Are GeV and TeV spectra connected? the case of Galactic γ-ray sources

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Introduction

To understand the Galactic objects that emits GeV-TeV emission, a spatial correlation study between the Fermi bright source catalog and TeV population was carried out in [1]. We extended our previous study by using the first Fermi catalog sources [2]. They were cross-correlated to the very high-energy (VHE; E>100 GeV) γ-ray sources in the literature. While it is found that a significant number of VHE sources were also detected in the GeV band, the GeV-TeV spectra of some of these spatially coincident sources cannot be described by a single spectral component. While some of these cases are γ-ray pulsars accompanied by VHE γ-ray emitting nebulae, we highlight cases where the 100 MeV to multi-TeV spectra of coincident 1FGL/VHE source pairs do not seem to be well fit by a single spectral component.

Spatial coincidence study

We cross-correlated the 1FGL source centroid positions with VHE γ-ray source centroid positions. Only sources that are not associated with an extragalactic source were considered. Using the same manner as described in [1], the VHE source extent and 95% uncertainty in the 1FGL source centroids are taken into account. All first Fermi/LAT sources are assumed to be point sources as in [2]. In total we identified 33 1FGL sources that are spatially coincident with one VHE source, respectively. In addition, the VHE source in the Westerlund 1 region, which are ~0.6 degree extended, is found to be spatially coincident with three 1FGL sources. The list of these 1FGL-VHE source pairs are presented in the table below.

Based on timing information and dedicated efforts, as well as spatial coincidences described in the corresponding literature, the 1FGL sources in the list of coincidences are categorized into several classes: 2 HMXBs (LS I +61^0 303 and LS 5039), 8 PSRs, 4 SNRs (IC 443, W28, W49B, W51C), 2 PSR/PWN (Crab and Vela), 6 SNR/PWN candidates, 1 H II region, and 13 unidentified sources.

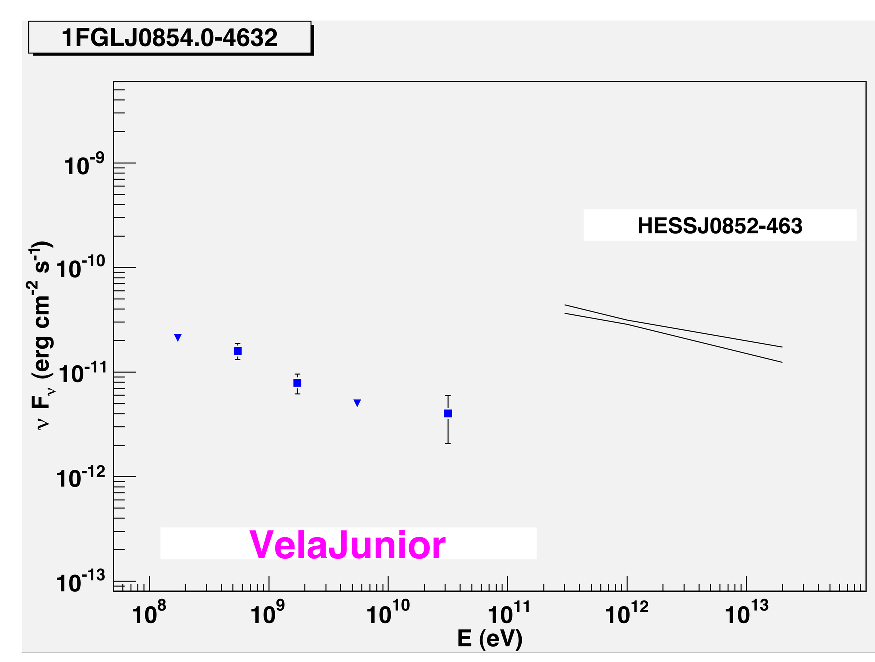
Table
List of 1FGL-VHE source pairs that are spatially coincident

