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DEGLI STUDI
DI PADOVA



Hunting for extreme blazars in the TeV band

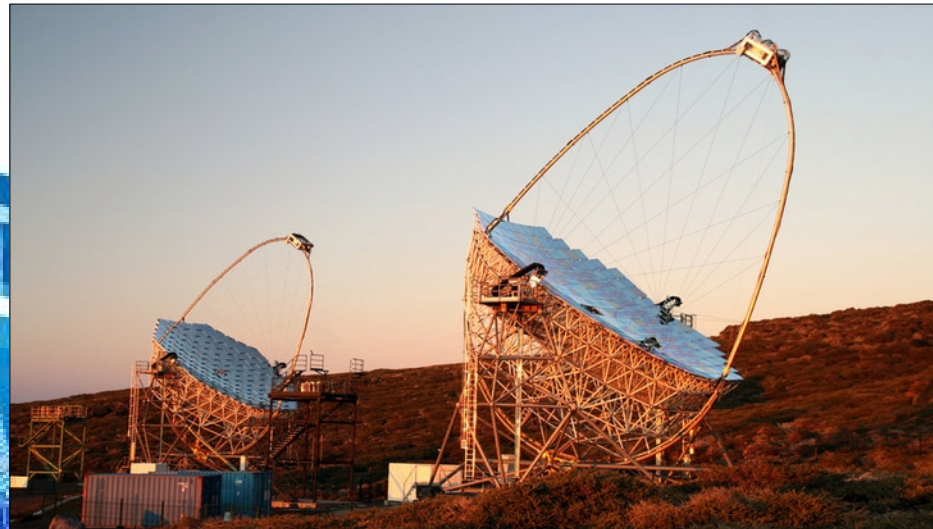
Luca Foffano, Elisa Prandini,
Simona Paiano, Cornelia Arcaro
On behalf of the MAGIC collaboration

and Alberto Franceschini

AGN13, Milano
October 9th, 2018

Overview

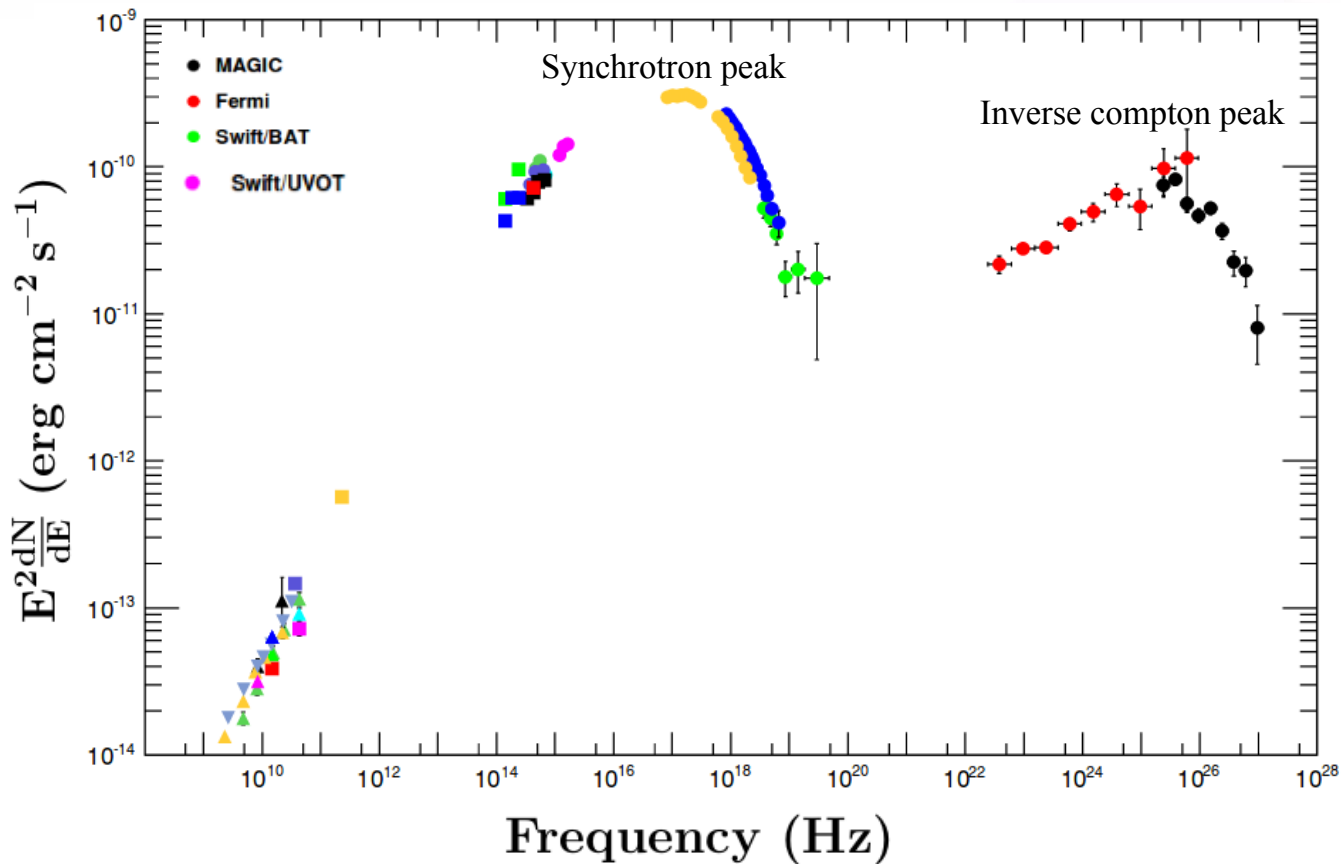
- Blazars and extreme blazars
- Extreme blazars hunting program in MAGIC
- Looking for new TeV extreme blazars candidates
- PGC 2402248: a new TeV extreme blazar detected by the MAGIC telescopes





