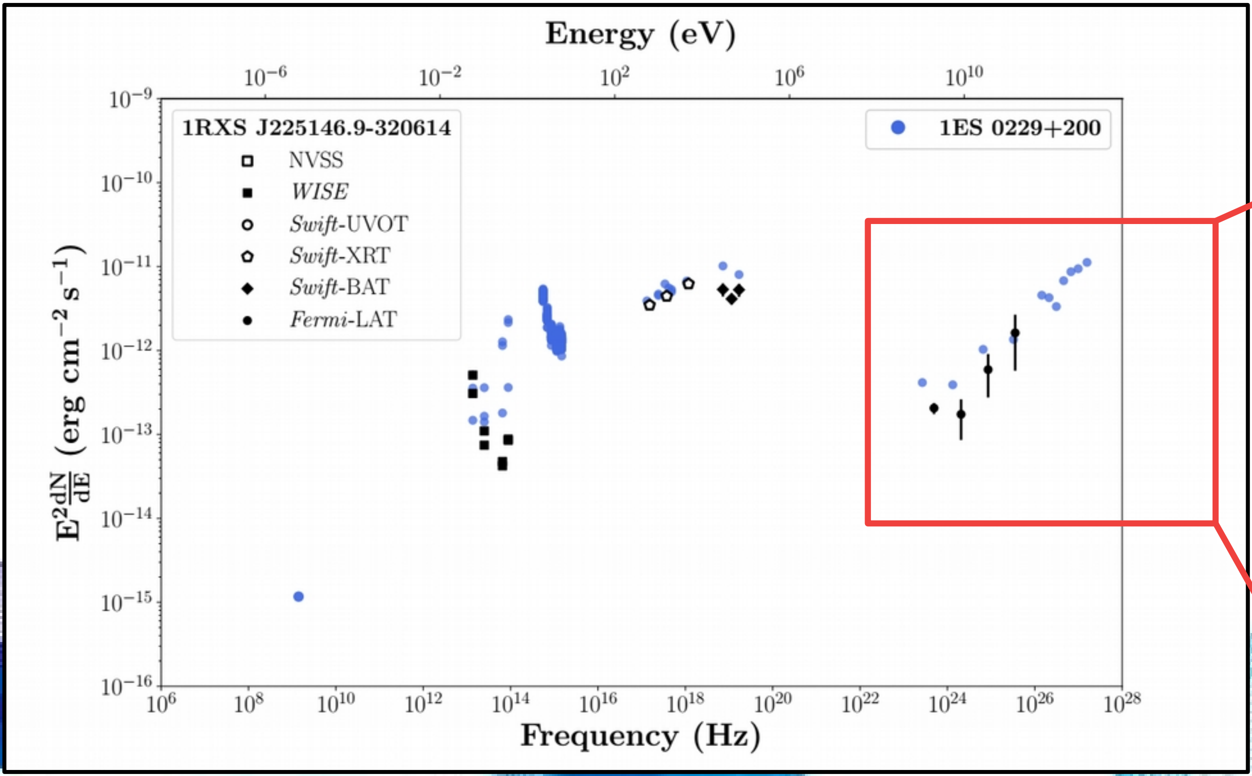

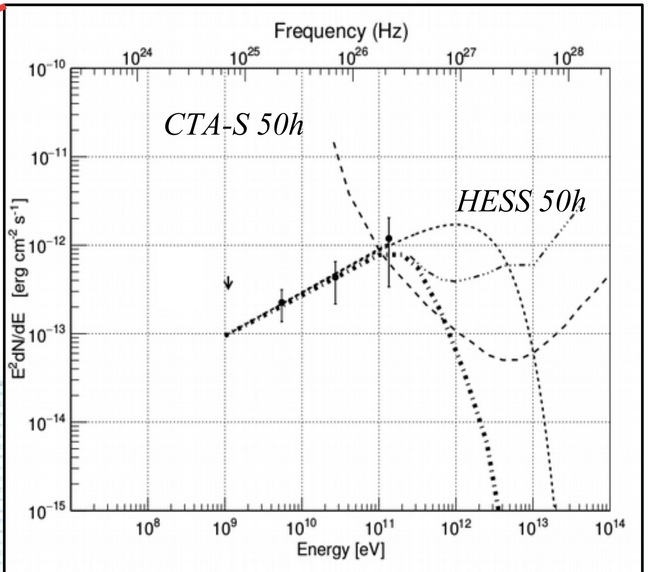

(f) 1RXS J225146.9–320614 with $z = 0.246$.

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

Conclusions

Take home message

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(Submitted)

- **Extreme blazars** are a new category of blazars with extreme spectral parameters
- We selected a **sample of 32 EHBLs** in the *Swift*-BAT 105-months catalogue
- We studied the TeV gamma-ray detected blazars, finding hints of **sub-classification**
- Need to increase the population of TeV gamma-ray detected EHBLs
- We performed extrapolations in order to **find new TeV EHBL candidates**
- Good targets also for the current generation IACTs
- New **simultaneous observations** would be crucial, especially at TeV energies
- Next steps: **interpretation** of the results in term of jet emission models

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Thank you!