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## **Searching for TeV-emitting candidates among the X-ray bright, non-Fermi detected blazar population**

**Antonio Iuliano (INFN Sezione di Napoli),  
Stefano Marchesi,  
Paolo Da Vela, Davide Miceli, Chiara Righi,  
Elisa Prandini, Michele Doro, Roberta Zanin**

16 April 2024

CTAO Symposium, Bologna



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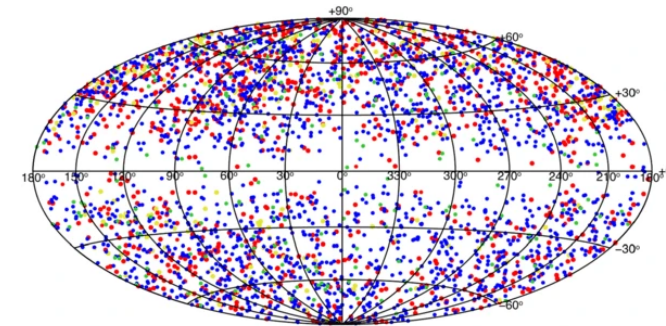


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## Introduction

- Goal: to investigate currently available X-ray observations of known blazars, with a complete and unbiased approach
- Starting point: the **Roma Multifrequency catalog of blazars, 5th edition**: <https://www.ssd.cnr.it/bzcat/>  
3561 blazars, selected on the basis of their radio emissions
- Four classes, according to multiwavelength properties:  
**5BZB**, **5BZG**, **5BZQ**, **5BZU** (colors as in sky distribution dots)
- Dividing the set of blazars in two groups, according to the presence or not of a counterpart in the Fermi-LAT 4FGL-DR4 catalog  
[https://fermi.gsfc.nasa.gov/ssc/data/access/lat/14yr\\_catalog/](https://fermi.gsfc.nasa.gov/ssc/data/access/lat/14yr_catalog/)



sky distribution in galactic  
coordinates of the blazars  
in the 5BZCAT catalogue,  
from paper  
Astrophys Space Sci 357, 75  
(2015)



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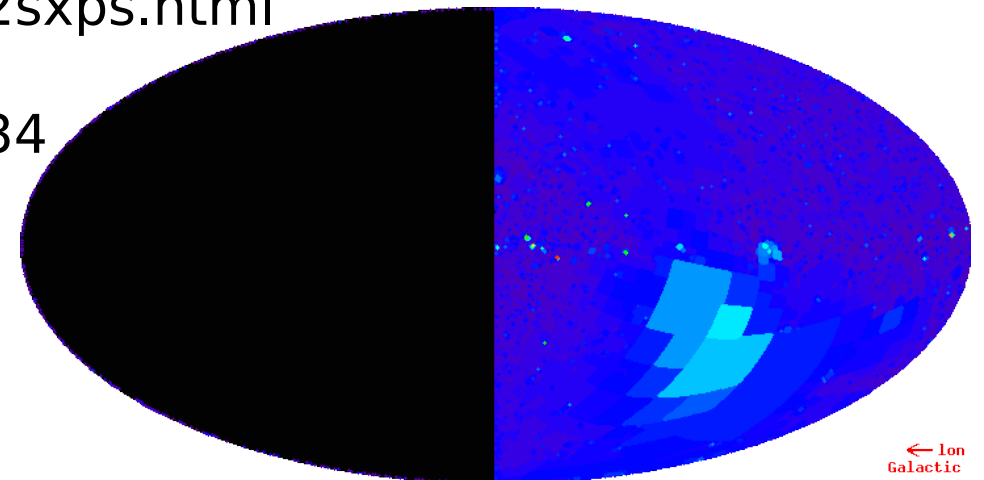
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## List of X-ray catalogs for cross-match

- **XMM-Newton Catalog** ( $>1300$  deg<sup>2</sup>; 4XMM-DR13)  
<http://xmm-catalog.irap.omp.eu/>
- **Chandra** ( $\sim 560$  deg<sup>2</sup>; CSC 2.0)  
<https://cxc.cfa.harvard.edu/csc/>
- **Swift-XRT** ( $\sim 3800$  deg<sup>2</sup>; 2SXPS)  
<https://heasarc.gsfc.nasa.gov/W3Browse/swift/swift2sxps.html>
- **eROSITA-DE** ( $20627$  deg<sup>2</sup>; eRASS1)  
<https://cdsarc.cds.unistra.fr/viz-bin/cat/J/A+A/682/A34>

eRASS1 coverage,  
From Vizier page,  
Acknowledgement:  
Andrea Merloni, am@mpe.mpg.de



← lon  
Galactic



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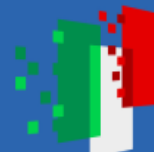


# Summary of 5BZCAT sources detected in different catalogs of X-ray sources

Marchesi et al. (in prep.)