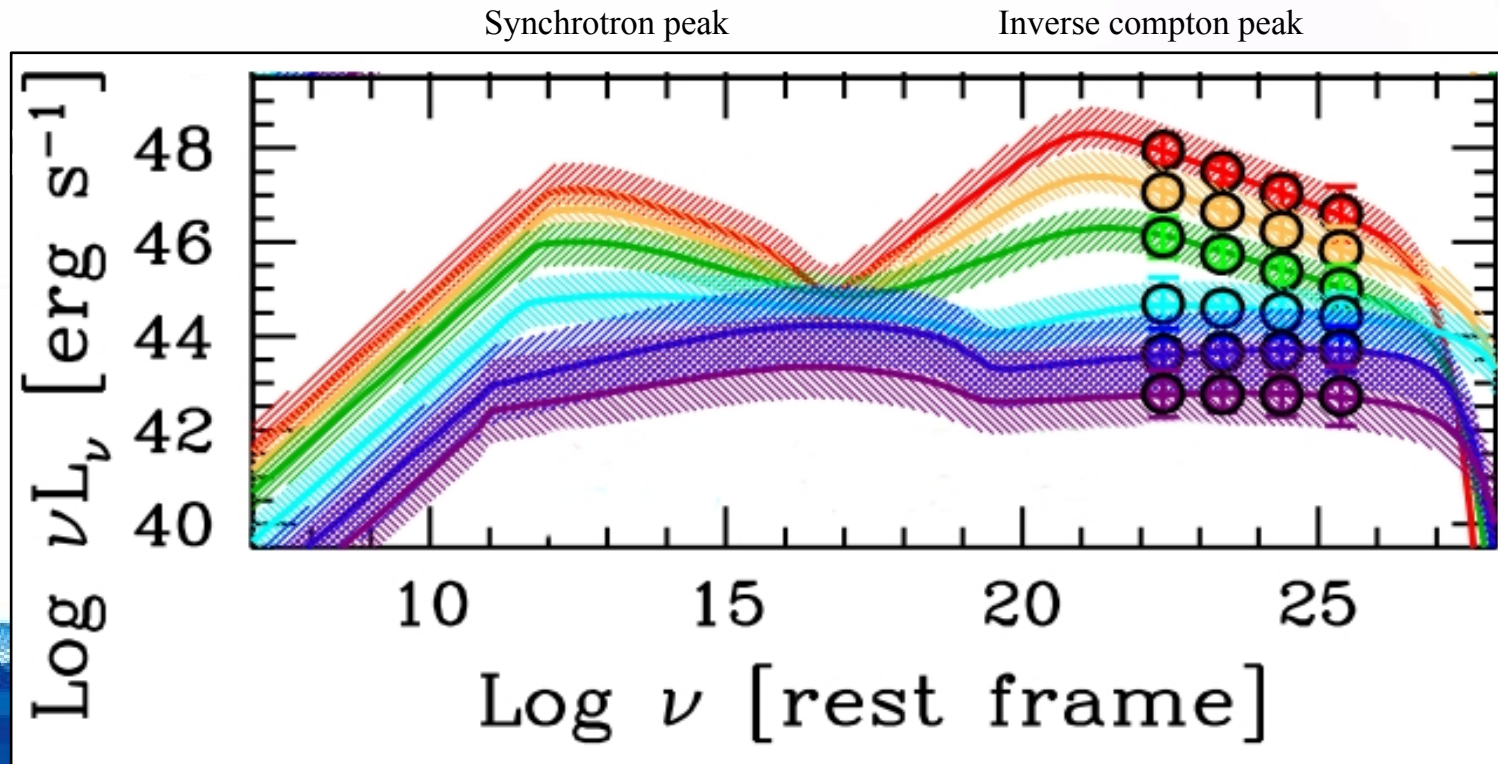
Blazars and extreme blazars

High synchrotron peaked BL Lac objects SED



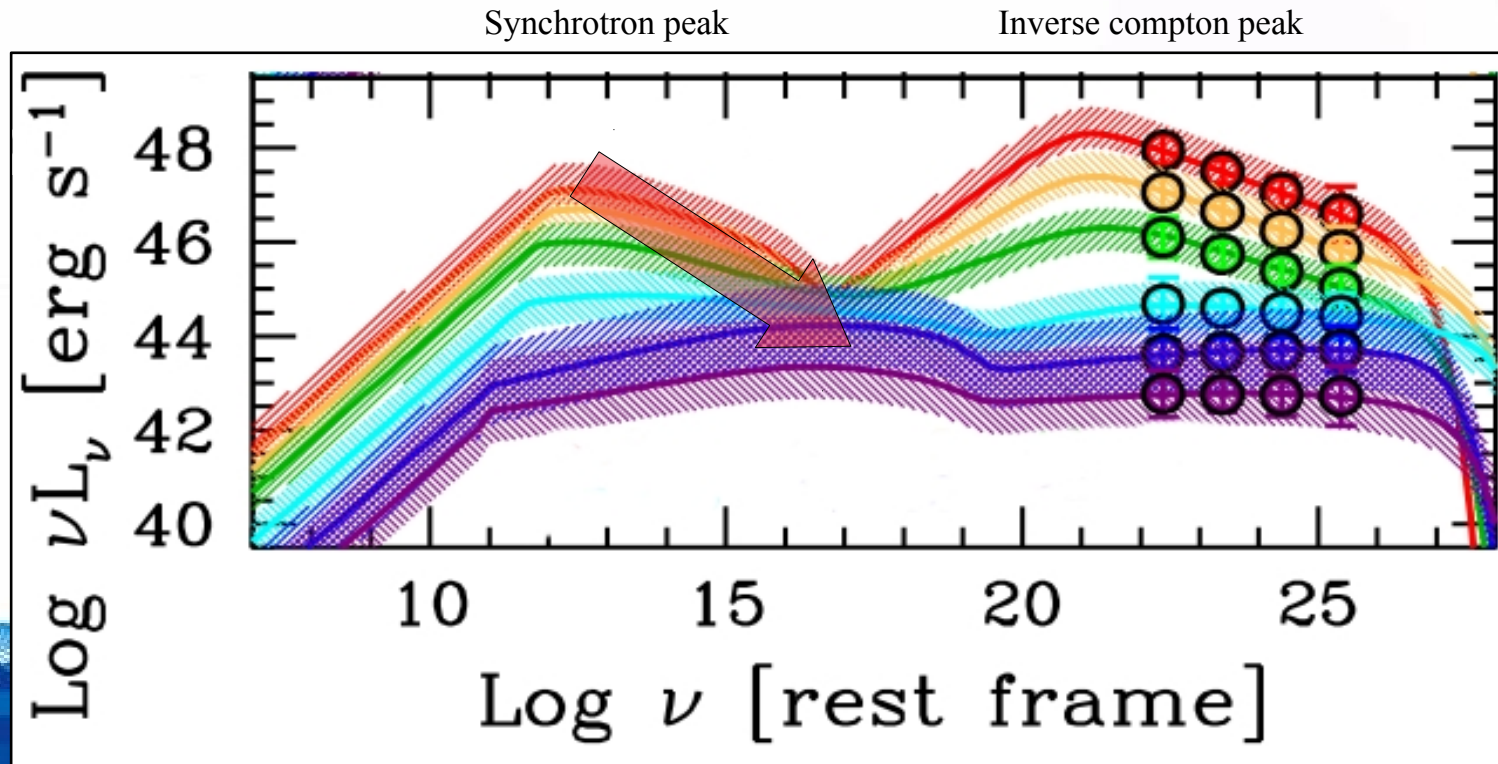
Mrk 421 multiwavelength campaign
The Astrophysical Journal, 736, 2 (2011)

