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

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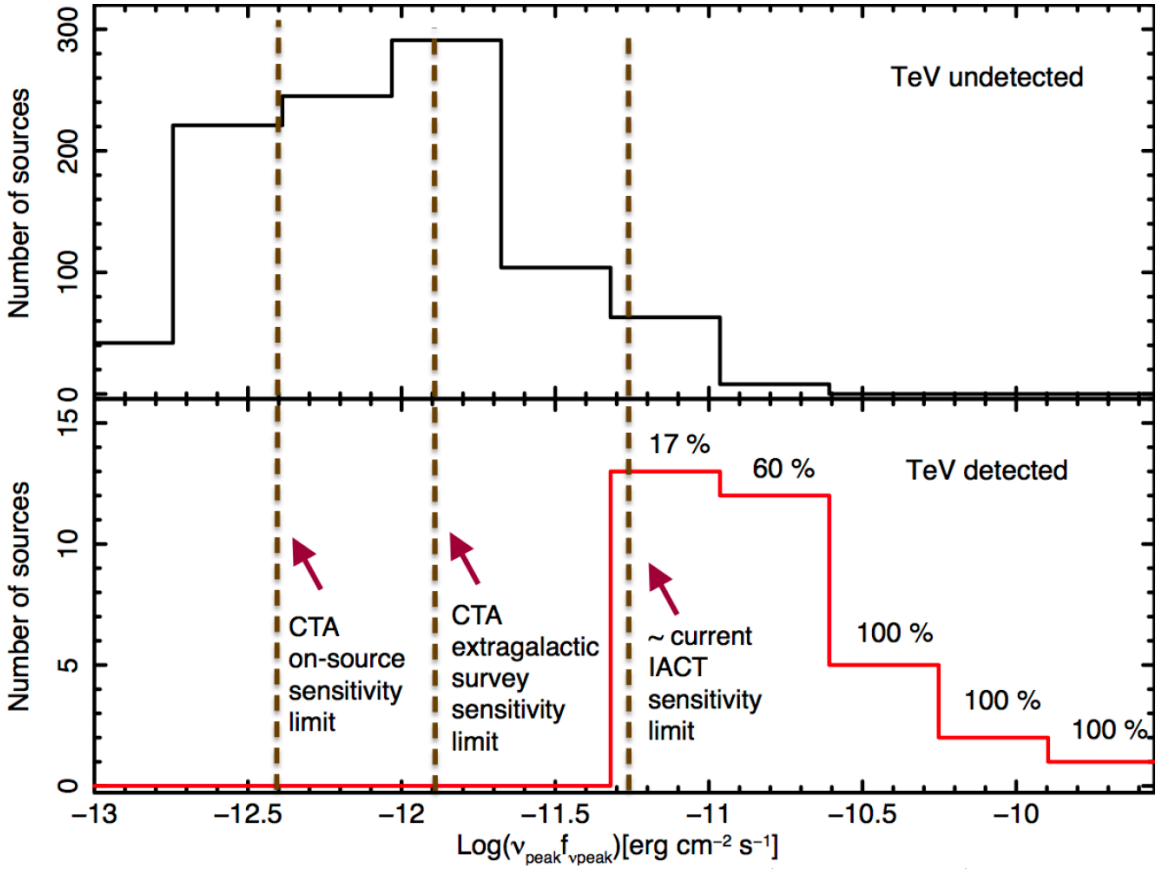
- As already mentioned in previous talks, there are now ~90 extragalactic sources in the TeVCAT.
- Predicted number of detection with future facilities is highly uncertain: simply extrapolating the Fermi-LAT results assuming a 1 TeV cutoff gives fairly low numbers (<~50 sources), but it's debatable that Fermi-LAT is the most efficient predictor of TeV emission in blazars.
- For example, Arsioli et al. (2015) showed how a combination of IR and X-ray information can more efficiently predict the TeV SED of a blazar.
- Multiple goals: first studies of populations, better constraints on Gamma-ray emission in AGN, studies of hard extreme blazars missed by Fermi…



