

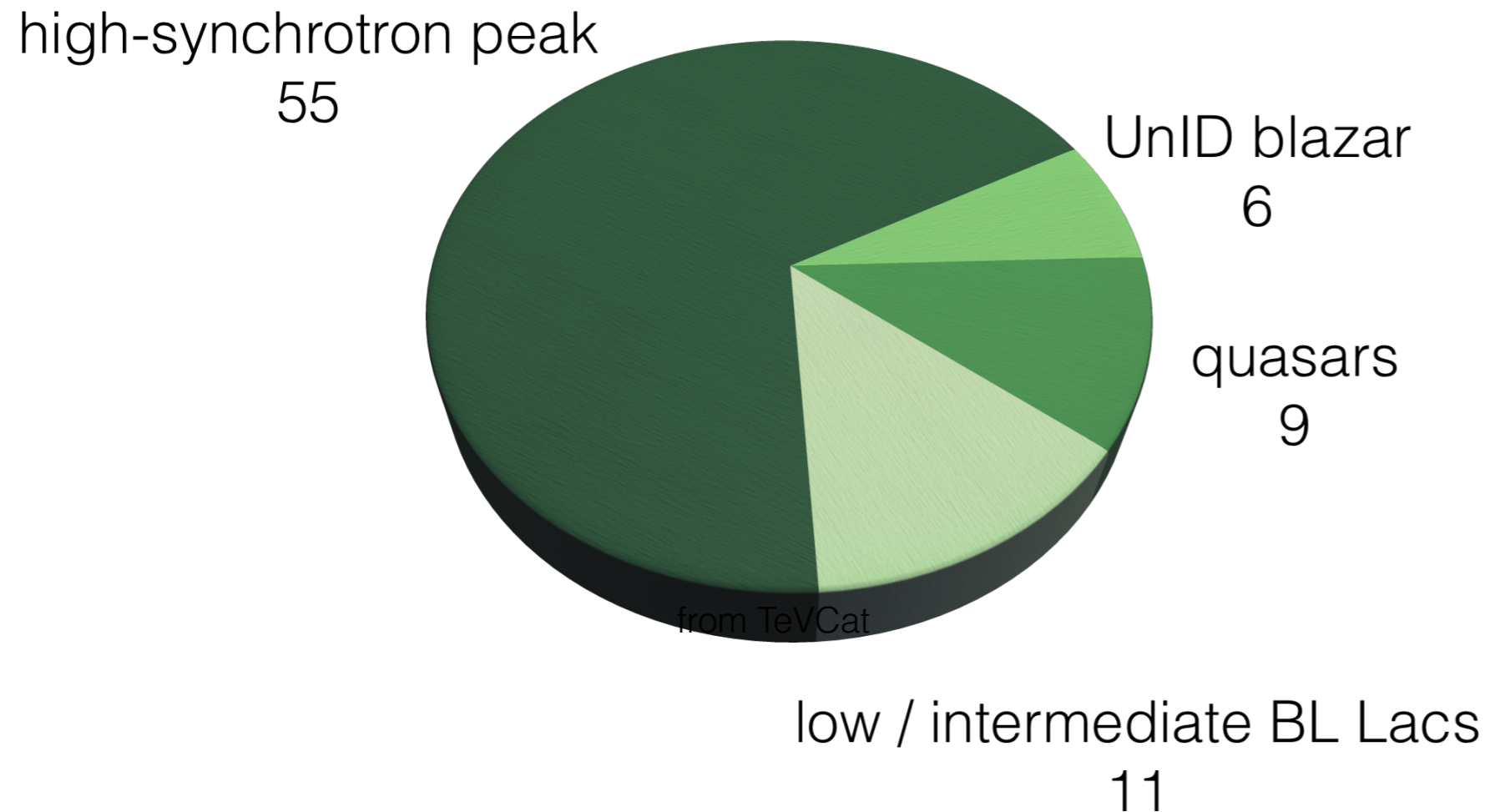
An unbiased search for TeV emission from high-frequency peaked BL Lacs