Blazars and extreme blazars



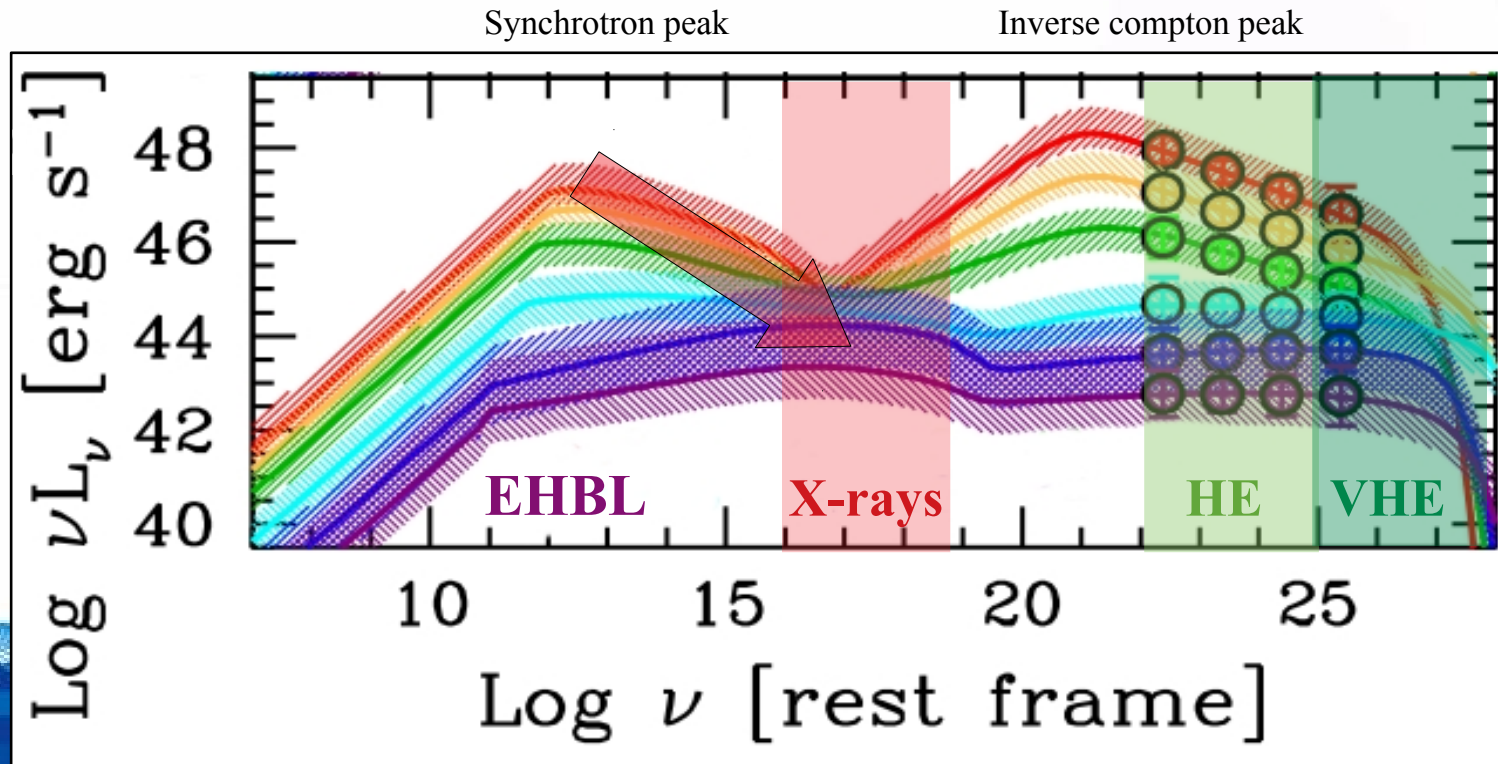
Extreme blazars in the so-called blazar sequence
Ghisellini +17

Blazars and extreme blazars



Extreme blazars in the so-called blazar sequence
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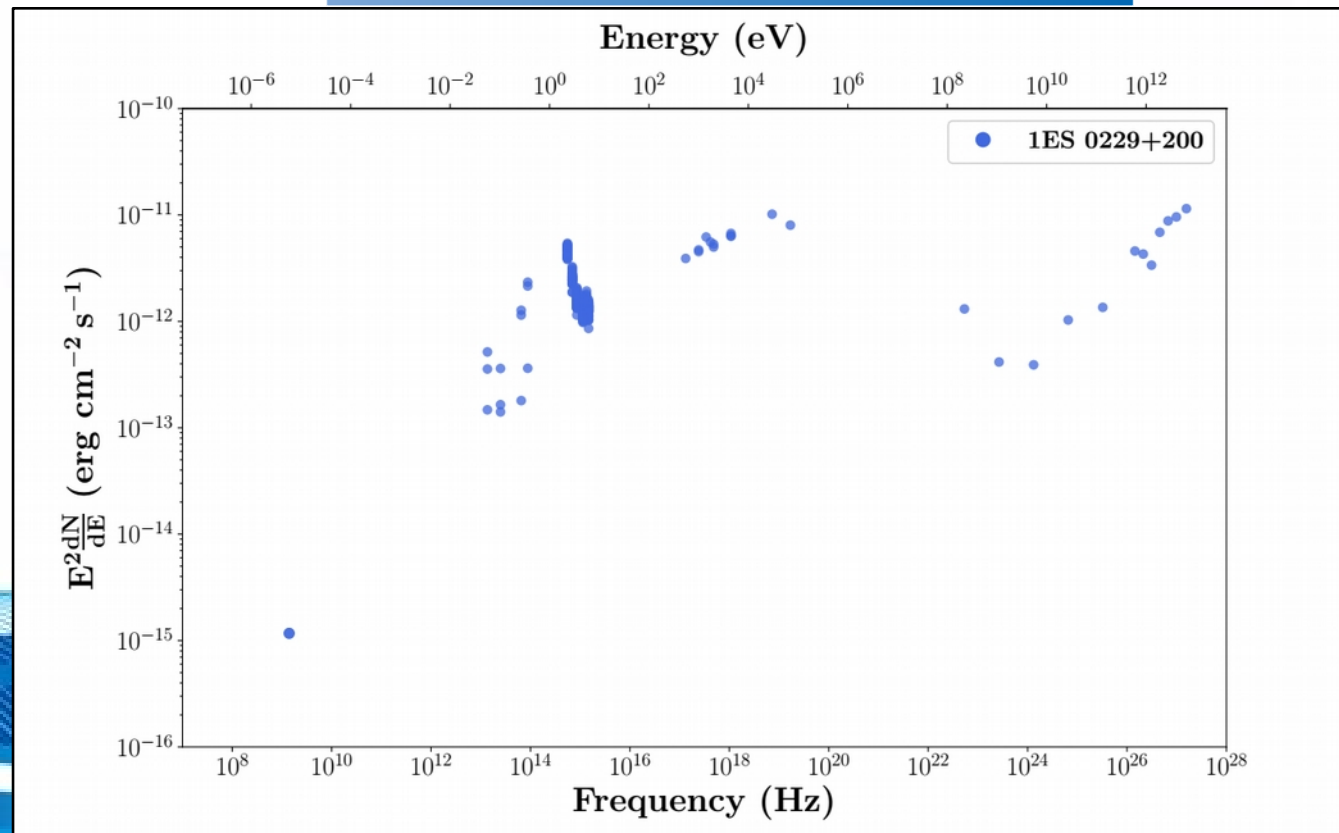
Blazars and extreme blazars