From the CTA White Paper

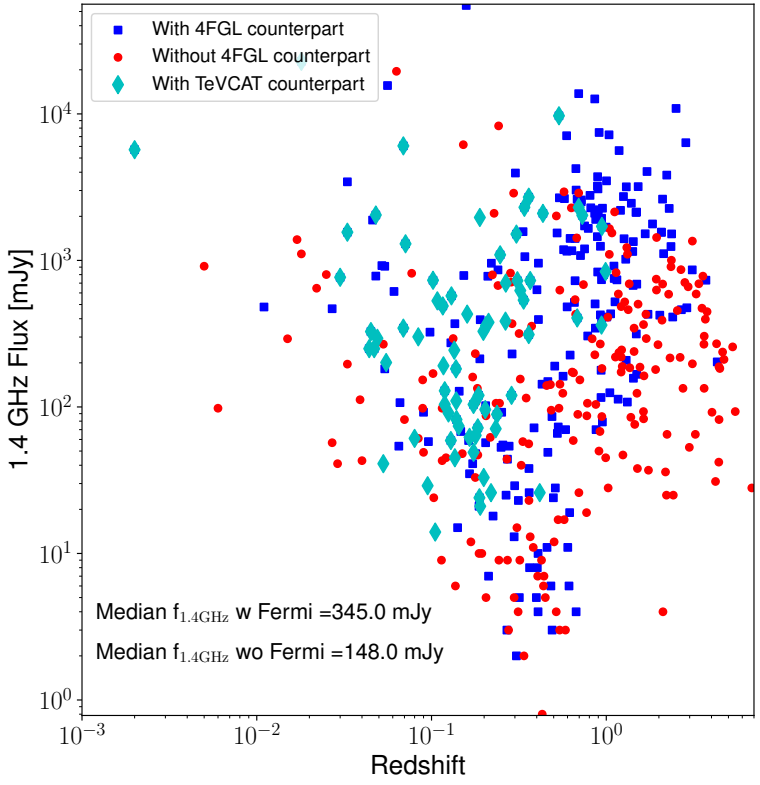
- Within this framework, we started investigating currently available X-ray observations of known blazars.
- The goal of this project is to obtain a more complete, possibly less biased understanding of the VHE emitting extragalactic population.
- As a first starting point, we selected the Roma Multifrequency catalog of blazars, 5th Edition (https://www.ssdc.asi.it/bzcat/): 3561 known blazars, selected based on their radio emission.
- We performed cross-matches in two different bands: first we searched for a Gamma-ray counterpart in the Fermi-LAT 4FGL DR4 catalog (most recent Fermi catalog, based on 14 years of observations).
- Then we searched for X-ray counterparts: public source catalogs are available for the three main telescopes covering the 0.5-10 keV band: *Chandra* (~560 deg^2; CSC 2.0: https://cxc.cfa.harvard.edu/csc/), XMM-*Newton* (>1300 deg^2; 4XMM-DR13: http://xmm-catalog.irap.omp.eu/), and Swift-XRT (~3800 deg^2; 2SXPS, {https://heasarc.gsfc.nasa.gov/W3Browse/swift/swift2sxps.html).