Manel Errando, on behalf of the VERITAS collaboration

Washington University in St. Louis

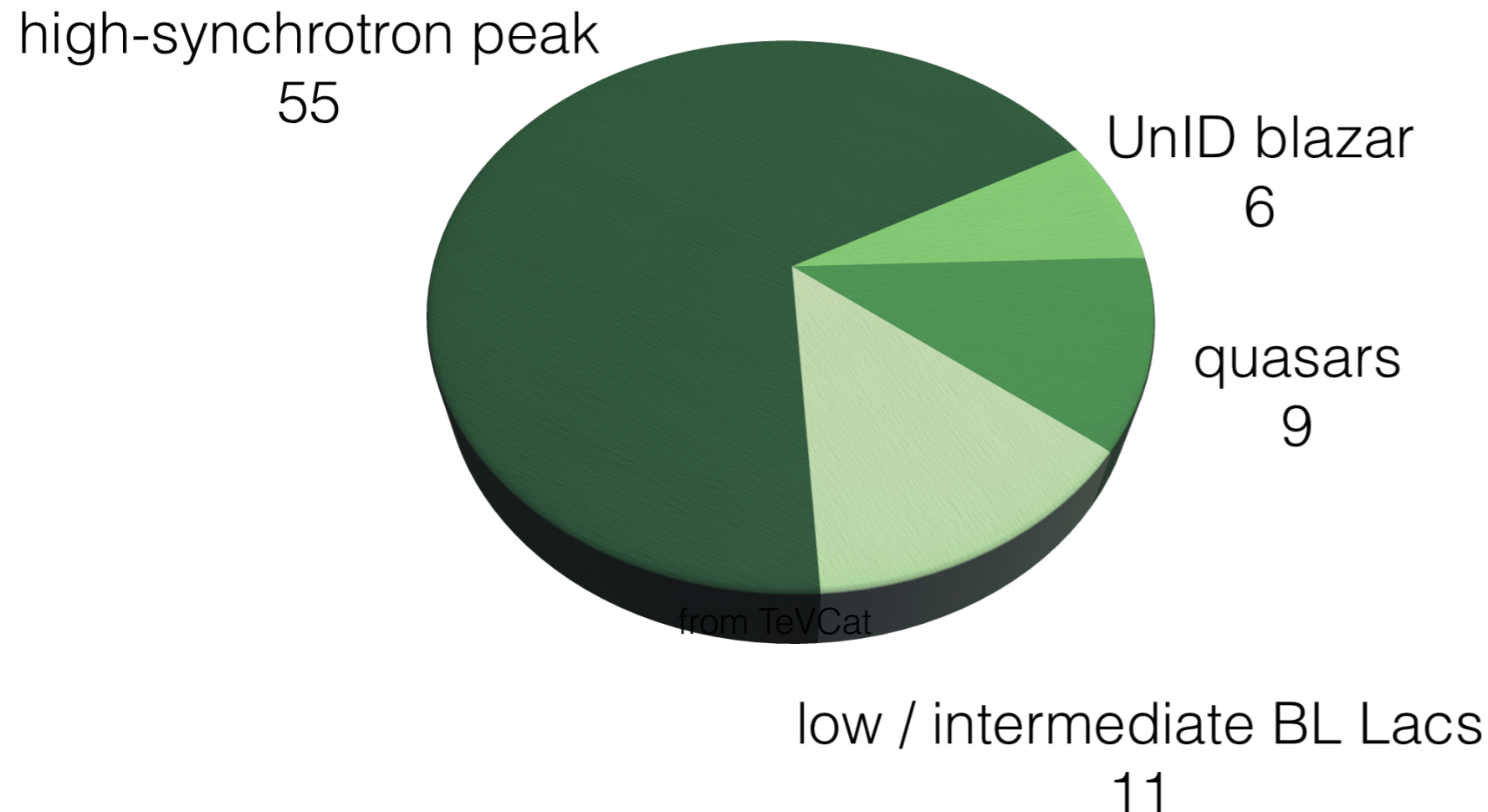


TeV-detected blazars



- There are 81 blazars detected at TeV energies, but their properties as a population (luminosity distribution, redshift distribution, etc) are poorly understood.
- The lack of blind extragalactic surveys combined with observational biases intrinsic to the operation of IACTs do not allow to conduct population studies based on published data.