Extreme blazars in the so-called blazar sequence
Ghisellini +17

Extreme blazars

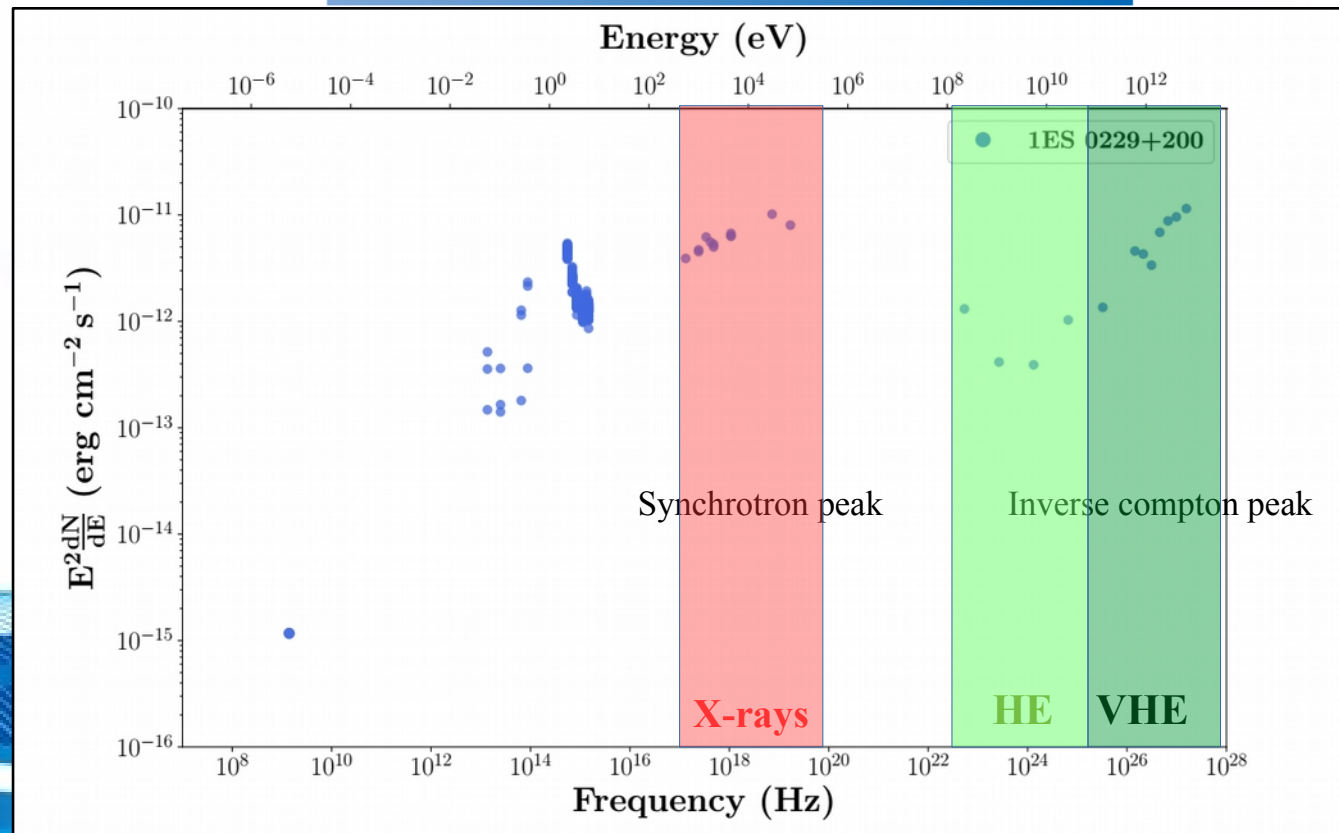
Archival SSDC data of 1ES 0229+200



We are looking for **the most extreme blazars** in the VHE gamma-ray band

Extreme blazars

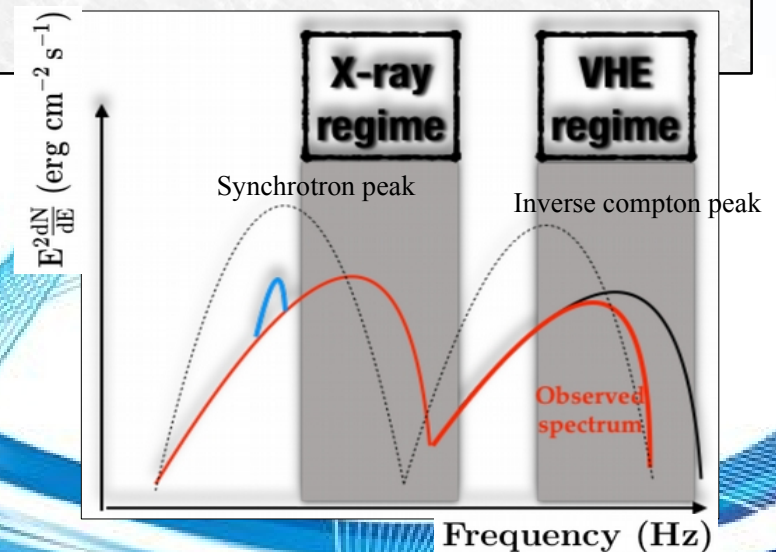
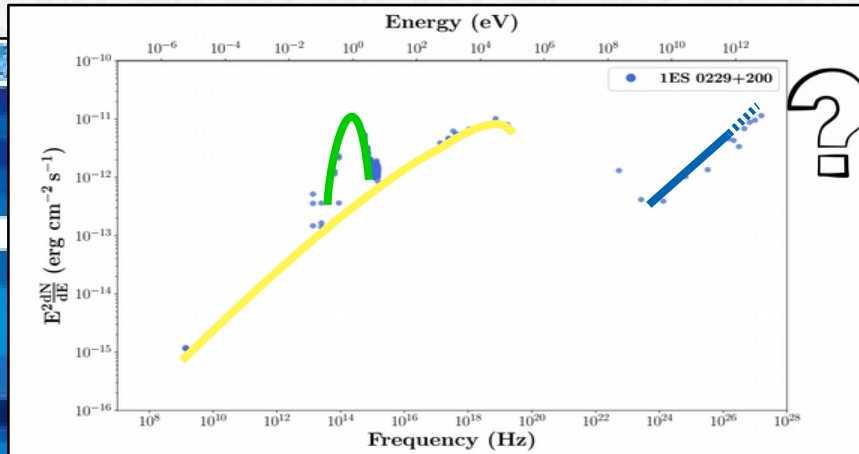
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We are looking for **the most extreme blazars** in the VHE gamma-ray band

