Fermi observations of TeV AGN

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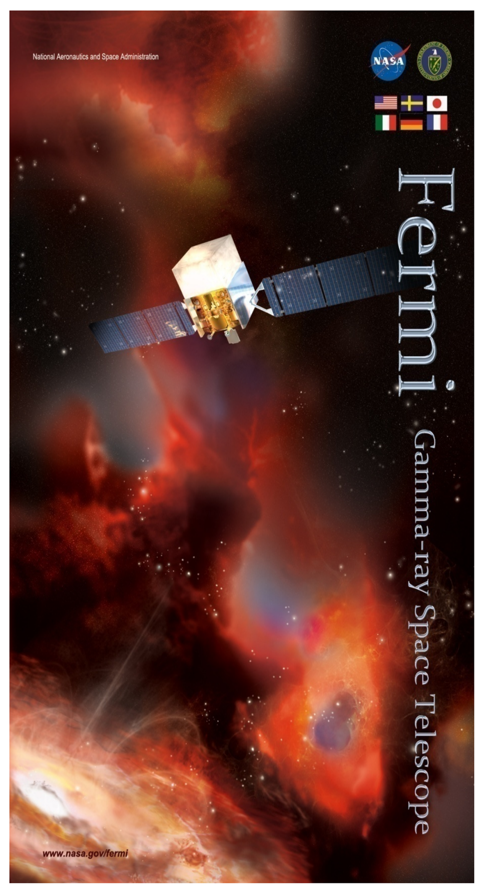
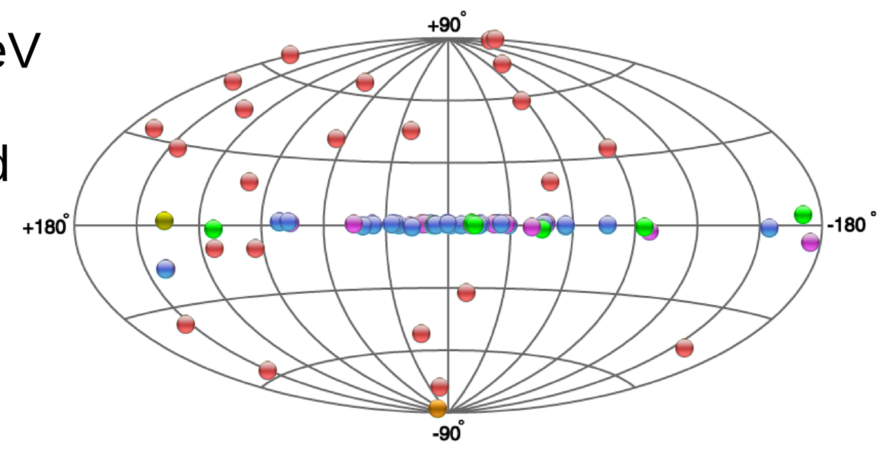


Results from Fermi observations of known TeV AGN are reported. Detections of 21 objects are made. Results are discussed individually and collectively.

Abstract

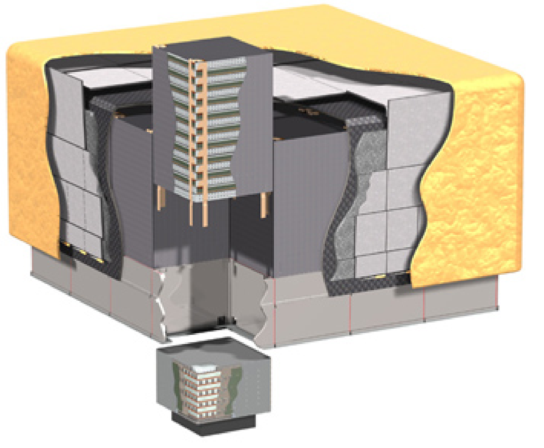
We report on observations of TeV-selected AGN made during the first 5.5 months of observations with the Large Area Telescope (LAT) on-board the Fermi Gamma-ray Space Telescope (Fermi). In total, 28 TeV AGN were selected for study. The Fermi observations show clear detections of 21 of these TeV-selected objects. Most can be described with a power law of spectral index harder than 2, with a spectral break generally required to accommodate the TeV measurements. Evidence for systematic evolution of the gamma-ray spectrum with redshift is presented and discussed in the context of the EBL.