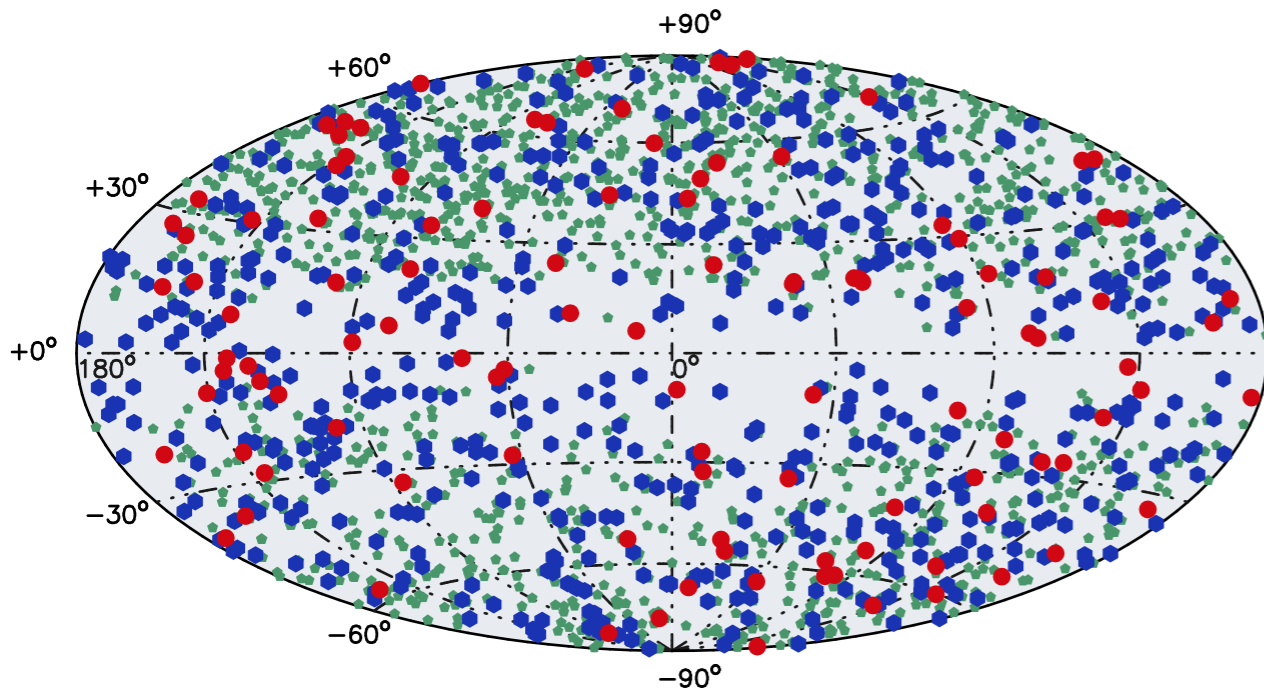
TeV-detected blazars



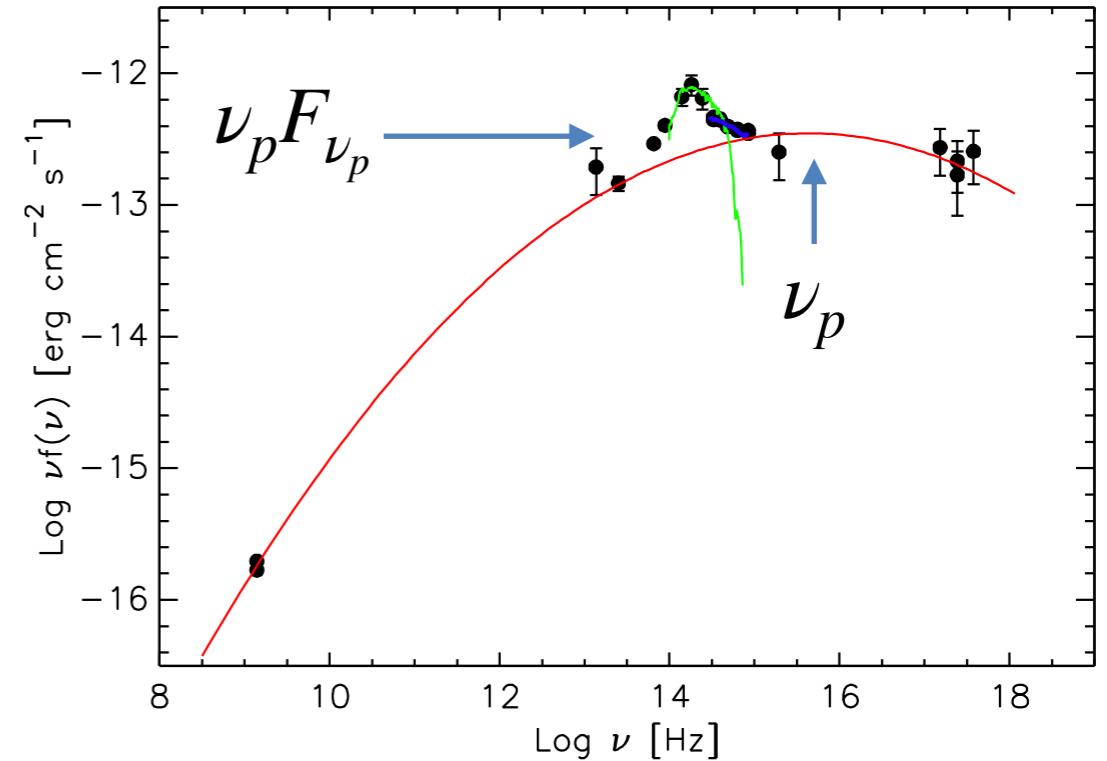
How many blazars with TeV luminosity $> L$ are there per cubic Mpc at a redshift z ?

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The VERITAS HBL sample



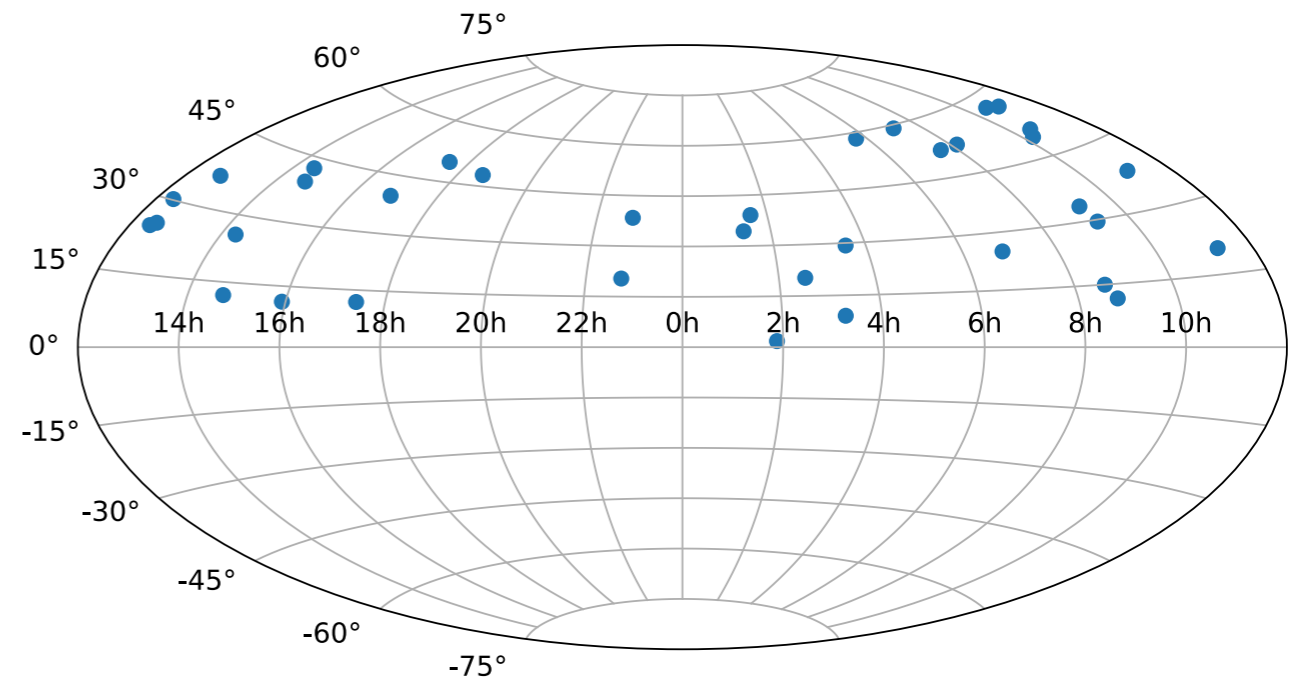
The 3HSP catalog (Chang et al. 2019)



- The 3HSP catalog (Chang et al. 2019, *A&A*, 632, 77) uses radio and X-ray data to select high-frequency-peaked BL Lacs.
- The catalog includes 2013 sources with synchrotron peak $> 10^{15}$ Hz and high degree of completeness.

The VERITAS HBL sample

- Based on the 3HSP catalog (Chan et al. 2019):
synchrotron peak in the UV to X-ray range.
- Good observing conditions with VERITAS: $1.7^\circ < \text{decl.} < 61.7^\circ$.
- Off the galactic plane: $|b| > 10^\circ$.
- Estimated synchrotron peak luminosity $> 6.3 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$.
- Total of 36 sources (21 already TeV-detected).



The VERITAS HBL sample, in celestial coordinates.

