The GeV-TeV extragalactic sky after two years of *Fermi* operation

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We discuss the properties of high latitude GeV-TeV sources in the context of 2 years of Fermi LAT data.

Abstract: We report on the characteristics of GeV-TeV emitting Active Galactic Nuclei (AGN) using observations made during the first two years of Fermi operation. Several TeV sources were recently discovered due in part to information derived from the Fermi data in the 100 MeV - 300 GeV energy range. We present the GeV spectral properties of the GeV-TeV sources detected by Fermi and compare them with the TeV measurements in order to characterize their high-energy spectral energy distributions from 100 MeV up to TeV energies, and study the evolution of their spectra with redshift in the context of the extragalactic background light (EBL).

1. Source Selection:

The sources presented here are the AGN from the 2-year *Fermi* catalog[1,2] that have TeV counterparts and thus, can be studied in the high-energy (HE) with *Fermi* and in the very-high-energy (VHE) regime with the ground-based Cherenkov arrays (CANGAROO, H.E.S.S., MAGIC, VERITAS). The sources were selected as follows:

1.1 HE Source Selection:

The analysis for 2FGL is described elsewhere[1] and is summarised here:

- Date range: ~2008.08.04 - 2010.08.04
- Energy range: 100 MeV - 100 GeV
- Instrument Response Functions p7v6
- Test statistic (TS) cutoff: 25 (~5 sigma)
- 2FGL has ~838 AGN (44% of total)

1.2 VHE Source Selection:

The VHE sources are the 45 AGN from the "*Default*" and "*Newly Announced*" catalogs of *TeVCat* (http://tevcat.in2p3.fr):

- Default catalog has 28 AGN
- Newly Announced catalog has 17 AGN
- Their breakdown by type and by year of discovery is shown in Figure 1

There are 39 so-called "GeV-TeV AGN". Their properties, along with those of the 6 VHE AGN not detected by *Fermi* are presented in Table 1.