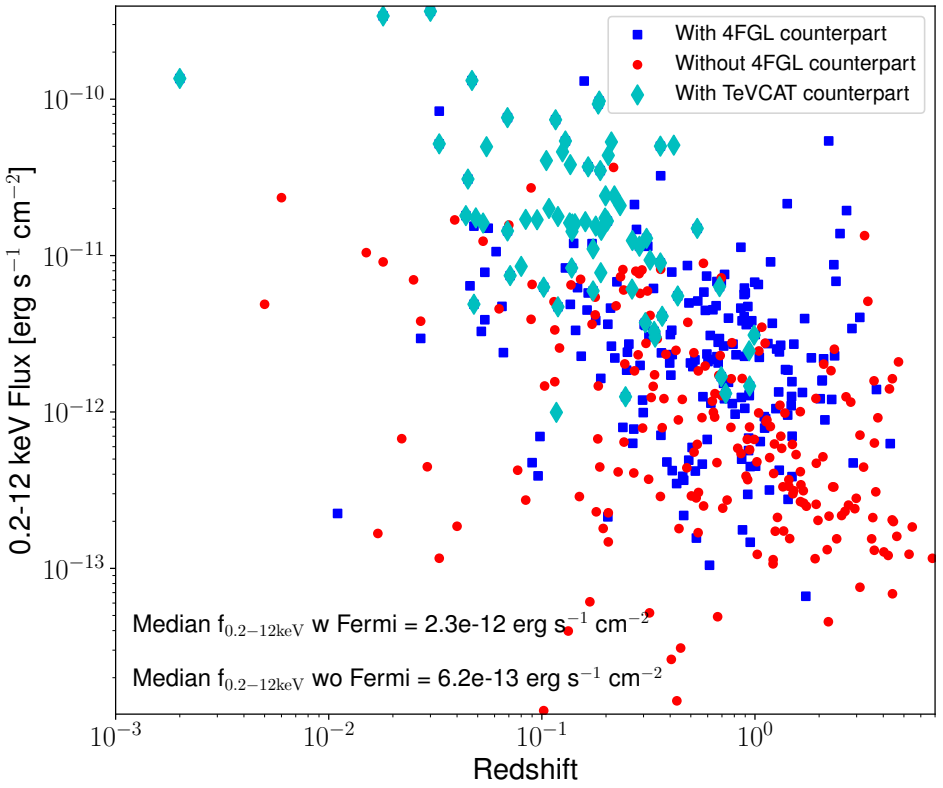
Catalog	X-ray Instrument	Sources	With *Fermi*-LAT	Without *Fermi*-LAT
4XMM-DR13	XMM-*Newton*	326	181 (56 %)	145 (44 %)
2CSC	*Chandra*	225	131 (58 %)	94 (42 %)
2SXPS	*Swift-XRT*	1670	1195 (72 %)	475 (28 %)
4XMM-DR13, 2CSC, 2SXPS		314	224 (71 %)	90 (28 %)
4XMM-DR13, 2CSC		16	5 (31 %)	11 (69 %)
4XMM-DR13 only		94	25 (27 %)	69 (73 %)
2CSC only		55	17 (31 %)	38 (69 %)
4XMM-DR13 or 2CSC		479	271 (57 %)	208 (43 %)
2SXPS only		1356	971 (72 %)	385 (28 %)
Overall		1835	1242 (68 %)	593 (32 %)
Of which in TeVCAT		76	76 (100 %)	0 (0 %)

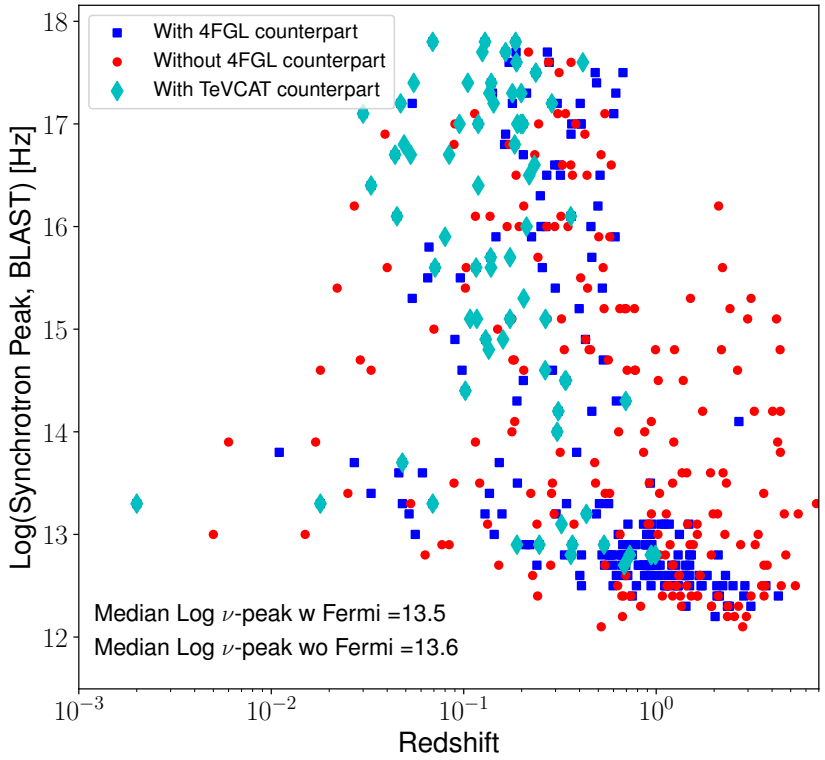
Table 1. Summary of 5BZCAT sources detected in different catalogs of X-ray sources. For each catalog, or combination of catalogs, we also report the number of sources with and without a counterpart in the *Fermi*-LAT 4FGL-DR4 catalog of sources detected in the 50 MeV–1 TeV energy range.