Introduction



http://tevcat.uchicago.edu/

At energies above approximately 100GeV (the TeV energy regime), ground-based gamma-ray observatories have detected 96 sources over the past two decades. The pace of discovery in this energy regime has been particularly high since the inception of the latest generation of instruments: H.E.S.S., CANGAROO, MAGIC and VERITAS. The majority of the TeV sources are galactic, however 30 extragalactic sources have also been detected, of which 28 correspond to Active Galactic Nuclei (AGN), the other two being starburst galaxies. Most (25) of these TeV AGN are blazars.



The Large Area Telescope is a pair-conversion telescope on the Fermi Gamma-ray Space Telescope (formerly GLAST), launched in June 2008. The Fermi LAT instrument detects gamma rays with energies between 20MeV and >300GeV (the GeV energy regime). In this poster we present the results of the first 5.5 months of Fermi-LAT observations of the known TeV blazars. The motivation for this study is two-fold: (i) to present as complete a picture of the high-energy emission as possible by combining the GeV and TeV results on these objects, and (ii) to help guide future TeV observations. For a selection of these GeV—TeV objects we present the GeV spectrum from Fermi and extrapolate it to TeV energies assuming absorption on the EBL, and compare these extrapolations to archival TeV measurements. Finally, we study the evolution of the spectrum of these objects as a function of redshift.

Results summary – Detected GeV-TeV AGN

In the table below we present the results of 5.5 months of observation of the TeV AGN with the Fermi LAT. Of the 28 objects selected for observation, a total of 21 were detected with TS>25 (approximately 5σ). This degree of connection between the TeV blazars and the GeV regime was not found by EGRET and the previous generation of TeV instruments, and is evident now only as a result of the improved sensitivity and greater overlap between the effective energy ranges of Fermi and the current generation of TeV instruments.

Name	TS [1]	Parameters of fitted power-law spectrum: Flux (>200 MeV) $F \pm \Delta F_{stat} \pm \Delta F_{sys}$ $[10^{-9}cm^{-2}s^{-1}]$	Parameters of fitted power-law spectrum: Photon Index $\Gamma \pm \Delta\Gamma_{stat} \pm \Delta\Gamma_{sys}$ [1]	Decorr. energy [GeV]	Highest energy photons: 1st [GeV]	Highest energy photons: 5th [GeV]	Probability of constant flux: 10 day [1]	Probability of constant flux: 28 day [1]
3C 66A	2221	96.7 ± 5.82 ± 3.39	1.93 ± 0.04 ± 0.04	1.54	111[a]	54	< 0.01	< 0.01
RGB J0710+591	42	0.087 ±0.049 ± 0.076	1.21 ± 0.25 ± 0.02	15.29	74	4	0.98	0.94
S5 0716+714	1668	79.9 ± 4.17 ± 2.84	2.16 ± 0.04 ± 0.05	0.82	63	9	< 0.01	< 0.01
1ES 0806+524	102	2.07 ± 0.38 ± 0.71	2.04 ± 0.14 ± 0.03	1.54	30	4	0.05	< 0.01
1ES 1011+496	889	32.0 ± 0.27 ± 0.29	1.82 ± 0.05 ± 0.03	1.50	168	32	0.54	0.50
Markarian 421	3980	94.3 ± 3.88 ± 2.60	1.78 ± 0.03 ± 0.04	1.35	801	155	0.06	0.02
Markarian 180	50	5.41 ± 1.69 ± 0.91	1.91 ± 0.18 ± 0.09	1.95	14	2	0.98	0.54
1ES 1218+304	147	7.56 ± 2.16 ± 0.67	1.63 ± 0.12 ± 0.04	5.17	356	31	0.53	0.06
W Comae	754	41.7 ± 3.40 ± 2.46	2.02 ± 0.06 ± 0.05	1.13	26	18	0.01	< 0.01
3C 279	6865	287 ± 7.13 ± 10.2	2.34 ± 0.03 ± 0.04	0.59	28	21	< 0.01	< 0.01
PKS 1424+240	800	34.35 ± 2.60 ± 1.37	1.85 ± 0.05 ± 0.04	1.50	137	30	< 0.01	0.16
H 1426+428	38	1.56 ± 1.05 ± 0.29	1.47 ± 0.30 ± 0.11	8.33	19	3	0.83	0.39
PG 1553+113	2009	54.8 ± 3.63 ± 0.85	1.69 ± 0.04 ± 0.04	2.32	157	76	0.40	0.54
Markarian 501	649	22.4 ± 2.52 ± 0.13	1.73 ± 0.06 ± 0.04	2.22	127	50	0.57	0.18
1ES 1959+650	306	25.1 ± 3.49 ± 2.83	1.99 ± 0.09 ± 0.07	1.60	75	21	0.91	0.29
PKS 2005-489	246	22.3 ± 3.09 ± 2.14	1.91 ± 0.09 ± 0.08	1.01	71	8	0.86	0.97
PKS 2155-304	3354	109 ± 4.45 ± 3.18	1.87 ± 0.03 ± 0.04	1.13	299	46	< 0.01	< 0.01
BL Lacertae	310	51.6 ± 5.81 ± 12.2	2.43 ± 0.10 ± 0.08	0.85	70	4	0.61	0.23
1ES 2344+514	37	3.67 ± 2.35 ± 1.62	1.76 ± 0.27 ± 0.23	5.28	53	3	0.76	0.46
M 87	31	7.56 ± 2.70 ± 2.24	2.30 ± 0.26 ± 0.14	1.11	8	1	0.43	0.57
Centaurus A	308	70.8 ± 5.97 ± 5.80	2.90 ± 0.11 ± 0.07	0.47	6	4	0.38	0.97