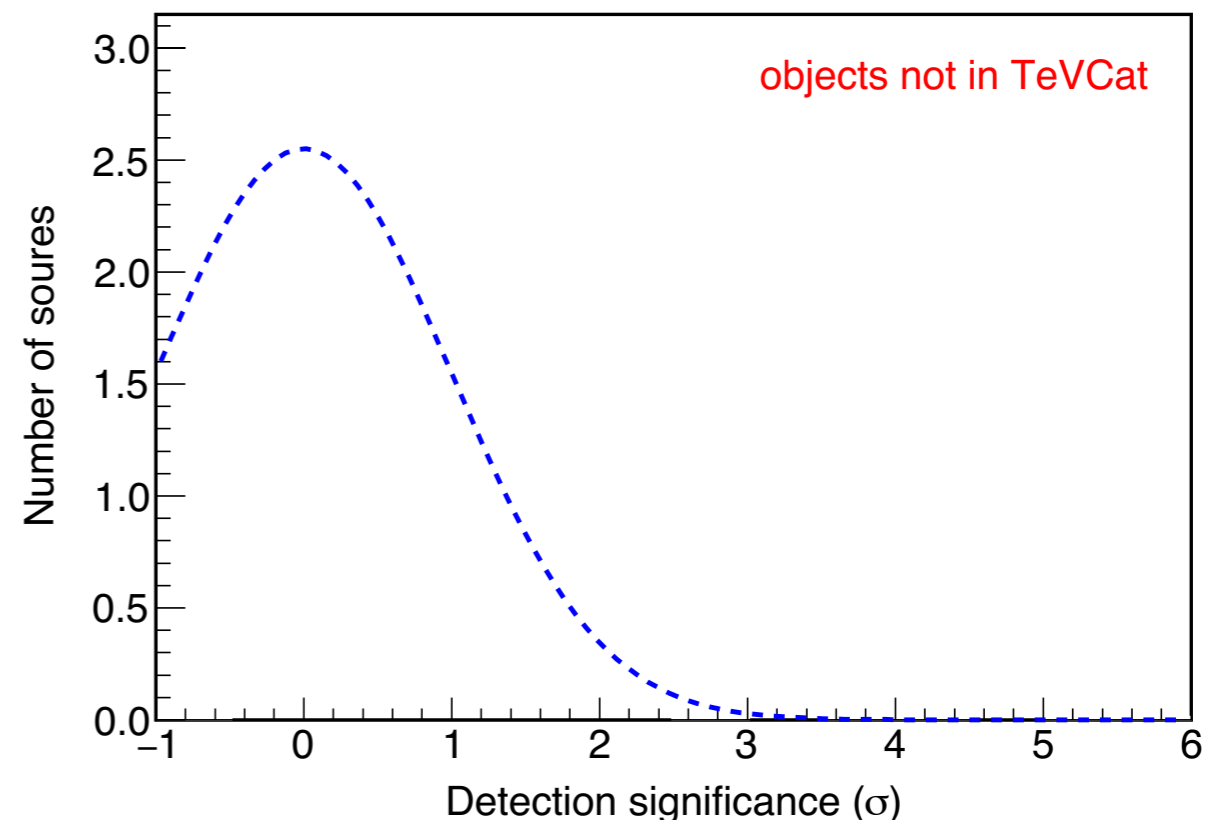


The VERITAS telescope array.

Observations and first results

- We use all 4-telescope data available for sources in the VERITAS HBL sample.
- To minimize bias in flux measurements, we remove all data runs that were triggered by other observations (optical, X-ray, Whipple 10-m, MAGIC, HAWC, VERITAS self-triggers).
- Minimum source exposure is 8h, median exposure is 35h.
- Goal of the observing campaign is to achieve 3σ -sensitivity for 1% Crab blazars.

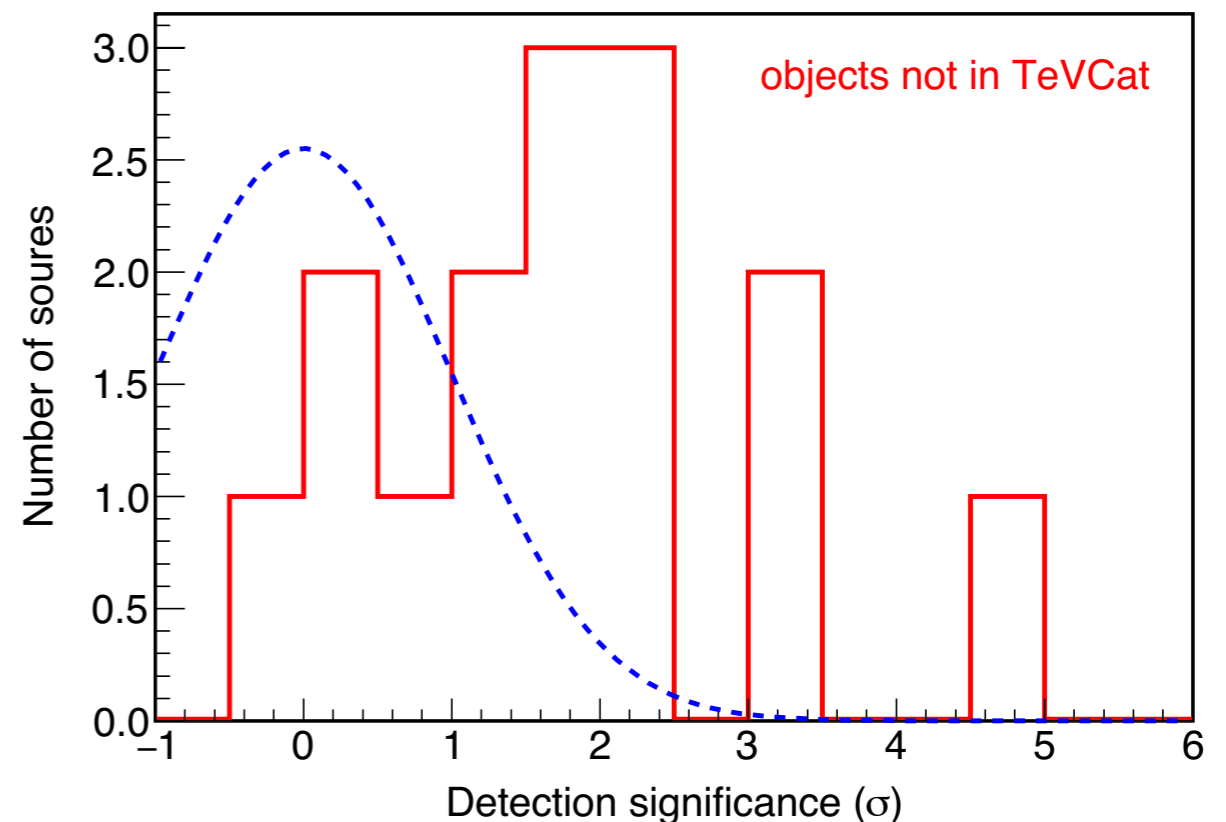
Using more than 1,800h of archival observations obtained since 2007 + 215h of dedicated observations completed in 2019-22. Minimum exposure 8h. Median exposure 35h.