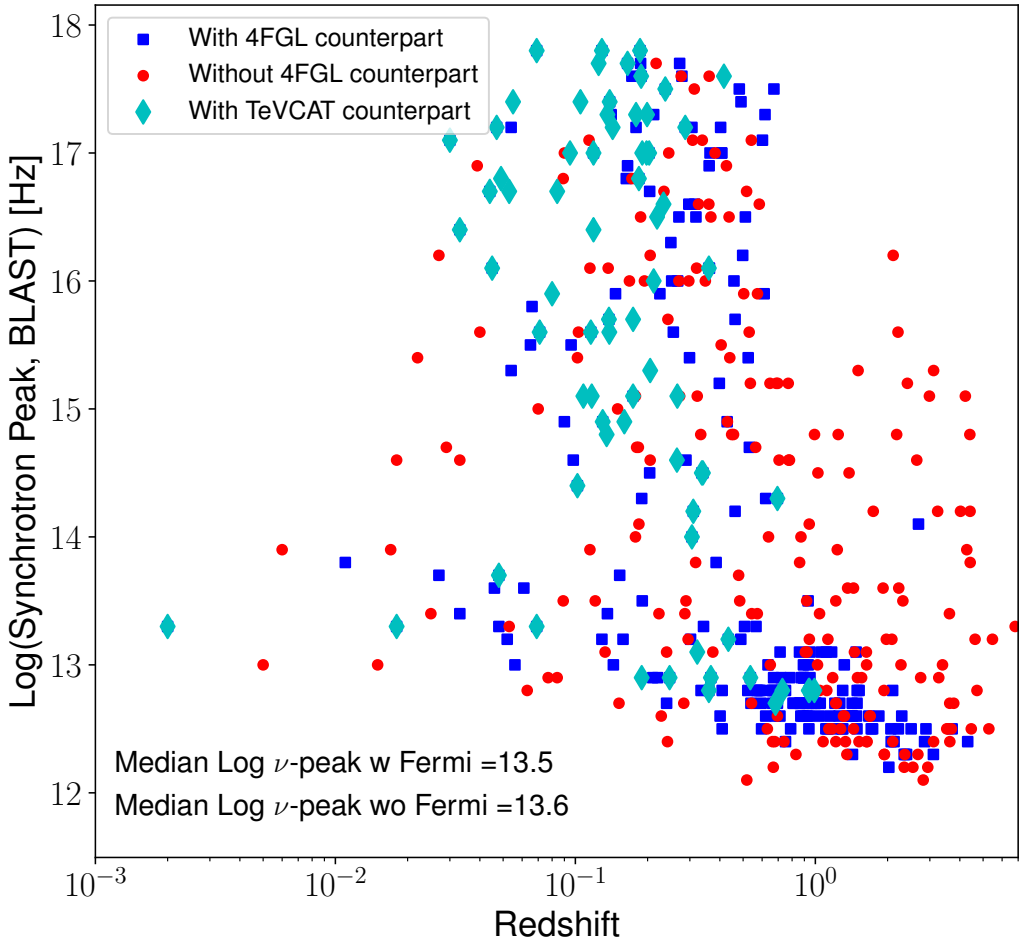
- We first used the sample of 479 sources with either Chandra or XMM counterpart to search for differences between the 4FGL-detected (271, 57%) and -non detected (208, 43%) sources.
- Compared multi-wavelength properties (R-band magnitude, 1.4 GHz flux from BZCAT; 0.2-12 keV flux from X-ray catalogs), as well as synchrotron peak frequency from BLAST (Glauch et al. 2022), a deep neural network-based tool implemented in VOU-Blazars (Chang+19).