Extreme blazars

- High **synchrotron peak** frequency $> 10^{17}$ Hz: hard X-rays
- High **“inverse compton” peak** frequency $> 10^{26}$ Hz: VHE
- **Hard spectrum** in X-rays and gamma-rays (important for cosmology wrt EBL, extragalactic studies IGMF, and neutrinos)
- Relatively **low luminosity** with respect to other blazars
- Potentially absorbed in the VHE due to interaction with optical-infrared diffuse background (EBL)
- **Galaxy** should be **detectable** in the optical range
- **Not well detected in the HE gamma-ray band** (*Fermi*-LAT)



Extreme blazars

- **Synchrotron Self-Compton (SSC) model** (only leptonic) works but with extreme parameters
 - extremely low magnetization in the emission zone, very high doppler factor or minimum Lorentz factor (*e.g. see Tavecchio+09 and Cerruti+15*)
- **Lepto-hadronic emission** models are favoured, but with a lot of free parameters...
- Should photo-hadronic processes be preferred?
- HBL are good candidates for **neutrino emission** (*e.g. see Padovani+16 and Resconi+17*)
 - what about EHBLS? Could EHBLS be neutrino sources?
- **Only few sources are known TeV EHBLS...**
 - 1ES 0229+200, 1ES 0347-121, RGB J0710+591, 1ES 1101-232

We need more sources!



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Extreme blazars with the MAGIC telescopes

Extreme blazars with MAGIC

Paper in preparation

Source	z	$\text{Log } v_{\text{sync,peak}}$
TXS 0210+515	0.049	17.3
BZB J0809+3455	0.083	16.6
RBS 0723	0.198	17.8
1ES 0927+500	0.187	17.5
RBS 0921	0.236	17.9
1ES 1426+428	0.129	18.1
1ES 2037+521	0.053	n.a.
RGB J2042+244	0.104	17.5
RGB J2313+147	0.163	17.7
1ES 0229+200	0.140	18.5

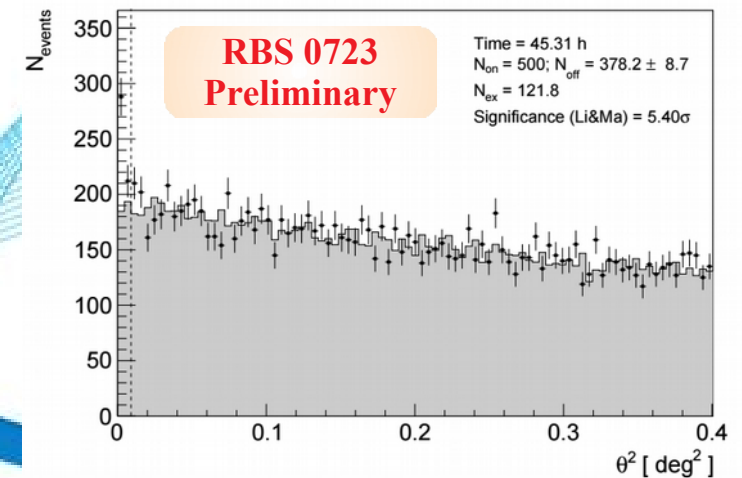
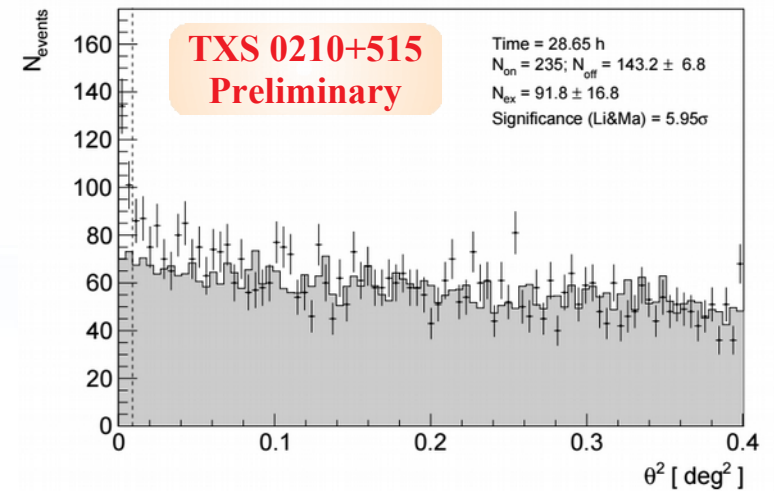
- **Nine** new targets
- Extreme synchrotron peak
(from 2WHSP Catalog)
- **Low redshift**: $0.049 < z < 0.236$
- More than **200 hours** of data
- All the targets are **TeV undetected**
(except for 1ES 1426+428) (Aharonian, F. et al.) (HEGRA Collaboration 2003, A&A, 403, 523)
- **1ES 0229+200** considered here for comparison
- Now performing **SED modelling** of these sources