Observations and first results

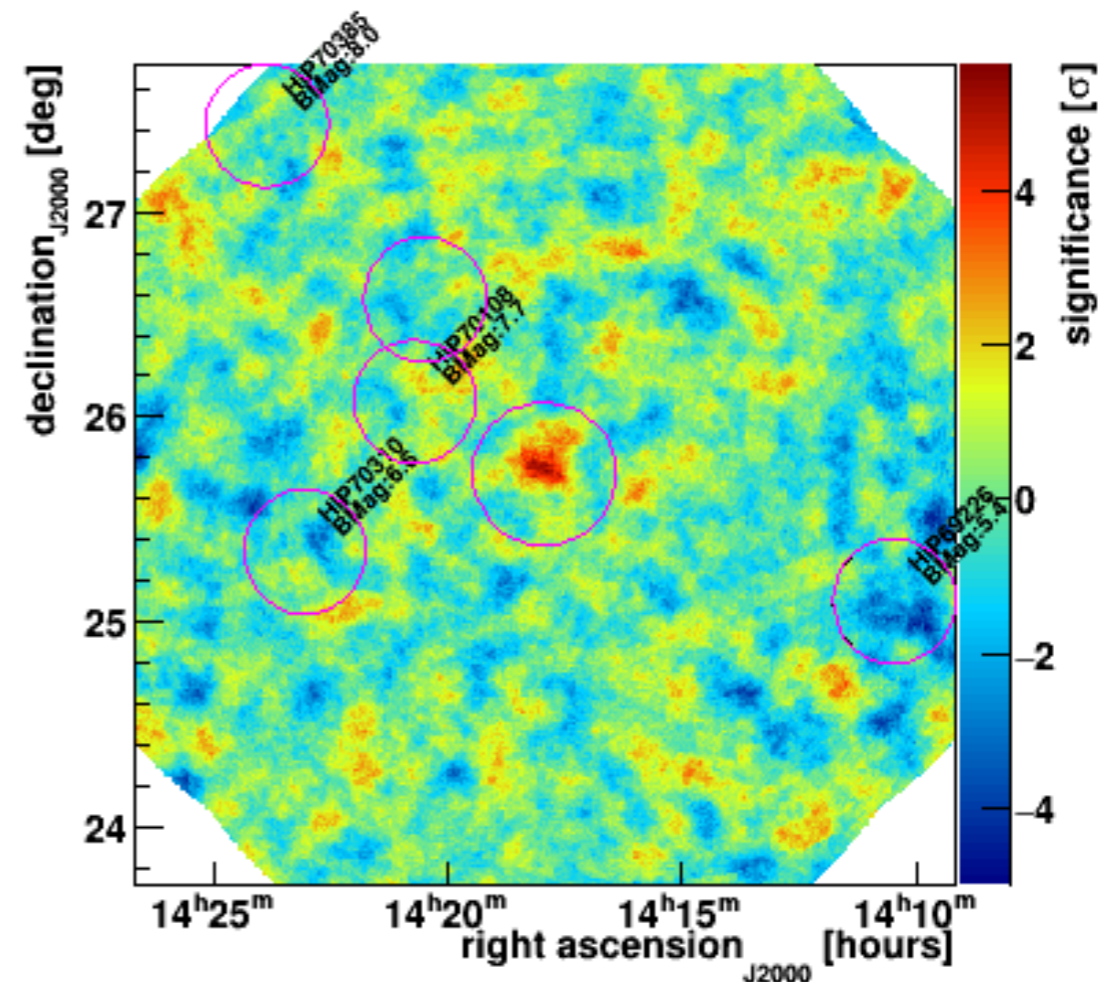
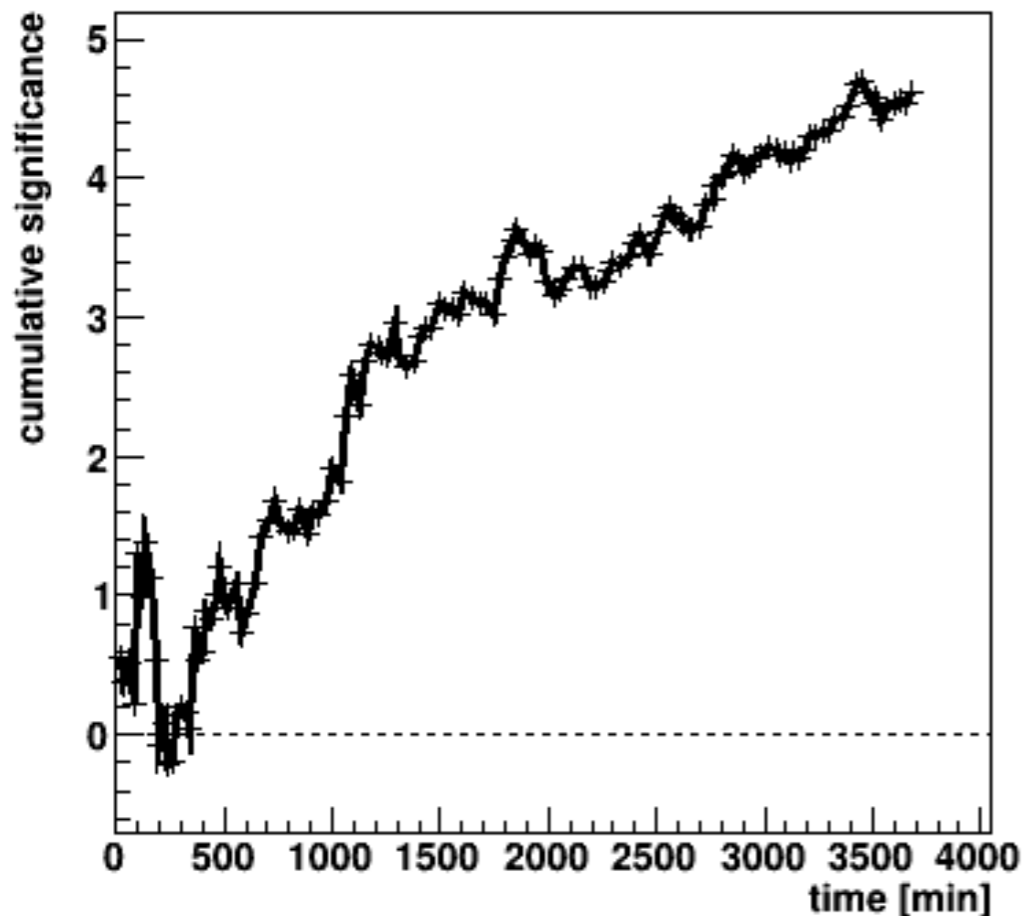
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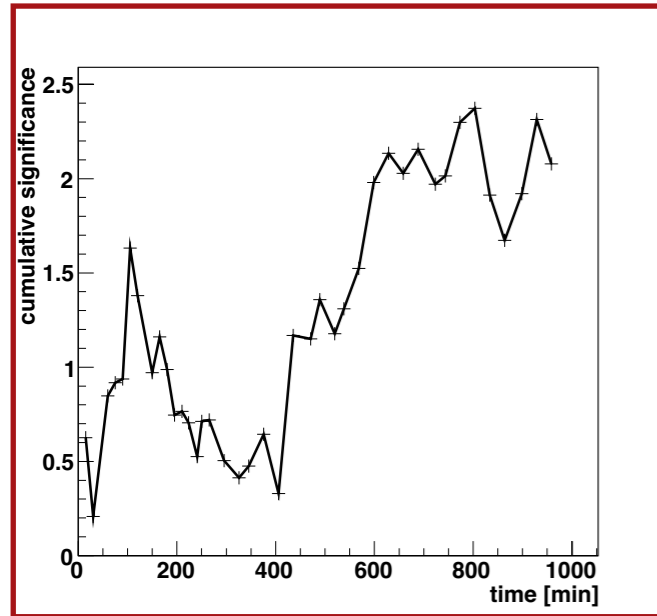
RBS 1366 = RGB J1417+257