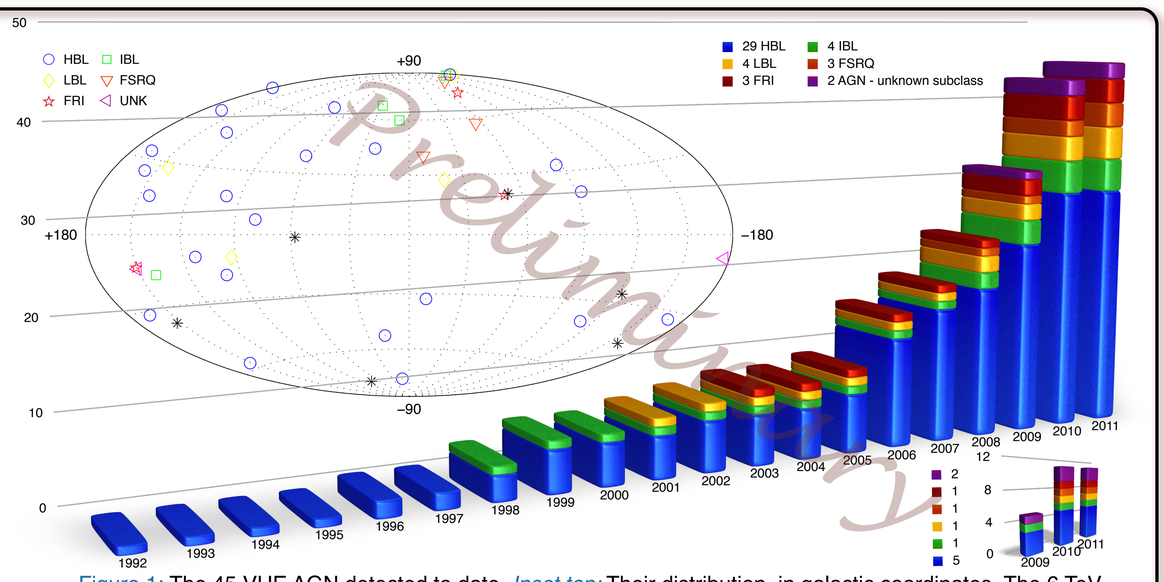

Figure 1: The 45 VHE AGN detected to date. *Inset top:* Their distribution, in galactic coordinates. The 6 TeV AGN, that are not in 2FGL are shown with black asterisks. H/I/LBL: High/Intermediate/Low-frequency-peaked BL Lac; FSRQ: Flat-spectrum radio-quasar; FRI: Fanaroff-Riley Type-1 galaxy; UNK: AGN of unknown subclass. *Inset bottom:* The TeV sources detected with the help of *Fermi* data (same legend as above).

2. GeV-TeV AGN Properties:

The difference between the 2FGL[1,2] and the TeV[3] spectral indices are plotted as a function of each AGN's redshift in Figure 2. It can be seen that, as the distance to the AGN increases, the difference between the GeV and TeV spectral indices also increases, confirming the trend previously reported[4]. This is interpretted as the effect of the extragalactic background light (EBL): the gamma-ray photons pair produce with the photons of the EBL and thus get absorbed, softening the spectrum in the VHE band. Figure 3 shows a composite spectral energy distribution (SED) for the 26 GeV-TeV AGN that have both HE and VHE spectral information available. For each AGN, the 2FGL spectrum is joined to that *measured* in the VHE band. Where available, the VHE spectrum measured during quiescence was used.

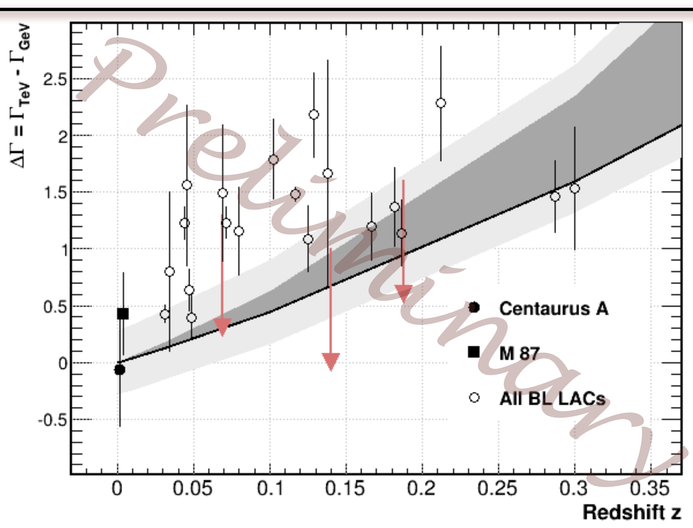

Figure 2: The difference between the *Fermi* spectral index and the VHE spectral index as a function of redshift. For the 3 BL Lacs with known redshifts that are not in 2FGL, an upper limit on the HE index of 1.5 was assumed (red points).

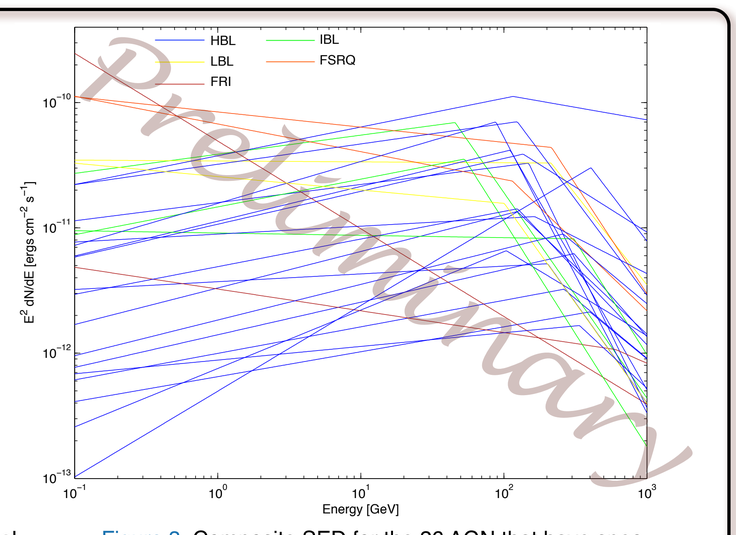

Figure 3: Composite SED for the 26 AGN that have spectral information available in the HE and VHE bands. The VHE spectra were not deabsorbed for EBL effects.