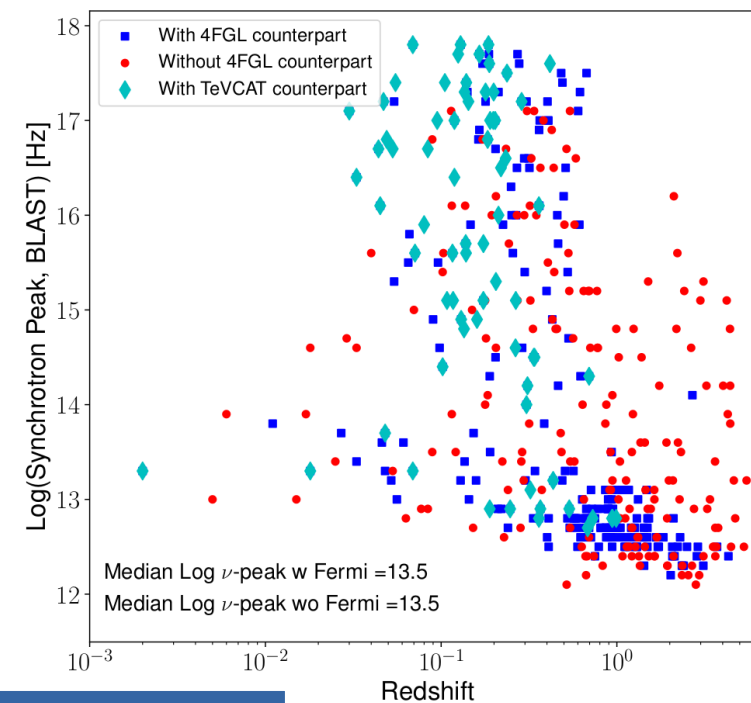
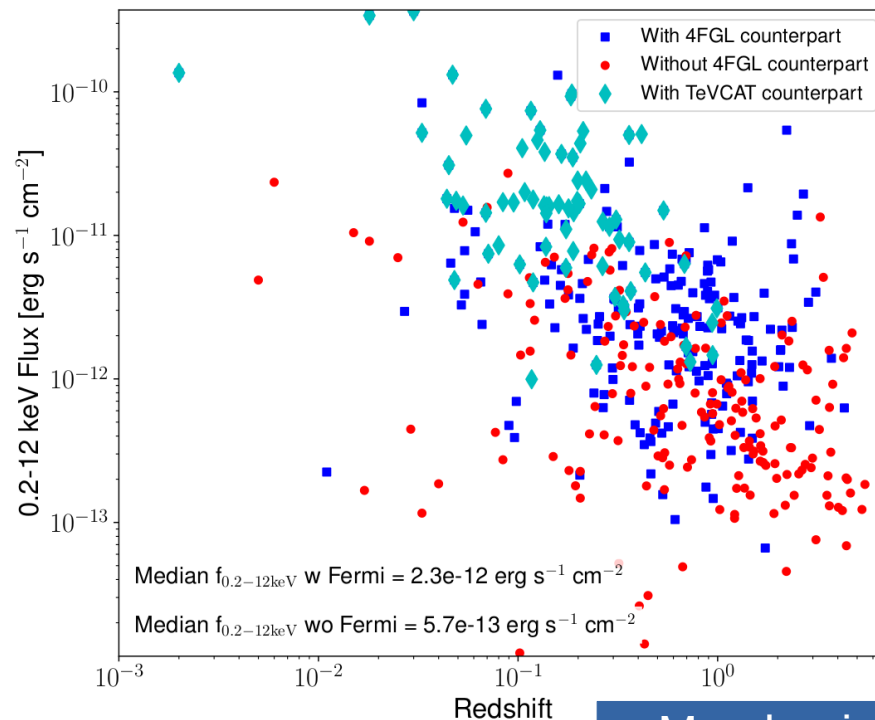
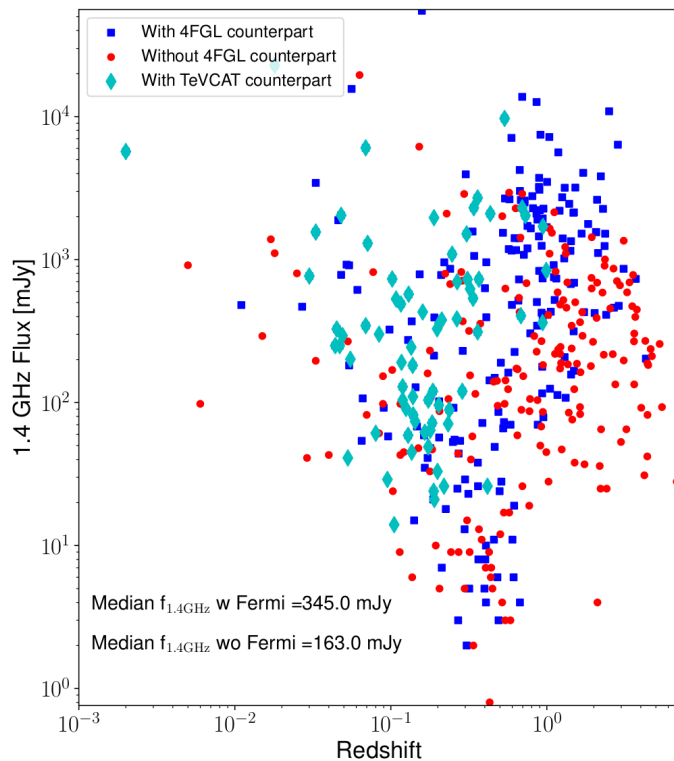
Catalog	X-ray Instrument	Area Covered deg <sup>2</sup>	Sources	With <i>Fermi</i> -LAT	Without <i>Fermi</i> -LAT
4XMM-DR13	<i>XMM-Newton</i>	1328	313	181 (58 %)	132 (42 %)
2CSC	<i>Chandra</i>	560	218	131 (60 %)	87 (40 %)
2SXPS	<i>Swift-XRT</i>	3790	1666	1191 (71 %)	475 (29 %)
eRASS1	eROSITA	20627	1379	726 (52 %)	653 (48 %)
4XMM-DR13 or 2CSC			464	271 (58 %)	193 (42 %)
2SXPS, no 4XMM or 2CSC			1347	968 (72 %)	379 (28 %)
eRASS1 only			624	189 (30 %)	435 (70 %)
Overall			2435	1428 (59 %)	1007 (41 %)
Of which in TeVCAT			77	77 (100 %)	0 (0 %)

<http://tevcat.uchicago.edu/>



## Multiwavelength distributions

- First, studied the properties of the 464 sources matched by either the XMM-Newton or the Chandra catalog. Compared multi-wavelength properties



Marchesi et al. (in prep.)