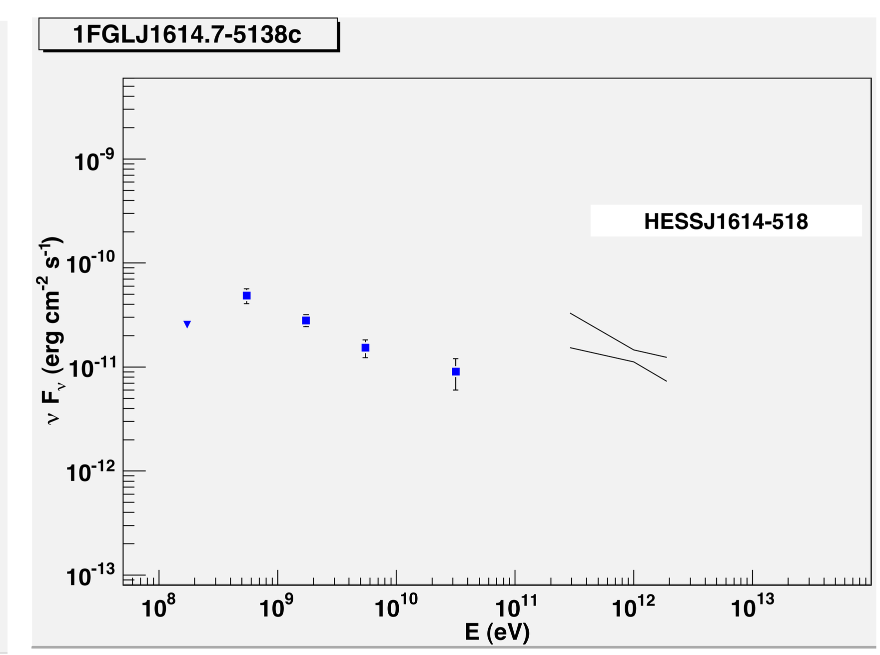
1FGL source	association[a]	class[b]	l (°)	b (°)	VHE γ-ray source	association[c]	l (°)	b (°)	extension[d] (°)	with 0FGL counterpart?[e]
J0240.5+6113	LS I+61 303	HMXB	135.66	1.08	VER J0240+612	LS I +61 303	135.70	1.08	PS	Y
J0534.5+2200	Crab	PSR/PWN	184.56	−5.76	HESS J0534+220	Crab nebula	184.56	−5.78	PS	Y
J0617.2+2233	IC 443[f]	SNR	189.08	3.07	VER J0616.9+2230	IC 443	189.08	2.92	0.16	Y
J0835.3−4510	Vela	PSR/PWN	263.56	−2.77	HESS J0835−455	Vela X	263.86	−3.09	0.43	Y
J0854.0−4632		SNR/PWN	266.64	−1.09	HESS J0852-463	RX J0852.0−4622	266.28	−1.24	1.0	N
J1023.0−5746	PSR J1023−5746	PSR	284.17	−0.41	HESS J1023−575	PSR J1023−5746/Westerlund 2	284.22	−0.40	0.18	Y
J1418.7−6057	PSR J1418−6058	PSR	313.34	0.11	HESS J1418−609	G313.3+0.1 (Rabbit)	313.25	0.15	0.06	Y
J1420.1−6048	PSR J1420−6048	PSR	313.50	0.20	HESS J1420−607	PSR J1420−6048	313.56	0.27	0.07	Y
J1501.6−4204		SNR/PWN	327.30	14.54	HESS J1502−421	SN 1006 SW	327.35	14.48	0.13	N
J1503.4−5805c		Unid	319.67	0.42	HESS J1503−582	FVW 319.8+0.3?[g]	319.62	0.29	0.26	N
J1614.7−5138c		Unid	331.69	−0.49	HESS J1614-518		331.52	−0.58	0.2	N
J1640.8−4634c		SNR/PWN	338.29	−0.06	HESS J1640-465	G338.3−0.0	338.32	−0.02	0.05	N
J1648.4−4609c	PSR J1648-4611[c]	PSR	339.47	−0.79	Westerlund 1 region[h,i]		339.55	−0.40	~0.9	Y
J1649.3−4501c		Unid	340.44	−0.18	same as above					
J1651.5−4602c		Unid	339.91	−1.12	same as above					
J1702.4−4147c		Unid	344.45	0.00	HESS J1702−420	PSR J1702−4128	344.26	−0.22	0.3	N
J1707.9−4110c		Unid	345.56	−0.44	HESS J1708−410		345.67	−0.44	0.08	N
J1709.7−4429	PSR B1706−44	PSR	343.10	−2.69	HESS J1708−443	PSR B1706−44/G343.1−2.3	343.06	−2.38	0.29	Y
J1711.7−3944c		SNR/PWN	347.15	−0.19	HESS J1713−397	RX J1713.7−3946	347.28	−0.38	0.25	N
J1718.2−3825	PSR J1718−3825	PSR	349.00	−0.40	HESS J1718-385	PSR J1718−3825?	348.83	−0.49	0.015	N
J1745.6−2900c		SNR/PWN	359.94	−0.05	HESS J1745−290	Sgr A*/G359.95−0.04	359.94	−0.04	PS	P
J1800.5−2359c	W28−A2[f]	H II region[f]	5.95	−0.37	HESS J1800−240B	W28−A2	5.90	−0.37	0.15	N
J1801.3−2322c	W28[f]	SNR	6.57	−0.22	HESS J1801−233	W 28	6.66	−0.27	0.17	Y
J1805.2−2137c		SNR/PWN	8.55	−0.14	HESS J1804−216	W 30/PSR J1803−2137?	8.40	−0.03	0.20	Y
J1808.5−1954c		Unid	10.43	0.03	HESS J1809−193	PSR J1809−1917?	10.92	0.08	0.53	N
J1810.9−1905c		Unid	11.42	−0.08	HESS J1809−193	PSR J1809−1917?	10.92	0.08	0.53	N
J1826.2−1450	LS 5039	HMXB	16.88	−1.29	HESS J1826−148	LS 5039	16.90	−1.28	PS	Y
J1837.5−0659c		Unid	25.13	−0.12	HESS J1837−069		25.18	−0.12	7′.2×3′	P
J1844.3−0309c		Unid	29.32	0.13	HESS J1843−033[h]		~29.08	~0.16	~0.2	Y
J1848.1−0145c		Unid	30.99	−0.08	HESS J1848−018[h]		30.98	−0.16	0.32	Y
J1907.9+0602	PSR J1907+0602	PSR	40.18	−0.89	HESS J1908+063	MGRO J1908+06	40.39	−0.79	0.34	Y
J1910.9+0906c	W 49B[f]	SNR	43.25	−0.16	W 49B region	W 49B	43.26	−0.19	PS	Y
J1913.7+1007c		Unid	44.48	−0.28	HESS J1912+101	PSR J1913+101	44.36	−0.08	0.27	N
J1922.9+1411	W 51C[f]	SNR	49.12	−0.38	HESS J1923+141[h]	W 51	49.14	−0.6	~0.15	Y
J2020.0+4049		Unid	78.37	2.53	VER J2019+407[h]	γ Cygni SNR?	78.33	2.54	0.16×0.11	Y
J2032.2+4127	PSR J2032.2+4127	PSR	80.22	1.03	TeV J2032+4130		80.23	1.10	0.10	Y