4 detections +
1 hint

Extreme blazars with MAGIC

Paper in preparation

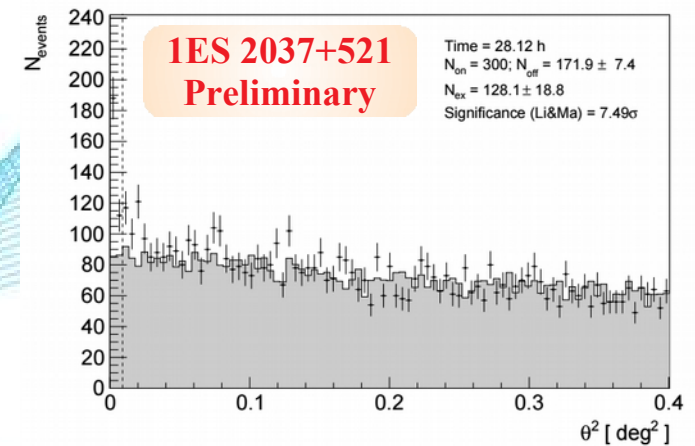
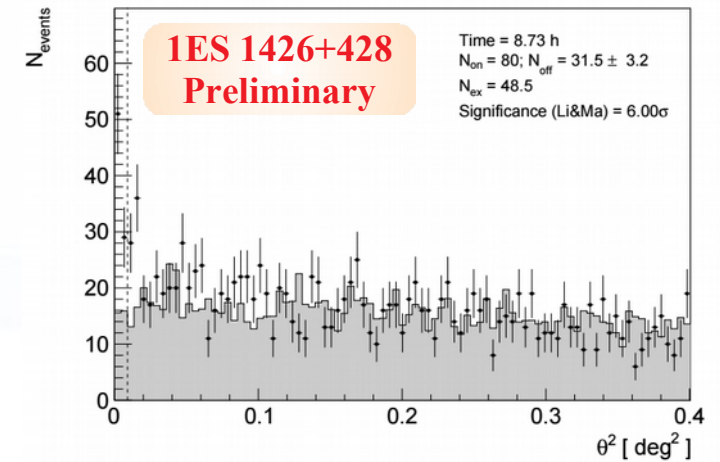
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Extreme blazars with MAGIC

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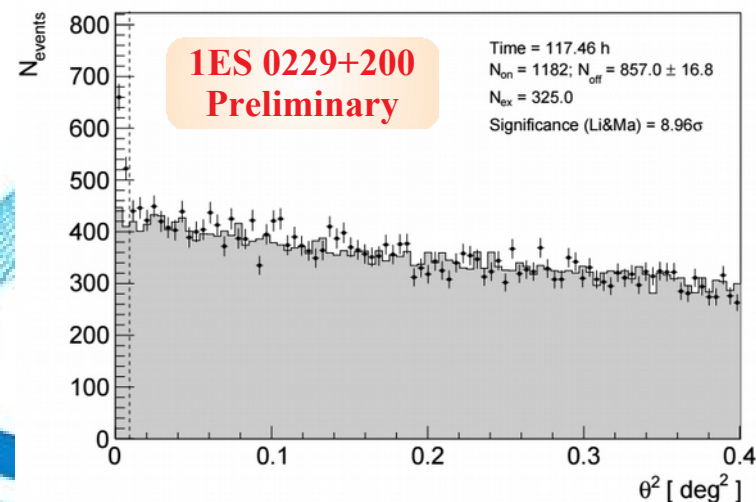
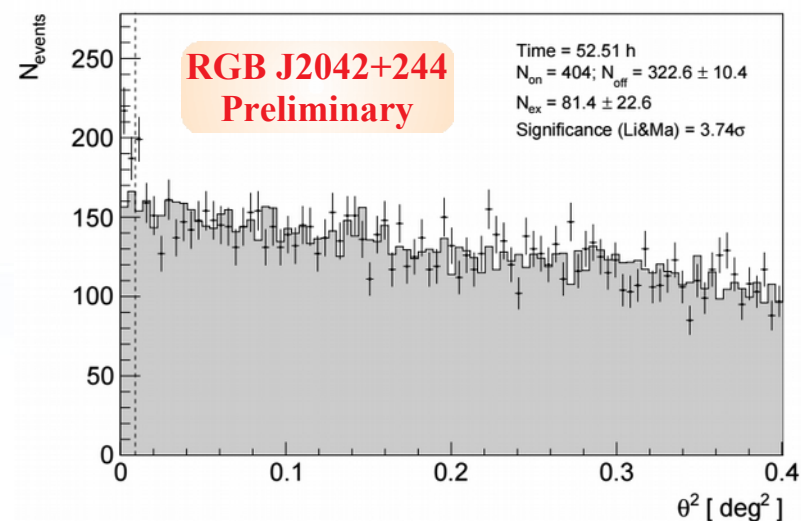
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Extreme blazars with MAGIC

Paper in preparation

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Extreme blazars with MAGIC

Paper in preparation

SED modelling

(following Asano+14)

SED modelling performed on the four new detections:

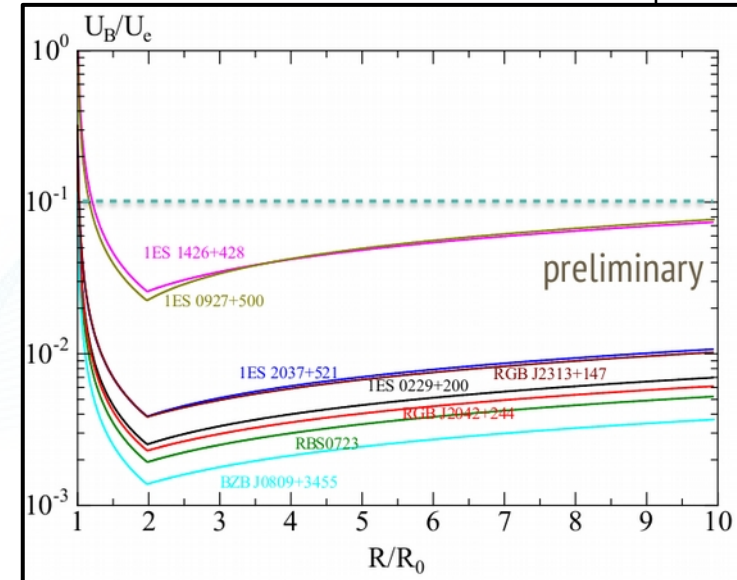
- Steady outflow
- Electron injection during the dynamical scale

Some considerations:

- SSC emission efficiency is low
- Relatively high electron energy density
- **Lower magnetization** compared to other usual blazars
- Synchrotron and IC peaks are generally not well constrained
- **Precise TeV and X-ray data are crucial**

Main physical processes considered:

- Electron injection
- Synchrotron emission and cooling
- Inverse Compton emission and cooling
- Adiabatic cooling
- Photon escape
- *No electron escape!*





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Looking for new TeV extreme blazars