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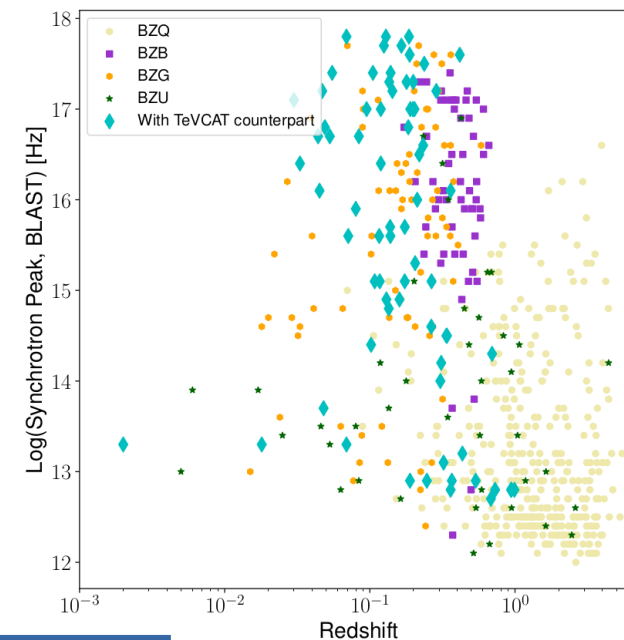
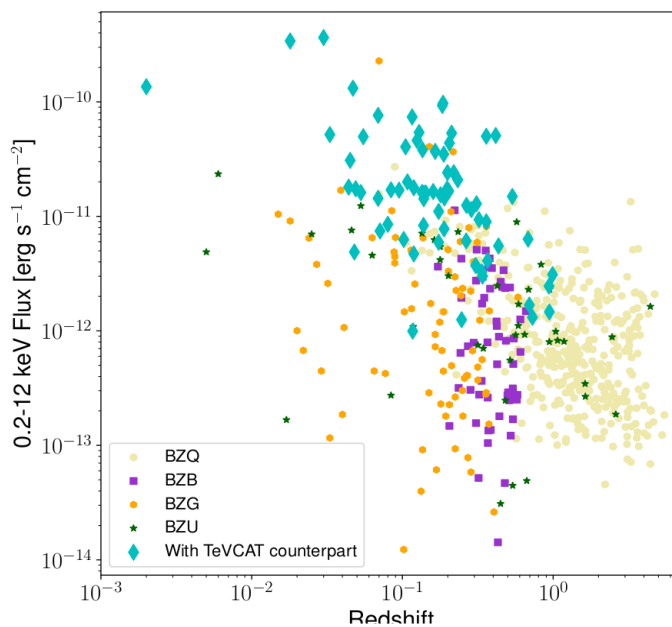
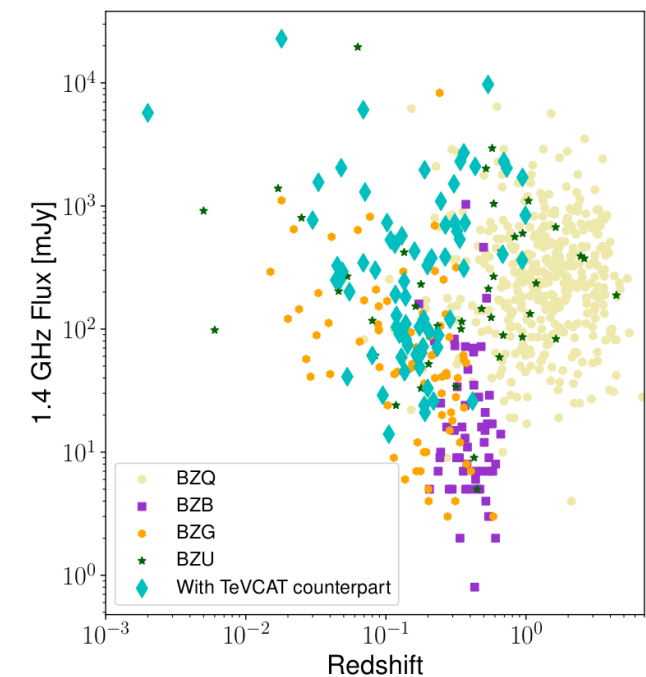


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## Blazar classes separation

- Adding the information from the 2SXPS catalog
- Breaking down the sample according to the blazar classes (FSQR, BLL, BLL + host, BCU)



Marchesi et al. (in prep.)



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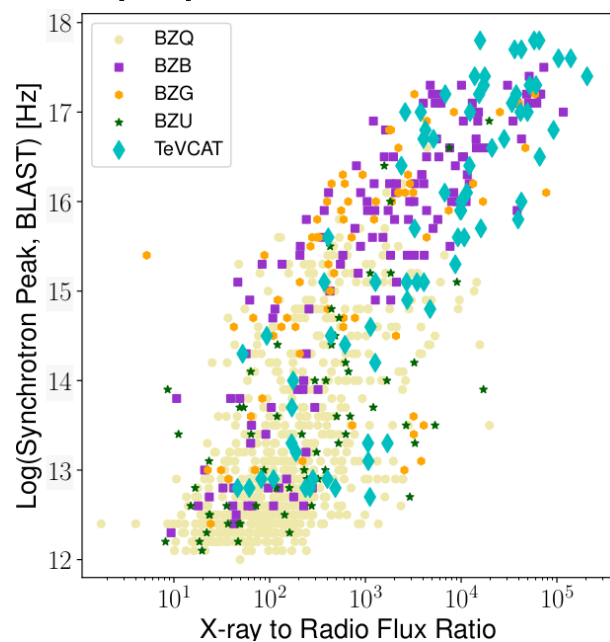