- Generally, 4FGL-detected sources are X-ray and radio brighter, partially because they are on average at lower redshift. We do not instead measure any significant difference in the median synchrotron peak.
- Despite the differences in fluxes, we identify a population of X-ray detected, non 4FGL sources in the parameter space where the current TeVCAT sources are detected.



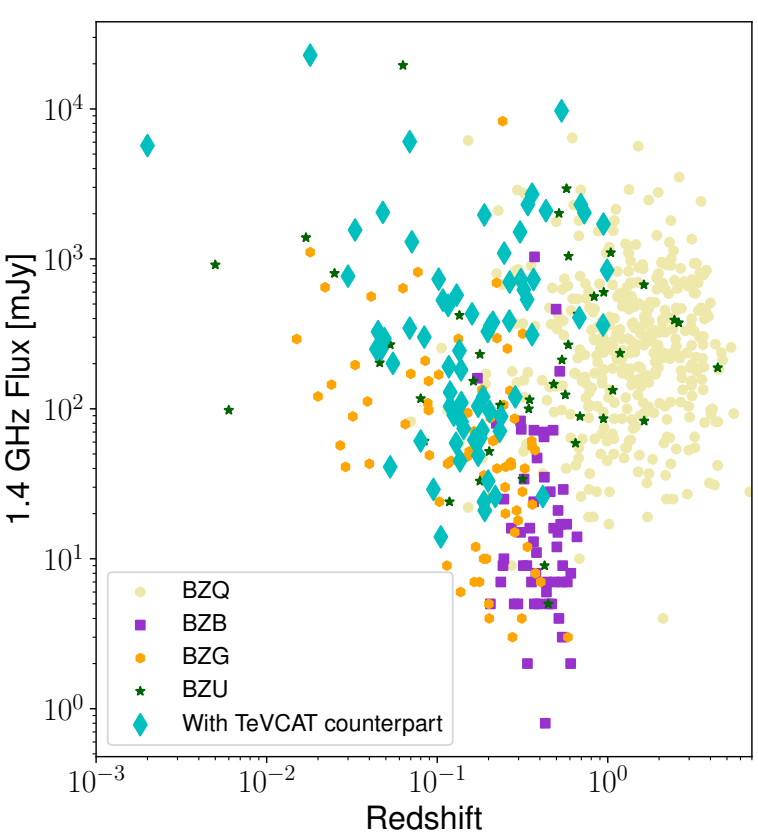


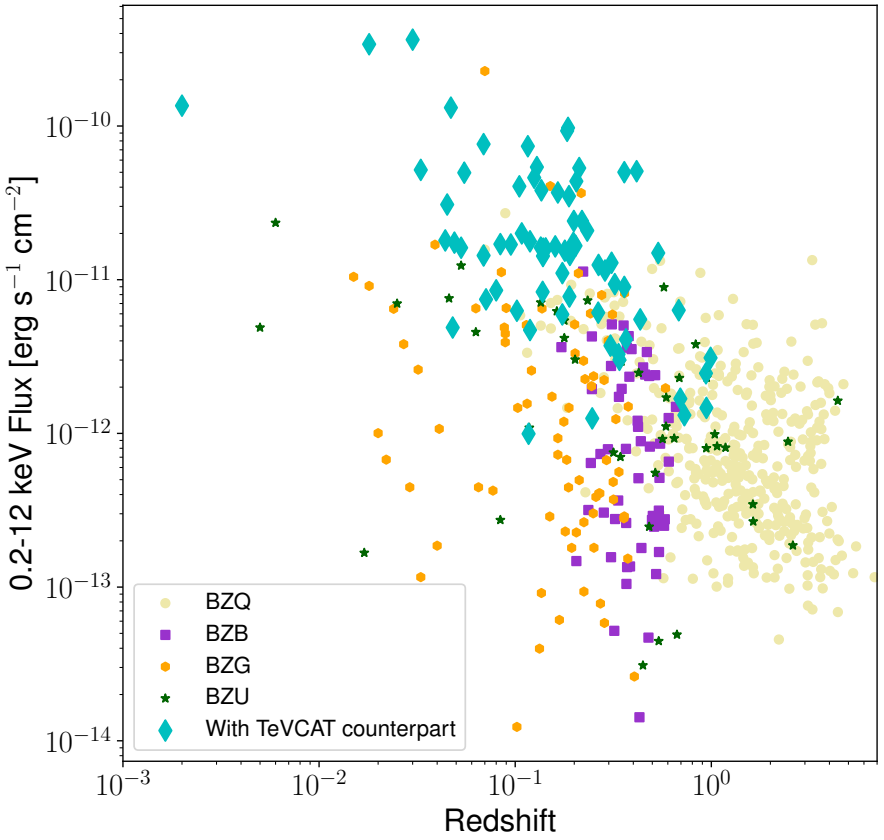