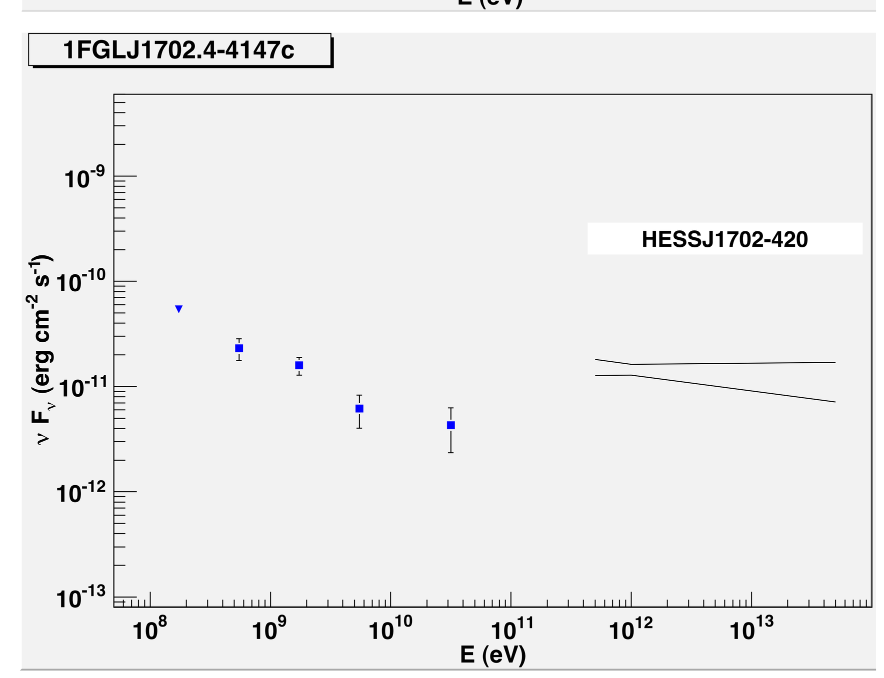
Notes. (a) based on timing information, unless otherwise specified (b) Source class according to the first Fermi/LAT catalog, unless otherwise specified. PSR: pulsar; SNR/PWN: supernova remnant/PWN; HMXB: high-mass X-ray binary; Unid: unidentified sources. The classification of those sources as SNR/PWN is based on spatial coincidence only. (c) based on spatial coincidence only (d) An entry of "PS" indicates that the source is point-like with respect to the point spread function of the respective instrument. (e) Coincidence level as defined in Tam et al. (2010) (f) The association is based on a morphological study by the Fermi/LAT collaboration. (g) FVW=Forbidden-Velocity-Wing. (h) These recent source discoveries are preliminary and they have been published in conference proceedings only. (i) The VHE emission has been detected by H.E.S.S. towards the direction of the massive stellar cluster. The coordinates refer to the nominal position of Westerlund 1.