The majority of the TeV blazars detected by Fermi have a photon index Γ < 2 in the GeV regime, the median index is Γ = 1.9. In contrast, the populations of 42 BL Lacs and 57 FSRQs from the LBAS sample have median indexes of Γ = 2.0 and Γ = 2.4 respectively. The TeV blazars are amongst the hardest extragalactic objects detected by Fermi. For many of the sources, especially those with harder spectra, no evidence for curvature is seen in the LAT energy range. Furthermore, many sources did not show evidence of significant variability over the period of the study.

References and Acknowledgements

For complete list of references used in this work see: **arXiv:0910.4881**   [1] Abdo, A. A., et al. 2009, ApJ, 700, 597

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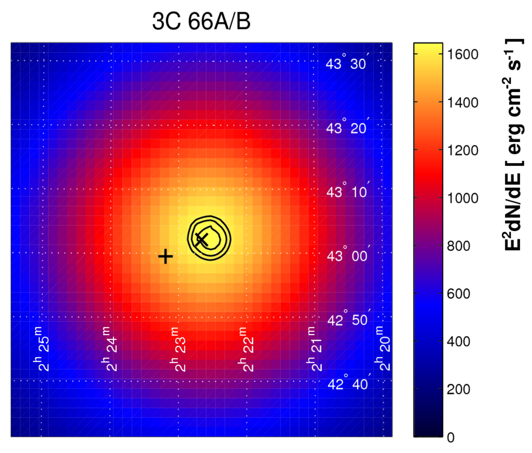
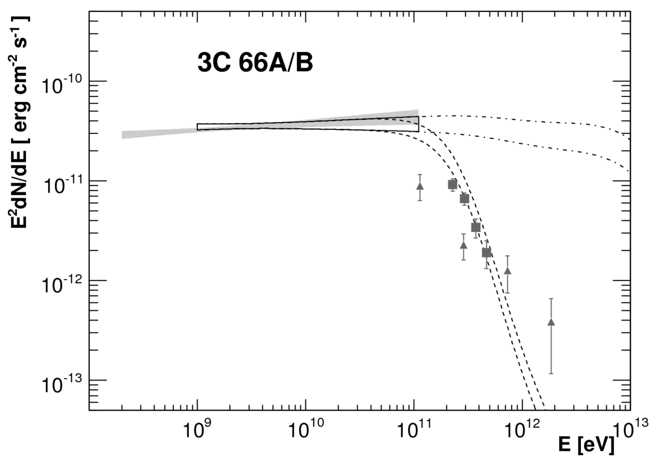
Discussion of Selected AGN