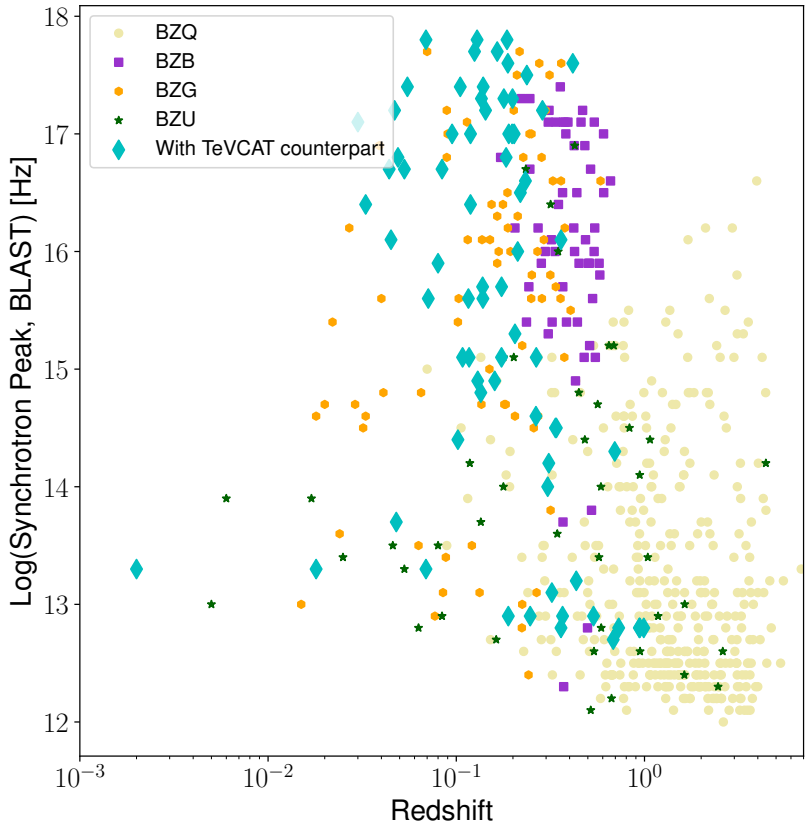


- Based on this first evidence, it is therefore plausible (as discussed in previous works) that it exists a population of blazars that can emit in the TeV while being undetected by Fermi-LAT.
- We further explore this possibility by including in the non-4FGL sample 593 sources with a 2SXPS counterpart, and by breaking down our sample in blazar classes (FSRQ, BLL, BLL+host, BCU).