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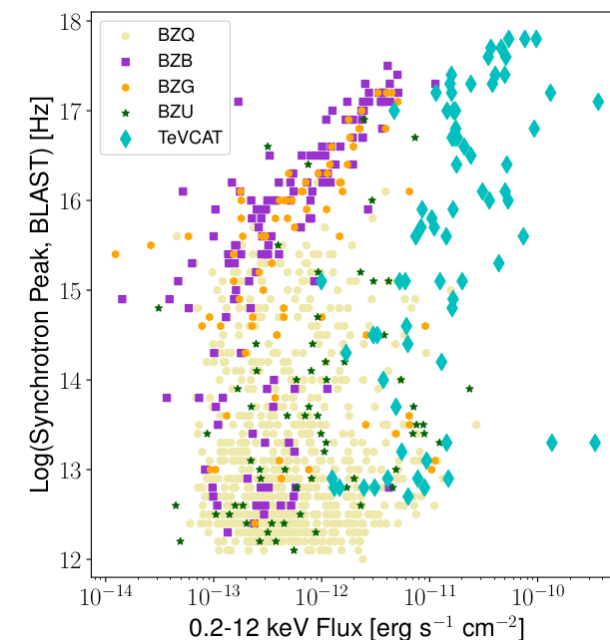


## X-ray to radio flux ratio

- Efficient predictor of TeV detectability
- Significant population of sources with high peak, high x-ray to radio flux ratio



Marchesi et al. (in prep.)

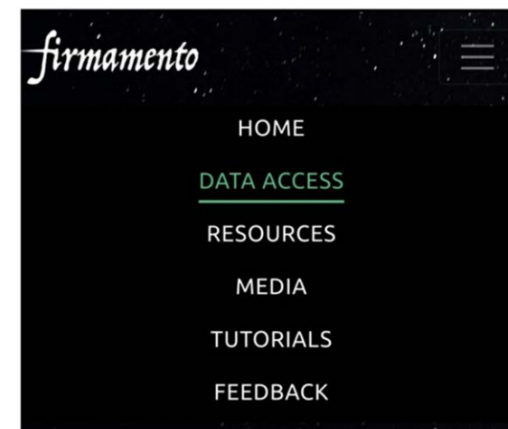




# SED Building with Firmamento

- Web browser tool with an updated version of the **VOU-Blazars** software (Chang+19)
- Provides synchrotron peak fitting with **BLAST** (Glauch et al. 2022), wPEAK and additional catalogs at all bands
- Applying Firmamento to the sample of selected candidates, in order to obtain SED distribution
- Resulting file can be used as input for fitting and extrapolation to TeV emission

Tripathi et al. 2024, AJ 167 116



Server Status: ● On Total Active Jobs: 0

User input Radio selected sources

Fermi unidentified sources

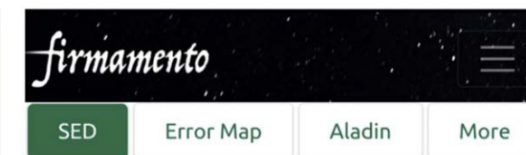
eRosita-EDR radio-matching sources

IceCube neutrino tracks

Object name eg. 3c279, or: 192.1549-5.89653

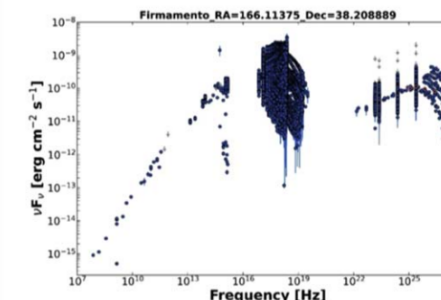
Mrk421

HELP



Documentation

SED graph from Voublazars



Results from BLAST ?

Log(nu\_peak): 17.1 ± 1.0 (1 sigma)

SED data (double-click to preview:)