L. Foffano, E. Prandini, A. Franceschini, S. Paiano

Looking for new TeV EHBL candidates

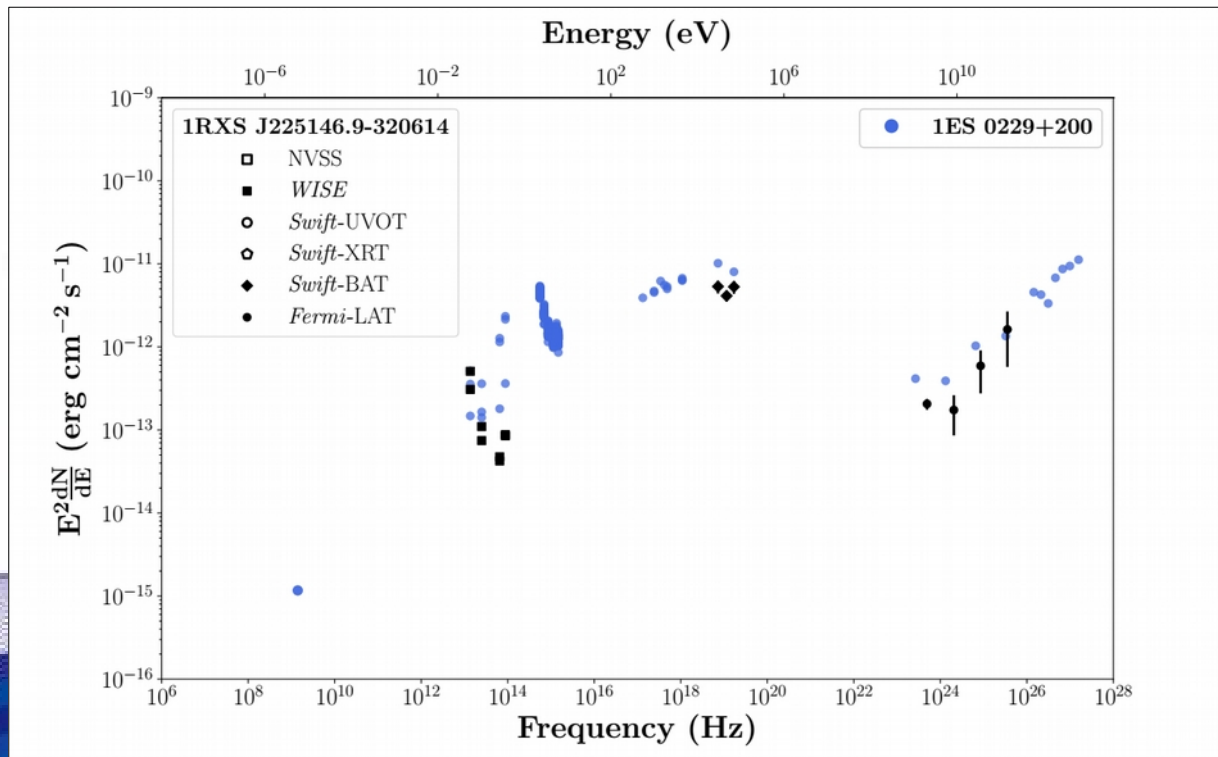
LF+
(Submitted)

We used the Swift-BAT 105-months **hard X-ray** catalogue

- Selecting **blazars** with good detection in the **hard X-ray** band
- Checking the synchrotron peak location above 10^{17} Hz (taking care of misclassifications and errors in peak estimations in the catalogues)
- Performing a new *Fermi*-LAT analysis over 10 years of data to verify the detection in the **HE gamma-ray** band
- Extrapolating the spectrum up to the **TeV gamma-ray** band to check detectability by Cherenkov telescopes
- Studying the final sample of 34 candidates, and looking for relations between already TeV detected and TeV undetected sources

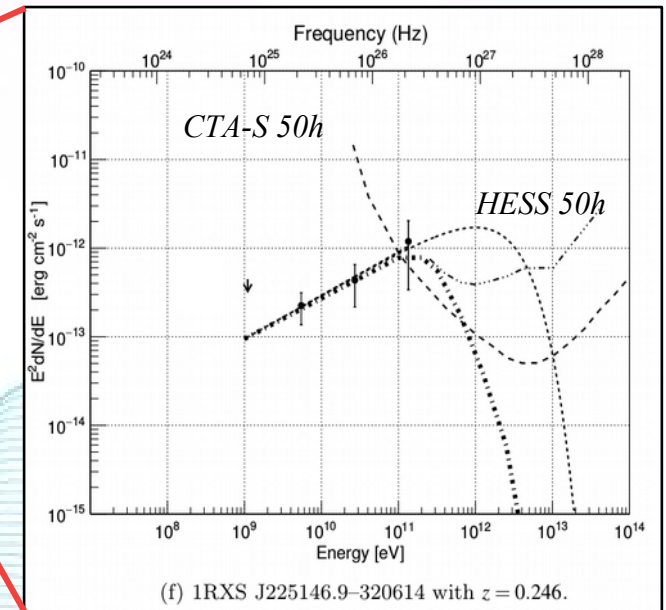
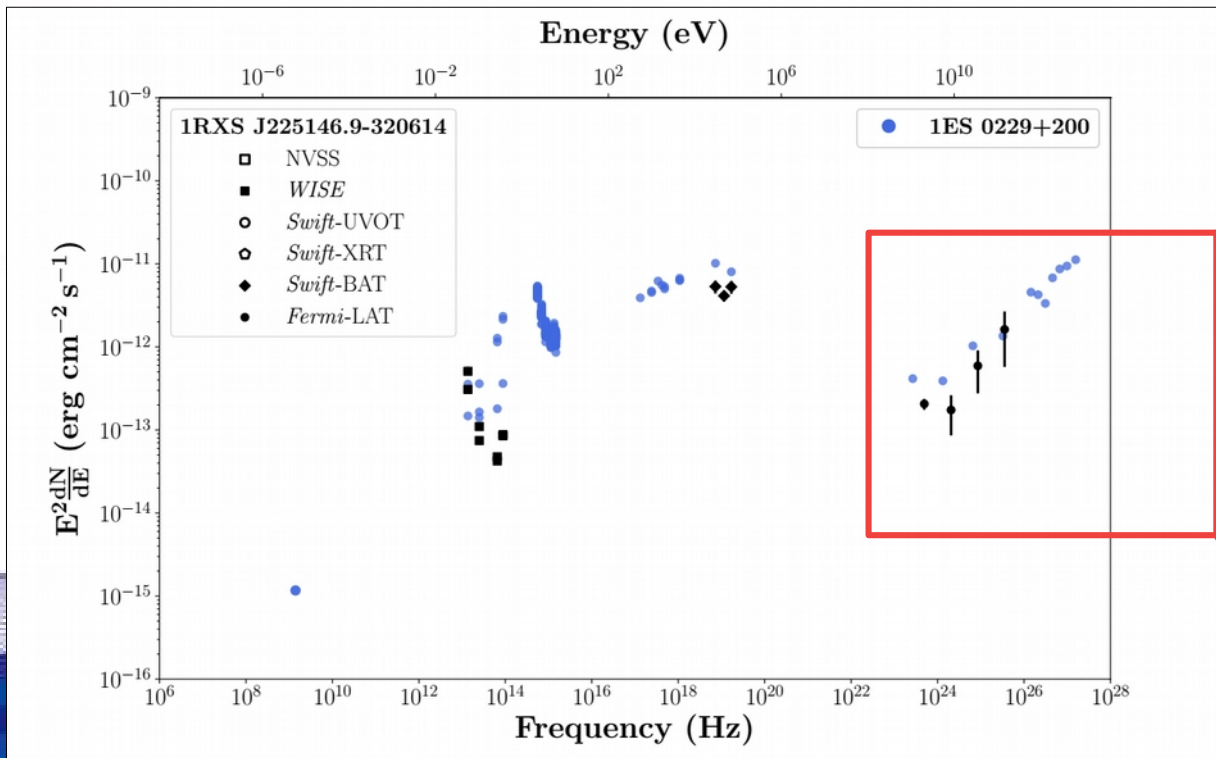
Looking for new TeV EHBL candidates