TeV Name	2FGL Name	1FGL Source	R.A. (J2000)	Dec. (J2000)	VHE Index	*Fermi* Index	z	Class
SHBL J001355.9-185406	-	-	00 13 56.0	-18 54 07	-*	-	0.095	HBL
RGB J0152+017	0152.6+0148	-	01 52 33.5	+01 46 40	2.95	1.79	**0.08**	HBL
3C 66A	0222.6+4302	Y	02 22 41.6	+43 02 35.5	3.64	1.85	< 0.58	IBL
1ES 0229+200	-	-	02 32 53.2	+20 16 21	2.50	-	**0.14**	HBL
IC 310	0316.6+4119	-	03 16 43.0	+41 19 29	-*	2.1	0.0189	**UNK**
NGC 1275	0319.8+4130	Y	03 19 48.1	+41 30 42	-*	2.00	0.0176	FRI
RBS 0413	0319.6+1849	Y	03 19 51.8	+18 45 34	-*	1.55	0.19	HBL
1ES 0347-121	-	-	03 49 23.0	-11 58 38	3.10	-	**0.188**	HBL
1ES 0414+009	0416.8+0105	Y	04 16 52.41	+01 05 24.3	-*	1.98	**0.287**	HBL
PKS 0447-439	0449.4-4350	Y	04 49 24.7	-43 50 09	4.36	1.86	> 0.176	HBL
1ES 0502+675	0508.0+6737	Y	05 07 56.2	+67 37 24	-*	1.49	0.341	HBL
VER J0521+211	0521.7+2113	Y	05 21 55	+21 11 24	-*	1.93	-	**UNK**
PKS 0548-322	-	-	05 50 42.9	-32 16 34	2.86	-	**0.069**	HBL
RGB J0710+591	0710.5+5908	Y	07 10 26.4	+59 09 00	2.69	1.53	**0.125**	HBL
S5 0716+714	0721.9+7120	Y	07 21 53.4	+71 20 36	3.45	2.01	**0.31**	LBL
1ES 0806+524	0809.8+5218	Y	08 09 59	+52 19 00	3.6	1.94	**0.138**	HBL
1RXS J101015.9-311909	1009.7-3123	-	10 10 15.9	-31 19 09	-*	2.34	0.143	HBL
1ES 1011+496	1015.1+4925	Y	10 15 04.1	+49 26 01	4.0	1.72	**0.212**	HBL
1ES 1101-232	1103.4-2330	Y	11 03 38	-23 29 31	2.94	1.8	**0.186**	HBL
Markarian 421	1104.4+3812	Y	11 04 27.3	+38 12 32	2.20	1.77	**0.031**	HBL
Markarian 180	1136.7+7009	Y	11 36 26.4	+70 09 27	3.3	1.74	**0.045**	HBL
1ES 1215+303	1217.8+3006	Y	12 17 52.1	+30 07 01	-*	2.02	0.13	LBL
1ES 1218+304	1221.3+3010	Y	12 21 21.9	+30 10 37	3.08	1.71	**0.182**	HBL