○ ASCII ○ CSV ○ SSDC SED input file





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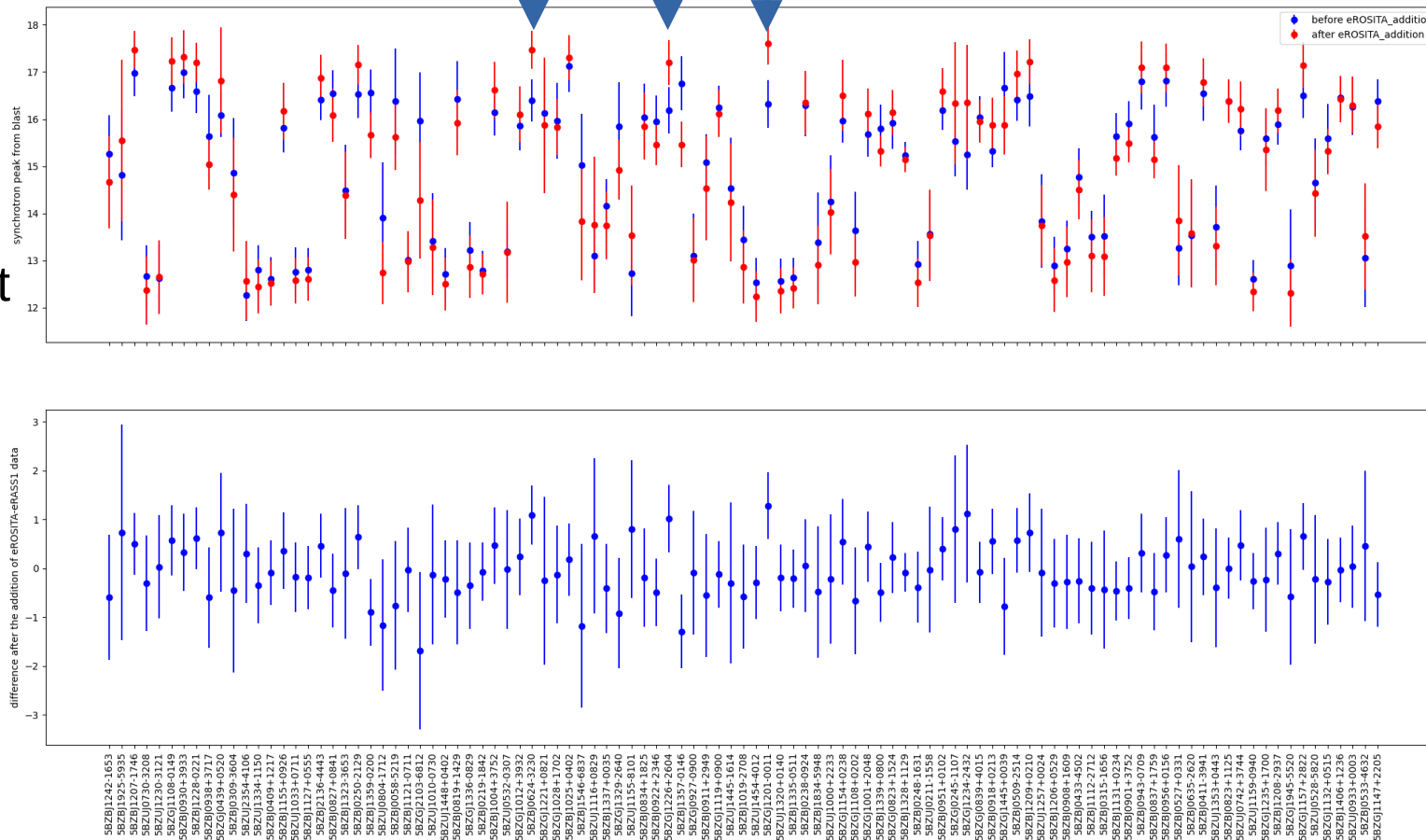


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# Synchrotron peaks with and without eROSITA

- Synchrotron peaks computed by BLAST. Error bars represent  $1\sigma$  uncertainty
- For most of the data, no significant change after eROSITA
- Cross-checking SEDs of remaining outliers



luliano et al. (in prep.)



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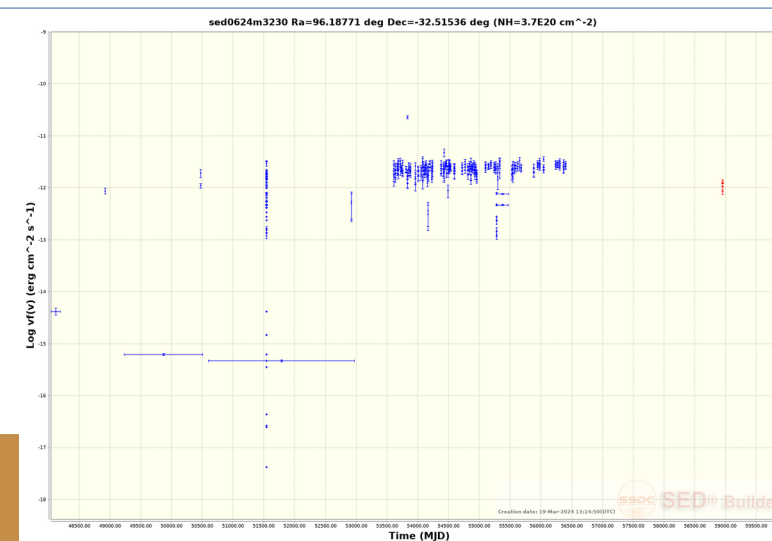
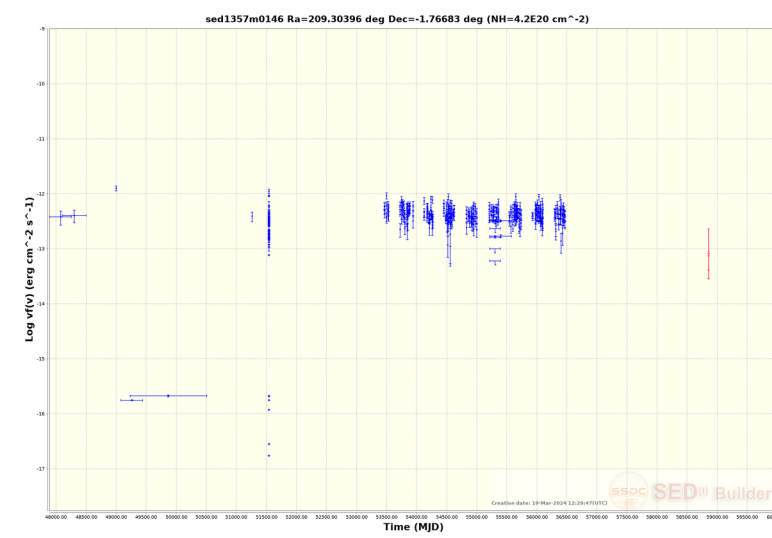
# Outlier SEDs and Light Curves

**5BZBJ1357-0146**

- Different values measured by eROSITA-eRASS1 with respect to other X-ray data
- Since eRASS1 data are more recent, difference may be explained with blazar variability

In **red**: data from the eROSITA eRASS1 catalog  
In **blue**: data from other catalogs  
SED and light curves produced with SSDC(ASI) SED Builder:  
<https://tools.ssdc.asi.it>