- Extreme BL Lac candidate (Costamante 2020, Toomey et al. 2020) at $z=0.237$ (Halpern et al. 1986).
- Previous VERITAS analysis showed 1.9σ in 10h (2008 - 2012), flux upper limit at $< 3.3\%$ Crab (Archambault et al. 2016).
- New dedicated analysis of 61h of exposure (2008 - 2022) yields a significance 4.6σ .
- Excluded 5h of exposure taken due to a self-trigger in 2008.

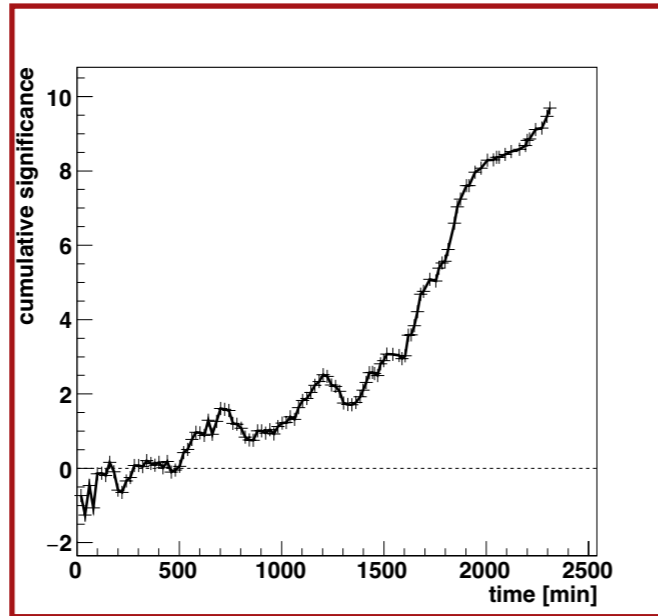


Analysis of known TeV emitters