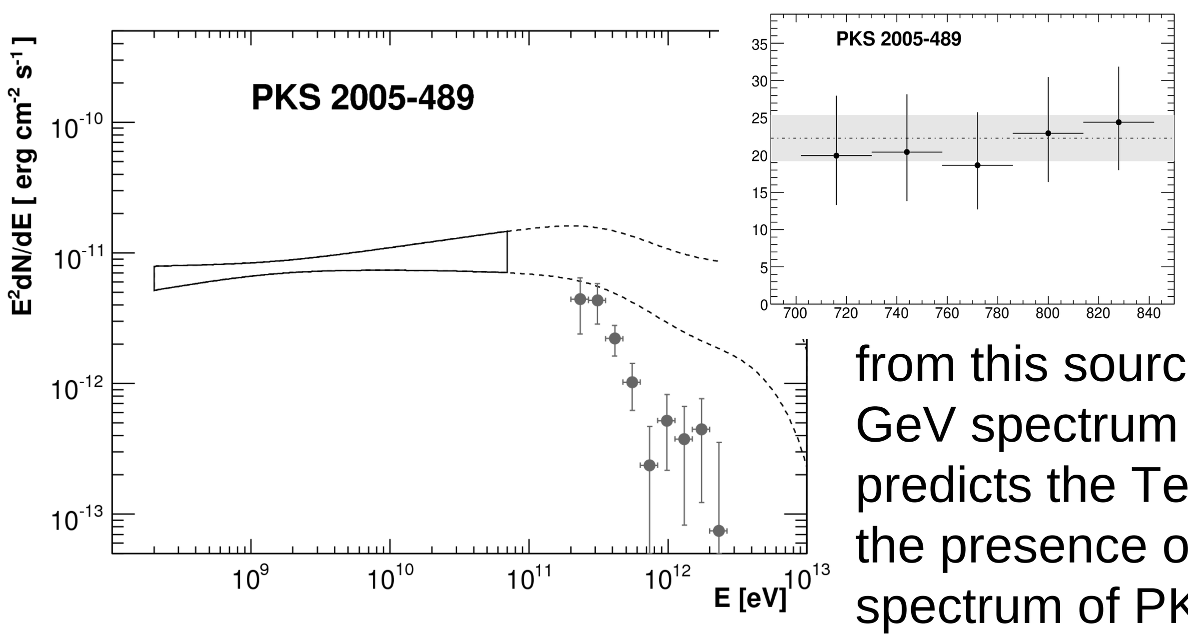




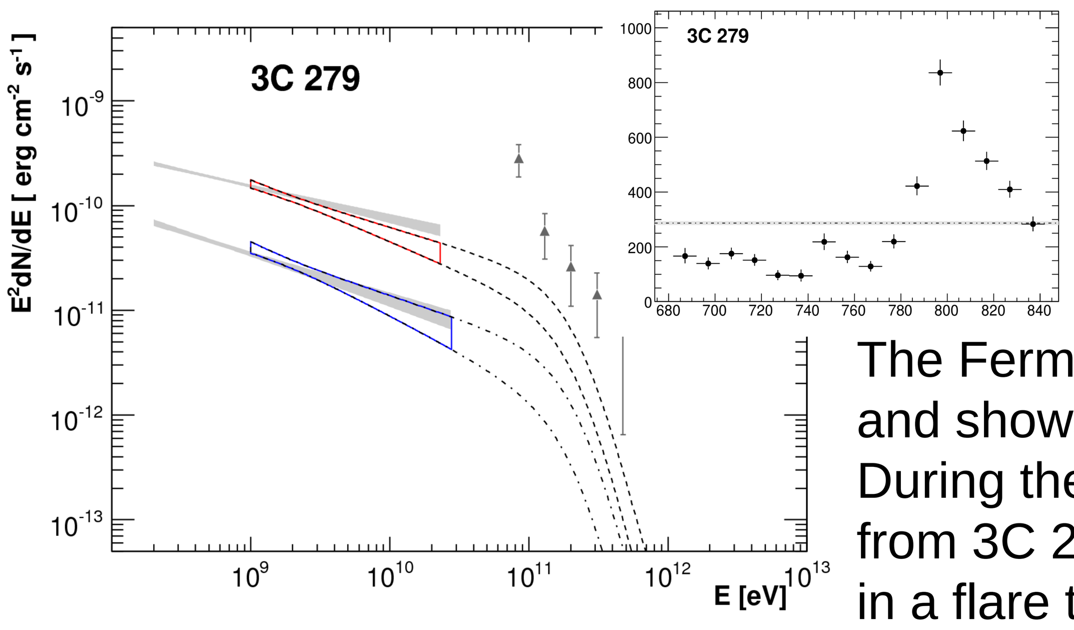
3C 66A/B: TeV emission from this region detected by VERITAS and MAGIC.

V: 3C 66A (HBL z=0.444?)
M: 3C 66B (RG z=0.0211)

Fermi detects hard GeV emission, coincident with 3C 66A. An extrapolation of the GeV spectrum to TeV energies is in better agreement with the TeV data measurements assuming z=0.444 than 0.0221.