**5BZBJ0624-3230**





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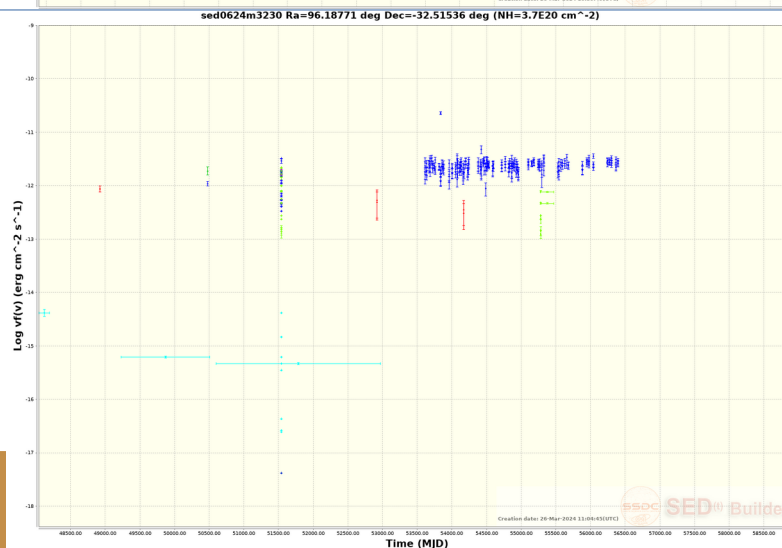
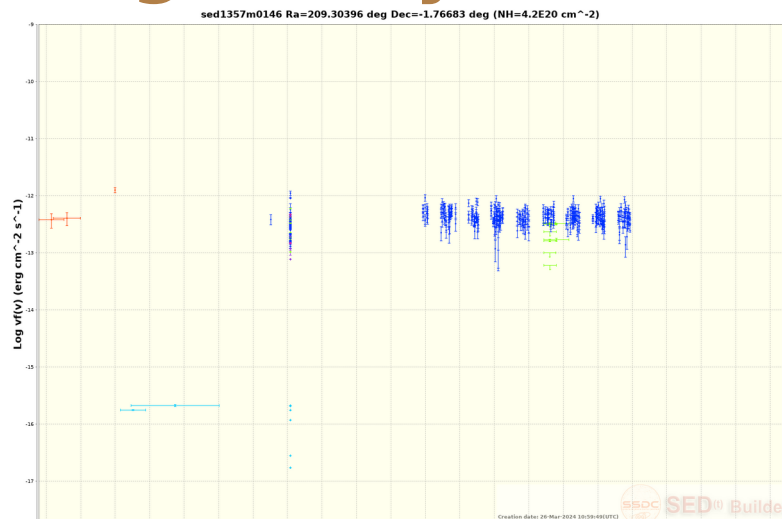


# Variability and change of synchrotron peak

5BZBJ1357-0146

- Clear stability in the optical band
- Possible explanation for synchrotron peak change after eROSITA data is variability in the X-ray band
- However, only a few points in the X-ray band, and far in time

SED and light curves produced with  
SSDC(ASI) SED Builder:  
<https://tools.ssdc.asi.it>



- Colors according to energy band:
- Red: x-ray
  - Blue: Optical
  - Green: Infrared
  - Cyan: Radio
  - Violet: UV

5BZBJ0624-3230

Iuliano et al. (in prep.)



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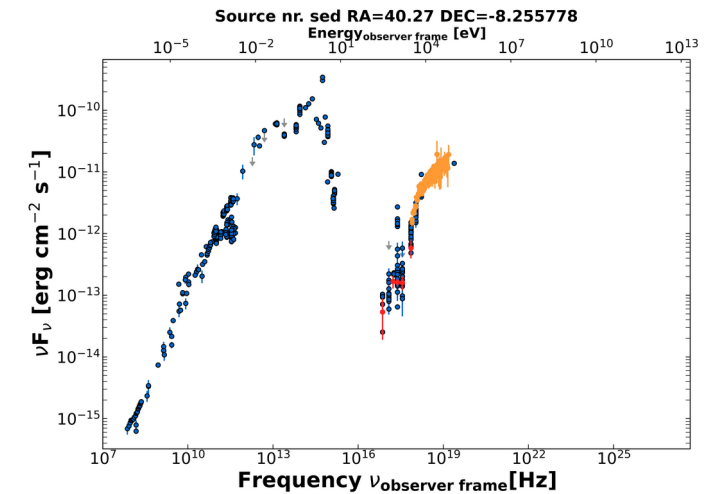
## Conclusions

Next steps:

- Model spectral distributions of interesting sources
- Possible application of Machine Learning tools
- Provide a catalog of sources with detectable TeV emission

Special thanks:

- CTA+ Project, in particular my local responsible Carla Aramo
- The CTA EGAL Working Group for their kind suggestions
- Paolo Giommi, for his kind assistance with the VOU-Blazars code and Firmamento



NuBlazar (MNRAS 514, 2022) (orange)  
eRASS1 (A&A/682/A34, 2024) (red)