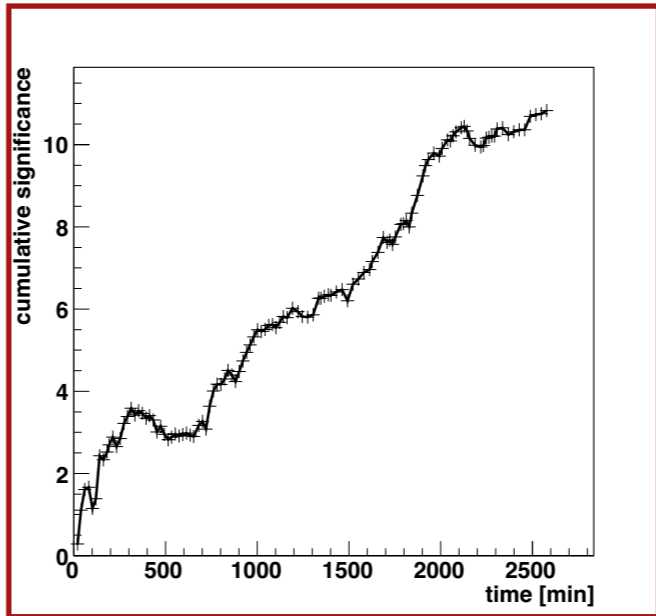
S3 1227+25



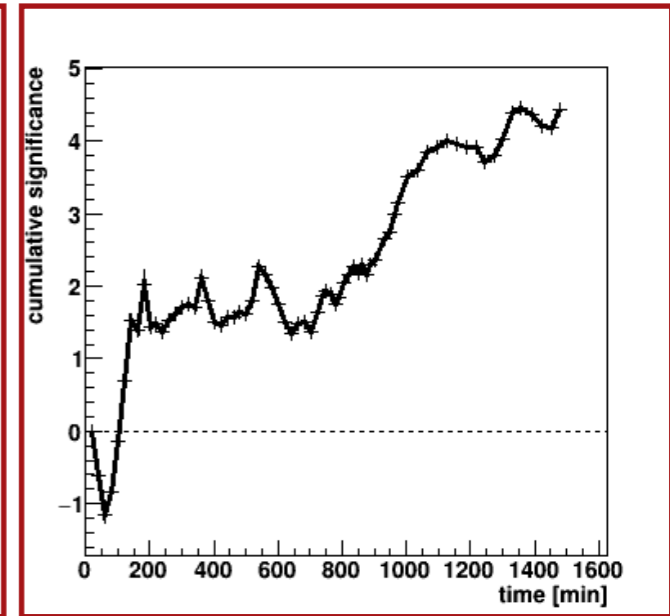
1ES 0647+25



1ES 0806+524

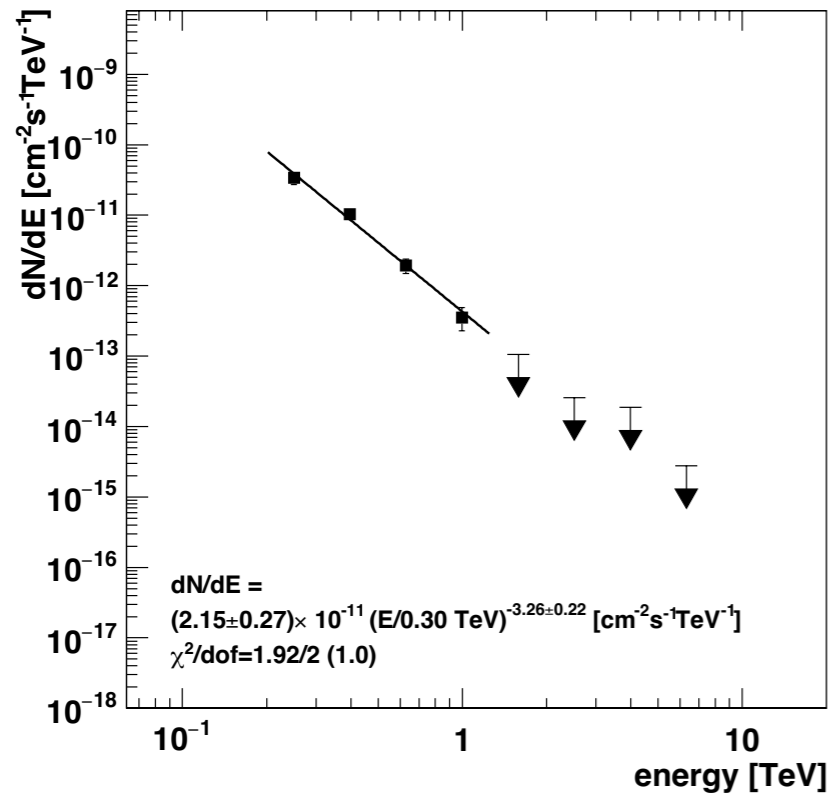


RGB J1725+118

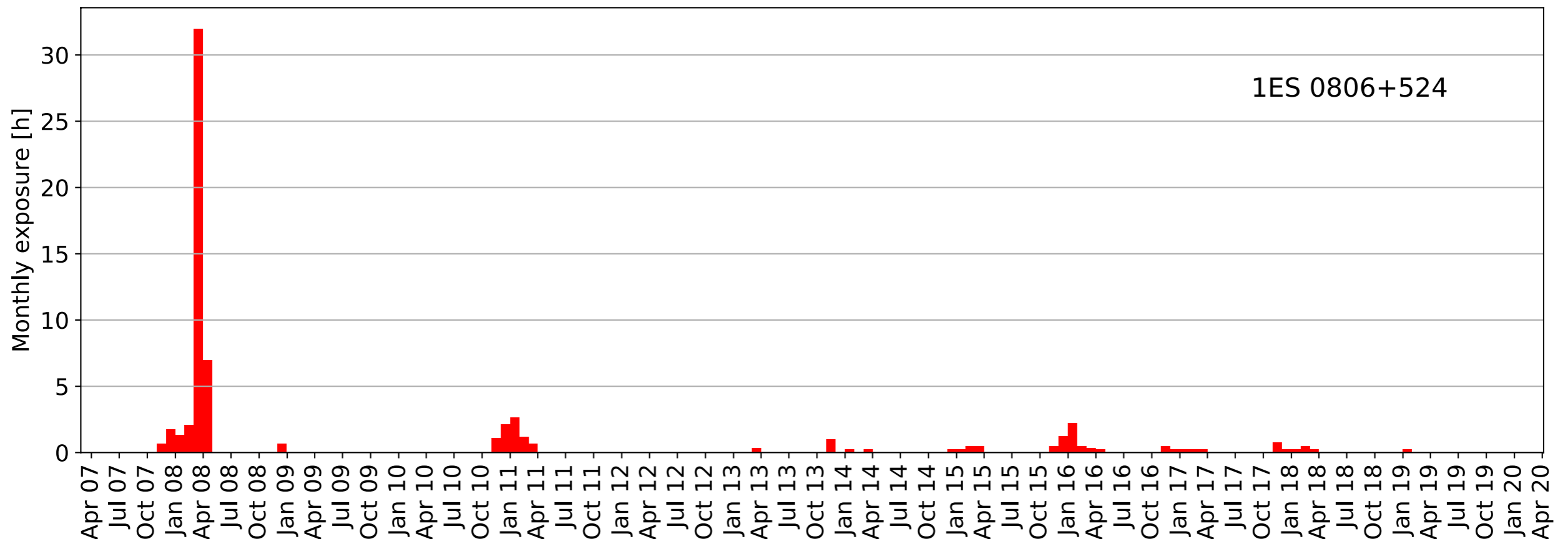


	Exposure	Significance	Flux (>0.2 TeV) in $10^{-12} \text{ cm}^{-2} \text{ s}^{-1}$
S3 1227+25	16h	2.0σ	< 4.8
1ES 0647+25	39h	9.7σ	6.0 ± 0.8
1ES 0806+524	43h	10.8σ	7.1 ± 0.7
RGB J1725+118	24h	4.4σ	