TeV Name	2FGL Name	1FGL Source	R.A. (J2000)	Dec. (J2000)	VHE Index	*Fermi* Index	z	Class
WComae	1221.4+2814	Y	12 21 31.7	+28 13 59	3.81	2.02	**0.102**	IBL
4C +21.35	1224.9+2122	Y	12 24 54.4	+21 22 46	3.75	2.12	0.432	FSRQ
M87	1230.8+1224	Y	12 30 49.4	+12 23 28	2.5	2.17	**0.004**	FRI
3C 279	1256.1-0547	Y	12 56 11.1	-05 47 22	3.1	2.22	0.536	FSRQ
1ES 1312-423	-	-	13 15 03.4	-42 36 50	-*	-	-	HBL
Centaurus A	1325.6-4300	Y	13 25 28	-43 01 06	2.7	2.76	**0.002**	FRI
PKS 1424+240	1427.0+2347	Y	14 27 00.39	+23 48 00.0	3.8	1.78	-	IBL
H 1426+428	1428.6+4240	Y	14 28 32.6	+42 40 21	3.50	1.32	**0.129**	HBL
1ES 1440+122	1442.7+1159	Y	14 42 48.3	+12 00 40	-*	1.41	-	IBL
PKS 1510-089	1512.8-0906	Y	15 12 50.5	-09 06 00	-*	2.29	0.36	FSRQ
AP Lib	1517.7-2421	Y	15 17 41.8	-24 22 19	-*	2.05	**0.049**	LBL
PG 1553+113	1555.7+1111	Y	15 55 43.0	+11 11 24	4.2	1.67	< 0.4	HBL
Markarian 501	1653.9+3945	Y	16 53 52.2	+39 45 36	2.72	1.74	**0.034**	HBL
HESS J1943+213	-	-	19 43 55	+21 18 08	-*	-	-	HBL
1ES 1959+650	2000.0+6509	Y	19 59 59.9	+65 08 55	2.58	1.94	**0.048**	HBL
MAGIC J2001+435	2001.1+4352	Y	20 01 13.5	+43 53 02.8	-*	1.90	-	HBL
PKS 2005-489	2009.5-4850	Y	20 09 27.0	-48 49 52	3.20	1.78	**0.071**	HBL
PKS 2155-304	2158.8-3013	Y	21 58 52.7	-30 13 18	3.53	1.84	**0.116**	HBL
BL Lacertae	2202.8+4216	Y	22 02 43.3	+42 16 40	3.6	2.11	**0.069**	LBL
B3 2247+381	2250.0+3825	Y	22 50 06.6	+38 25 58	-*	1.84	0.119	HBL
1ES 2344+514	2347.0+5142	Y	23 47 04.8	+51 42 18	2.95	1.72	**0.044**	HBL
H 2356-309	2359.0-3037	Y	23 59 09	-30 37 22	3.06	1.89	**0.165**	HBL

*The TeV index has not yet been reported for these sources. **Only BL Lacs with known z and VHE-measured spectral indices are used.

Table 1: The 45 TeV AGN; 39 are in 2FGL The 11 TeV AGN that were detected as a result of *Fermi* are in **blue bold**, 2 of which are of **unknown** classification. The 25 AGN used to make Figure 2 have their **redshift in blue bold****.

3. Conclusions:

All 6 of the VHE AGN that are not in 2FGL are HBLs. Since the launch of Fermi, the detections of 22 TeV AGN have been reported: 11 of these were as a result of Fermi data 2 of these newly-detected AGN are currently of unknown classification. The trend reported previously[4] of an increasing difference between the Fermi and VHE spectral indices as a function of redshift has been confirmed.

References

[1] Burnett, T. "*The Second Fermi LAT Catalog: Construction and Contents*", 3rd Fermi Symp. (this meeting), 09 May, 11:30; [2] Thompson D. J. "*The Second Fermi LAT Catalog: Caveats and Classifications*", 3rd Fermi Symp. (this meeting), 09 May, 11:55; [3] Wakely, S. P. & Horan, D. (2008), Proc. 30th ICRC, 3, 1341 (http://tevcat.uchicago.edu / http://tevcat.in2p3.fr); [4] Abdo et al.(2009), ApJ 707, 1310