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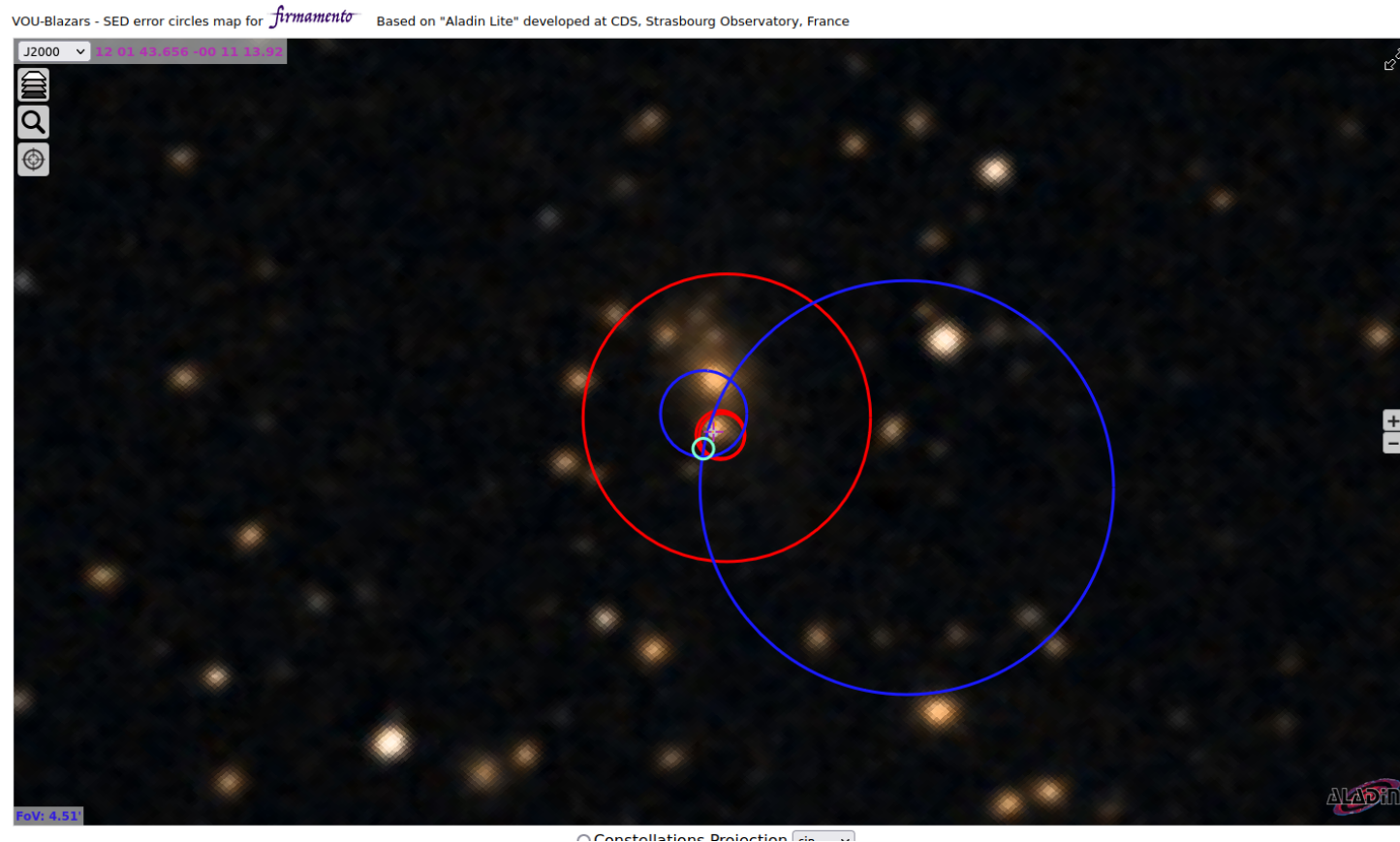
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# Thank you for your attention





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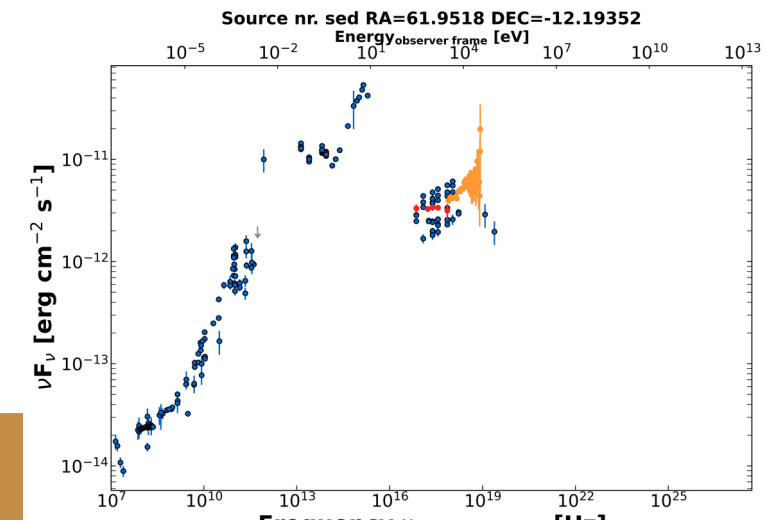
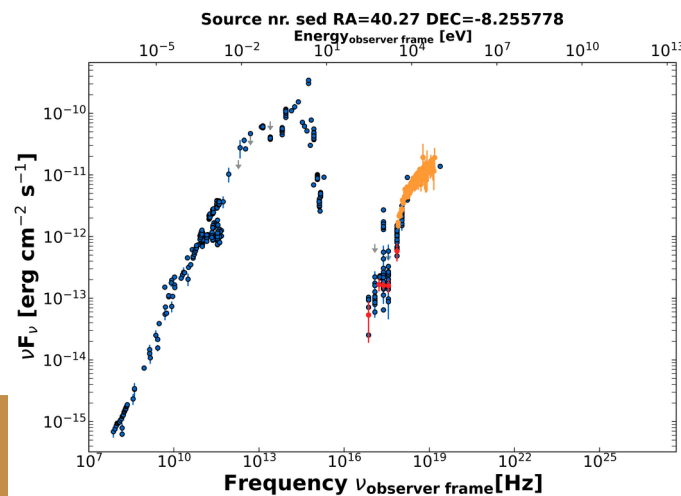