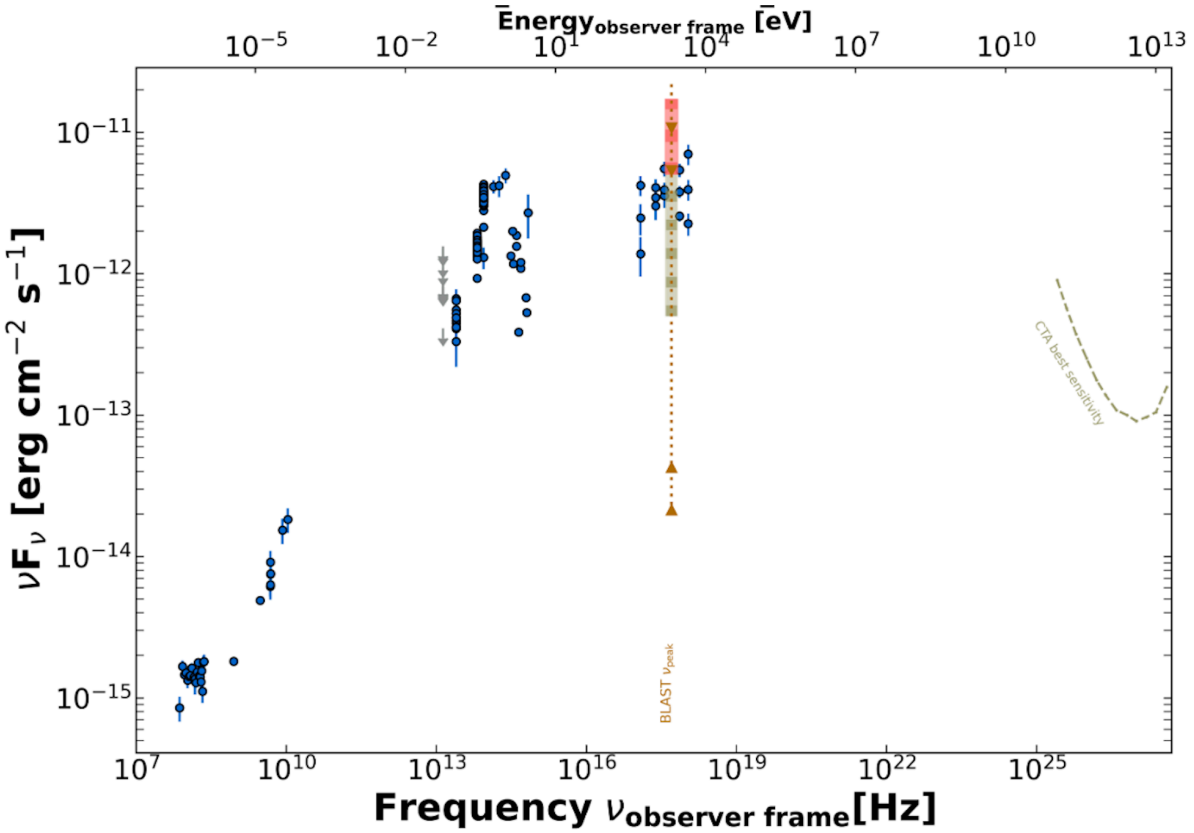
- As known, TeV-emitting population dominated by BLL (BZB or BZG): X-ray (and radio) bright, high (log(frequency)>15) synchrotron peak.