1ES 0806+524 $z=0.137$



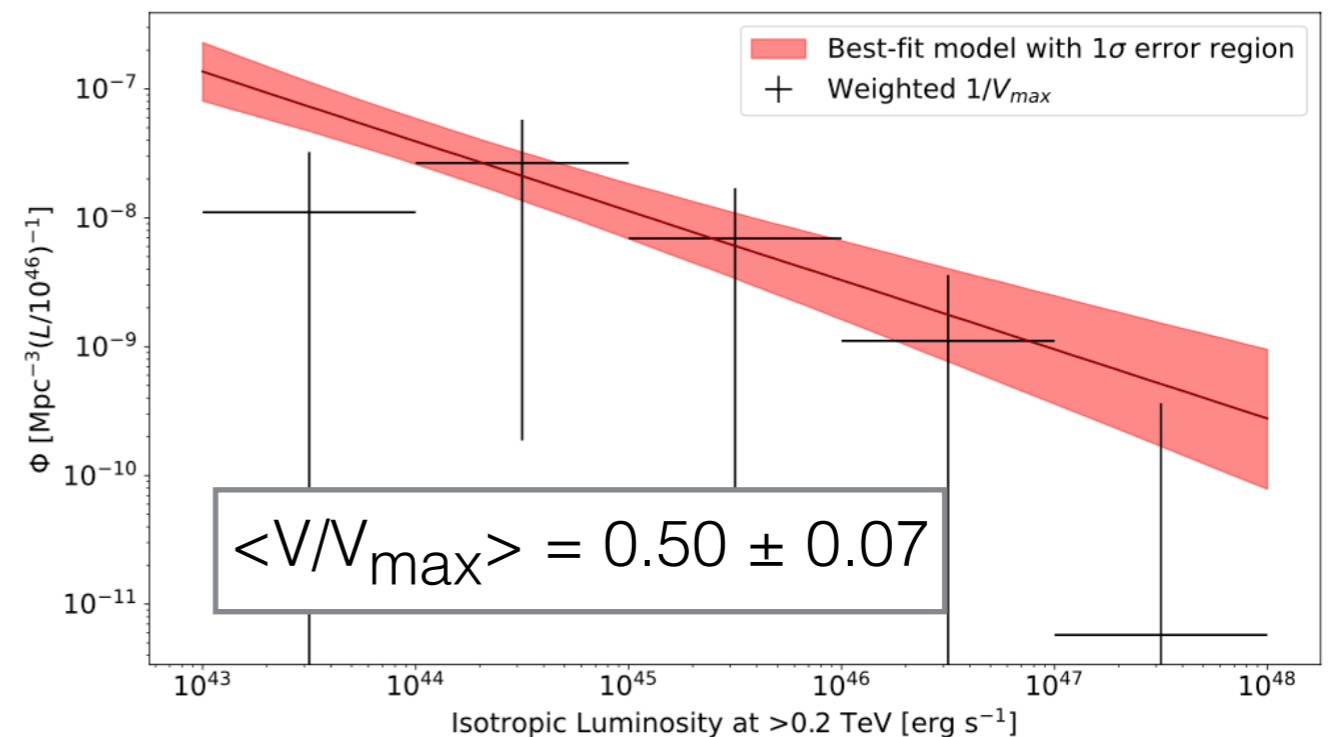
- First TeV detection by VERITAS in 2006 - 2008 (Acciari+ 2009), 6.3σ in 65h (30h of < 3 telescope data), $1.8 \pm 0.4\%$ Crab, spectral index 3.6 ± 1.0 .
- MAGIC published a $3.7 \pm 0.7\%$ Crab flux (Aleksic+ 2015), including a short 9% Crab flare.
- New dedicated analysis of 43 h of 4-telescope exposure, 10.8σ , $3.3 \pm 0.3\%$ Crab.



Summary and outlook

- Analysis of the complete sample of 36 sources is underway.
- Campaign has already resulted in one > 4 sigma hint of TeV emission from a new TeV blazar, and revised unbiased flux estimates for many others.
- Will be reporting fluxes, flux upper limits, and spectral information.
- Survey results will lead to the first measurement of the luminosity function of TeV-emitting HBLs.
- VERITAS campaign can inform future extragalactic surveys with pointed instruments such as CTA.

Expected luminosity function from simulations of VERITAS data



Ari Brill, PhD thesis

Backup slides

Object	RA (J2000)	decl. (J2000)	z	TeVCat?
1ES 0120+340	01:23:08.6	+34:20:48.5	0.270	
RGB J0136+391	01:36:32.6	+39:05:59.2		Y
RGB J0152+017	01:52:39.6	+01:47:17.4	0.080	Y
1ES 0229+200	02:32:48.6	+20:17:17.3	0.139	Y
RGB J0316+090	03:16:12.7	+09:04:43.2	0.372	
1FGL J0333.7+2919	03:33:49.0	+29:16:31.5		
GB6 J0540+5823	05:40:30.0	+58:23:38.4		
1ES 0647+250	06:50:46.5	+25:02:59.5	0.203	Y
RGB J0710+591	07:10:30.1	+59:08:20.5	0.120	Y
PGC 2402248	07:33:26.8	+51:53:55.9	0.090	Y
1ES 0806+524	08:09:49.2	+52:18:58.3	0.137	Y
87GB 083437.4+150850	08:37:24.6	+14:58:20.6	0.278	
RGB J0847+115	08:47:12.9	+11:33:50.2	0.198	Y
RX J0910.6+3329	09:10:37.0	+33:29:24.4	0.350	
B2 0912+29	09:15:52.4	+29:33:24.0	0.190	
1ES 1011+496	10:15:04.1	+49:26:00.8	0.200	Y
1ES 1028+511	10:31:18.5	+50:53:35.9	0.360	
RGB J1037+571	10:37:44.3	+57:11:55.7	0.330	

Table 1: The VERITAS HBL sample. Some of the quoted redshifts are uncertain.

Object	RA (J2000)	decl. (J2000)	z	TeVCat?
RGB J1058+564	10:58:37.7	+56:28:11.2	0.143	
Mrk 421	11:04:27.3	+38:12:31.9	0.030	Y
RX 1117.1+2014	11:17:06.3	+20:14:07.5	0.138	
1ES 1218+304	12:21:22.0	+30:10:37.2	0.180	Y
MS 1221.8+2452	12:24:24.2	+24:36:23.6	0.218	Y
S3 1227+25	12:30:14.1	+25:18:07.1	0.135	Y
RGB J1243+364	12:43:12.7	+36:27:44.0	0.310	
RBS 1366	14:17:56.7	+25:43:25.9	0.240	
H 1426+428	14:28:32.6	+42:40:21.0	0.129	Y
RGB J1439+395	14:39:17.5	+39:32:42.8	0.344	
1ES 1440+122	14:42:48.2	+12:00:40.3	0.160	Y
PG 1553+113	15:55:43.0	+11:11:24.4	0.360	Y
Mrk 501	16:53:52.2	+39:45:36.5	0.030	Y
H 1722+119	17:25:04.3	+11:52:15.5	0.180	Y
1ES 1727+502	17:28:18.6	+50:13:10.5	0.055	Y
RGB J1838+480	18:38:49.1	+48:02:34.4	0.300	
RGB J2243+203	22:43:54.7	+20:21:03.8		Y
B3 2247+381	22:50:05.7	+38:24:37.2	0.119	Y

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