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## NuBlazar and eRASS1 catalogues

- **NuBlazar** (MNRAS 514, 2022): catalog of 124 sources from NuStar measurements
- Already included in VOU-Blazars catalog lists used in our analysis
- Making an independent check of building SEDs directly from NuBlazar list
- From NuBlazar (**orange**) list, returned 54 sources with eRASS1 data (**red**)





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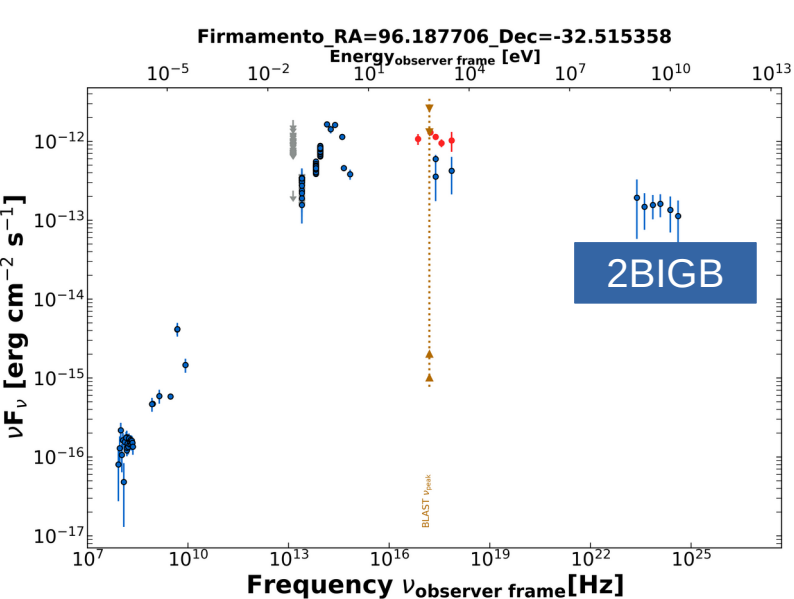
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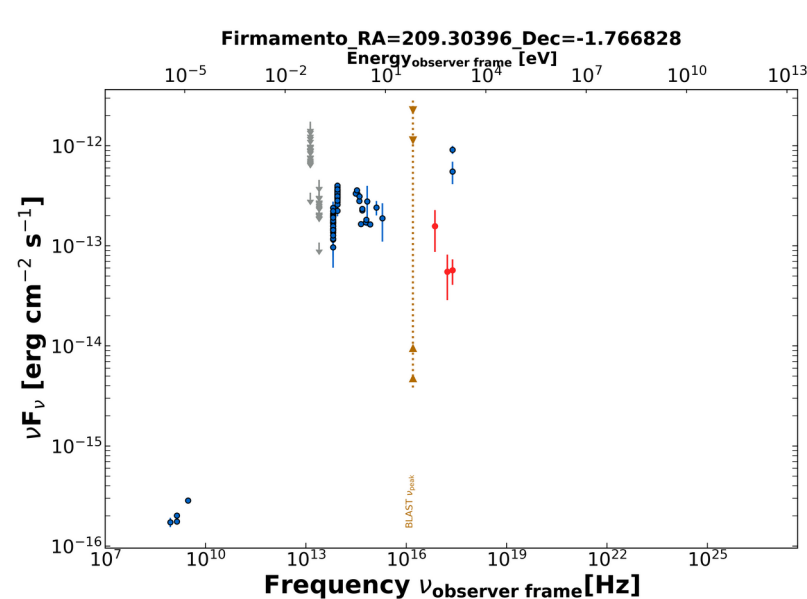
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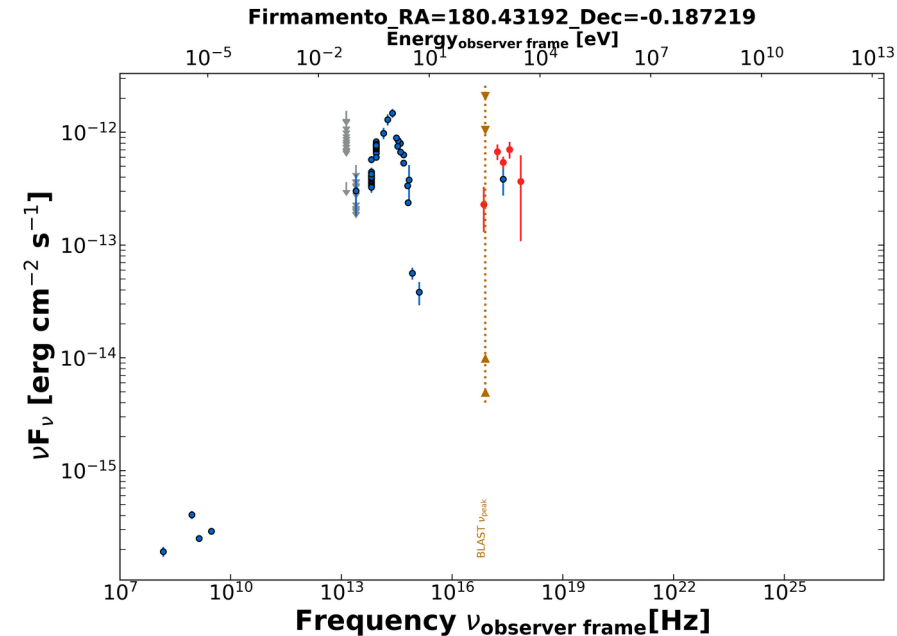
## SED of outliers



1.79  $\sigma$



1.72  $\sigma$



1.88  $\sigma$

In red: data from the eROSITA eRASS1 catalogue  
In blue: data from other catalogues