LF+
(Submitted)



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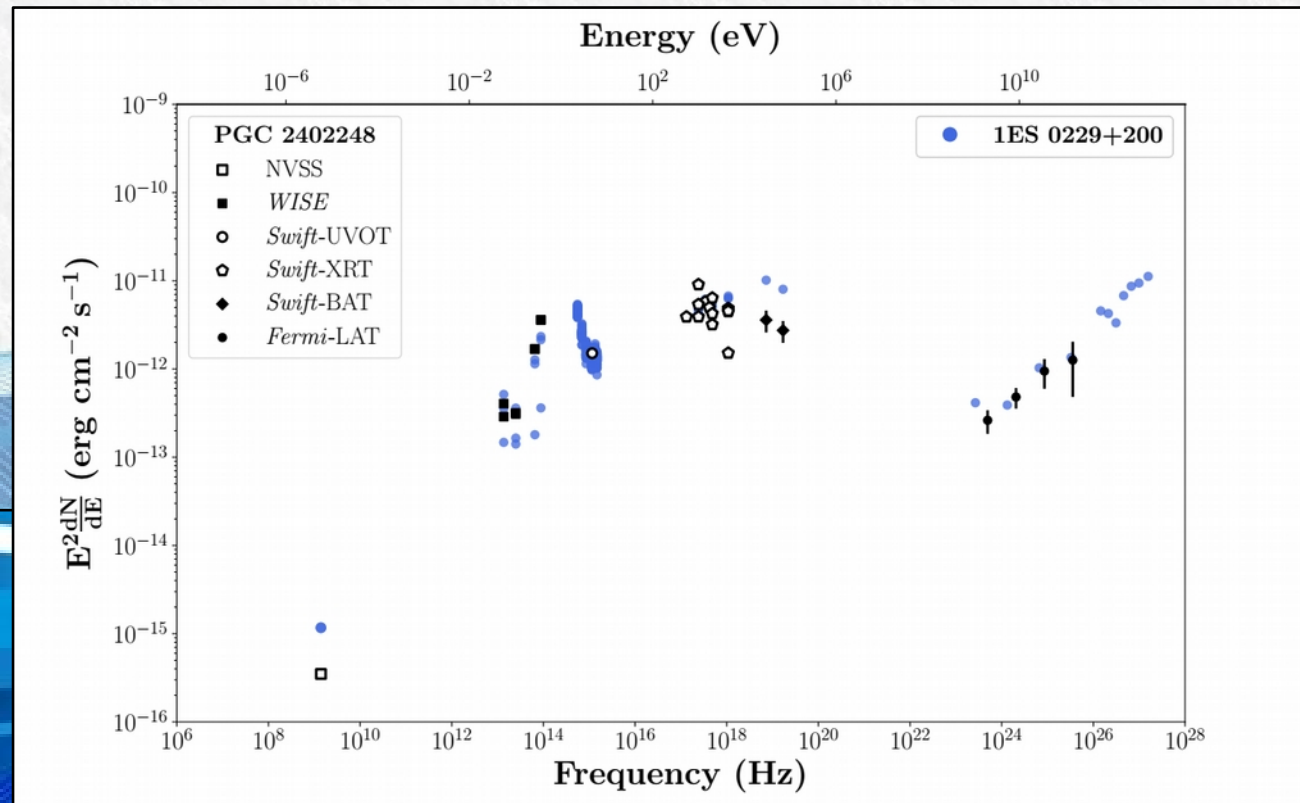
PGC 2402248 TeV detection with the MAGIC telescopes

PGC 2402248 TeV detection

Paper in preparation

A similar method was used in the 2WHSP catalogue to select the source **PGC 2402248**:

- It was proposed to the MAGIC collaboration as TeV EHBL candidate



PGC 2402248 TeV detection

Paper in preparation

A similar method was used in the 2WHSP catalogue to select the source **PGC 2402248**:

- It was proposed to the MAGIC collaboration as TeV EHBL candidate
- It was accepted as first source to be observed
- It was **successfully** detected by MAGIC after 23 h

First detection of very-high-energy gamma-ray emission from the extreme blazar PGC 2402248 with the MAGIC telescopes

ATel #11548; **Razmik Mirzoyan (Max-Planck-Institute for Physics, Munich), on behalf of the MAGIC collaboration**
on 19 Apr 2018; 15:30 UT

Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)



Conclusions

Take home message

- **Extreme blazars** could be a new category of blazars with extreme spectral parameters
- We need more TeV gamma-ray detected EHBLs
- The MAGIC collaboration detected **5 new TeV EHBLs + 1 hint**
- We are extracting **new TeV EHBL candidates** studying their proprieties in the **hard X-ray** and **HE gamma-ray** bands
 - This method was successful in detecting **PGC 2402248** in the VHE gamma-ray band by the MAGIC telescopes
- This work will continue with other catalogues



eXtreme19

22-25 January 2019
Padova

Topics:

- The blazar family
- Mechanisms of particle acceleration and radiation in jets
- Extreme blazars as neutrino factories
- Extreme blazars and the connection with the highest energy cosmic rays
- Cosmology and fundamental physics
- Future observatories

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Anna Francowiak (DESY)
Kumiko Kotera (IAP)
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Alessia Spolon (UniPD)

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More info

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extreme19@dfa.unipd.it

web
<https://agenda.infn.it/event/eXtreme19>

**Abstract welcome
by October 31st**