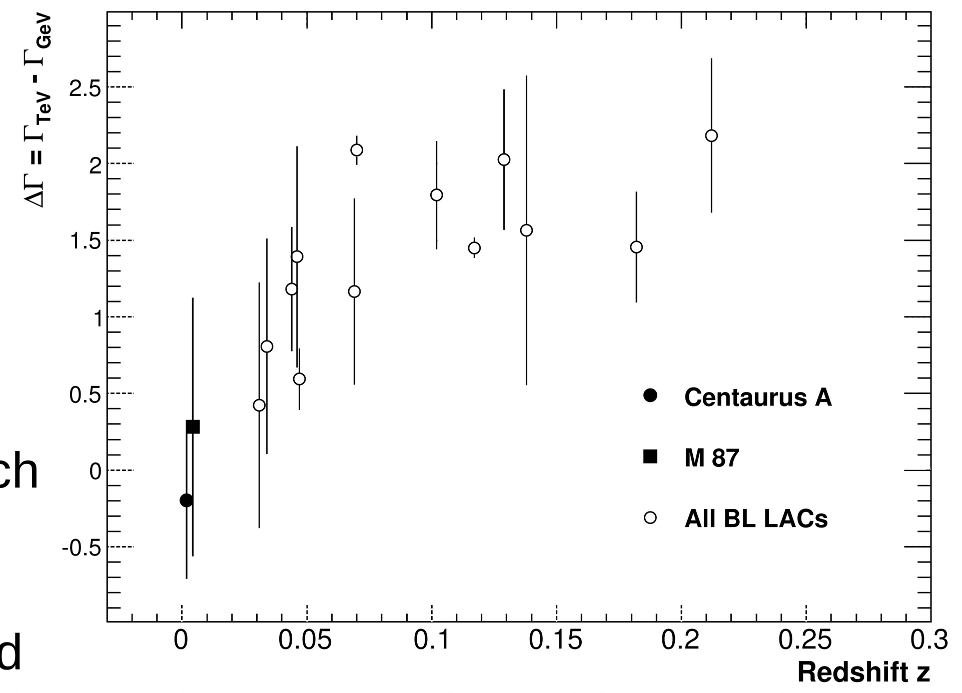


PKS 2005-489: A H.E.S.S.-detected HBL with no evidence of TeV variability. Fermi detects hard steady emission from this source. An extrapolation of the GeV spectrum to TeV energies over-predicts the TeV spectrum, suggesting the presence of intrinsic curvature in the spectrum of PKS 2005-489.



3C 279: Detected by MAGIC during a flaring episode, 3C 279 is the most distant TeV source (with a known redshift) detected to date. The Fermi spectrum is relatively soft, and shows clear evidence for curvature. During the period of the the study the flux from 3C 279 increased by a factor of ~5 in a flare that lasted ~50 days. The spectra for the flaring and non-flaring emission is shown. An extrapolation of both to TeV energies under-predicts the flux measured by MAGIC, showing that it must correspond to a extreme flaring state.

Evolution of Spectra with Redshift



In the LBAS study [1], no significant relation between the GeV photon index and redshift was found for either the sample of BL Lacs or FSRQs. The GeV—TeV sources provide a population in which the effects of spectral evolution with redshift can be studied across a much wider energy range than LBAS. The presence of a redshift-dependent spectral break in these sources could be indicative of the effects of absorption on the EBL, and provide experimental evidence for this absorption in a manner independent of any specific EBL-density model. The difference in the TeV and GeV spectral indices for 15 of the GeV—TeV sources is shown. It is evident that the difference between the GeV and TeV spectral indices increases with redshift. At low redshifts the radio galaxies M 87 and Cen A have ΔΓ ~ 0, as do the near-by BL Lacs. At *z*>0.1, all of the BL Lacs are consistent with ΔΓ ≥ 1.5.

Conclusions

In 5.5 months of observation the Fermi LAT has detected GeV emission from 21 TeV-selected AGN (and from 17 previously observed by TeV groups for which upper limits have been published). Many exhibit an increasing spectrum (Γ < 2) in the GeV range confirming the presence of a high energy peak in νF_ν representation. The intrinsic spectrum for some of the TeV sources can be well described by a single power-law across the energy range spanned by the Fermi LAT and the TeV observatories, with any breaks in the measured gamma-ray spectra between the two regimes being consistent with the effects of absorption with a model of minimal EBL density. Redshift-dependent evolution is detected in the spectra of objects detected at GeV and TeV energies. The most reasonable explanation for this is absorption on the EBL.