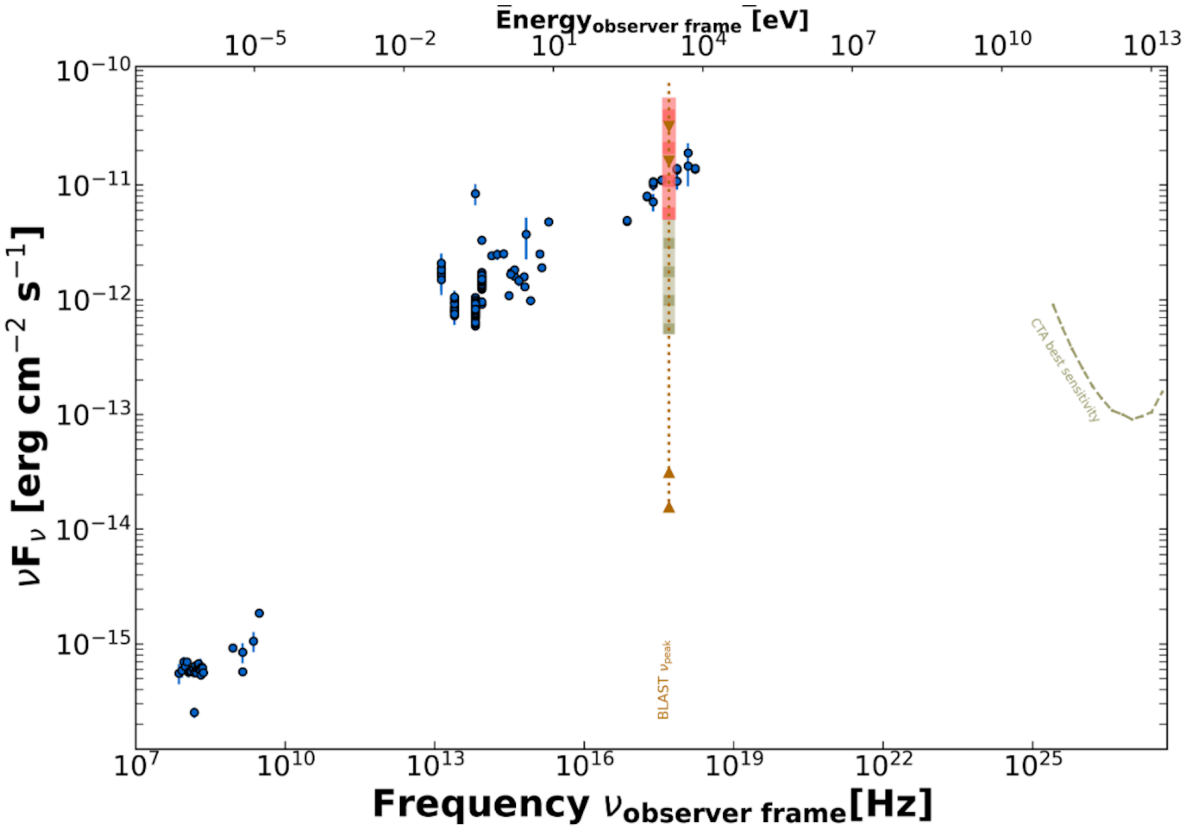






- We now plan to explore in greater detail the population of non-4FGL sources that are X-ray bright and have high synchrotron peak. Potential interesting LST candidates!





- In summary, currently available X-ray catalog already allow us to explore the non-Fermi emitting blazar population to select a sample of candidate TeV-emitters. Several potential candidates for LST proposal!
- A further, key step forward will be provided by the release of the eROSITA eRASS1 catalog (six months of observations, 50% of the sky, ~20,000 deg^2, flux limit ~5E-14 in the 0.5-2 keV band) by the end of **January 2024**.
- eROSITA scanned the whole sky in the X-rays, up to ~4-5 keV; average resolution ~30".
- Based on previous preliminary releases, the catalogs should include X-ray information (fluxes, hardness ratios, photon indices…) as well as information on the optical/nIR counterparts (including photometric redshifts and WISE colors).
- We plan to match this catalog with the BZCat to further enhance our studies of the X-ray blazars population as a CTA predictor (preliminary work done by A. Iuliano).