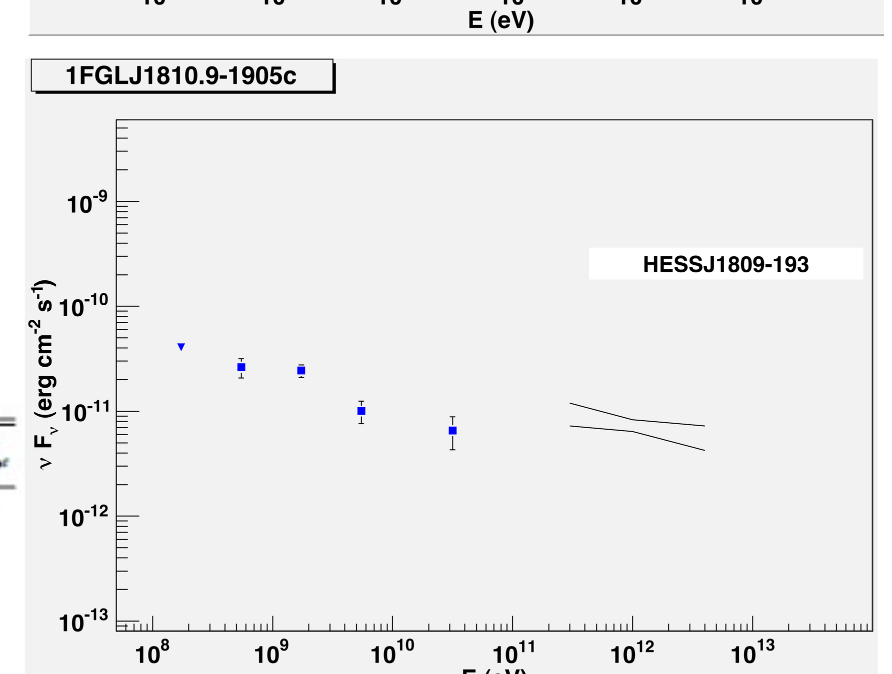
GeV-TeV spectra

The GeV spectral points are taken from the 1FGL catalog where point-source analysis was used, while the VHE spectra shown are the best-fit power law taken form the respective literature. We identify several cases where the 0.1-100 GeV spectra and the VHE spectra cannot be described by a single spectral components, as shown in the following figure. In several other cases, the GeV emission come from a γ-ray pulsar that shows cutoff and VHE emission mostly likely come from the associated PWN. We only highlight cases where the 1FGL source is not identified as a pulsar.









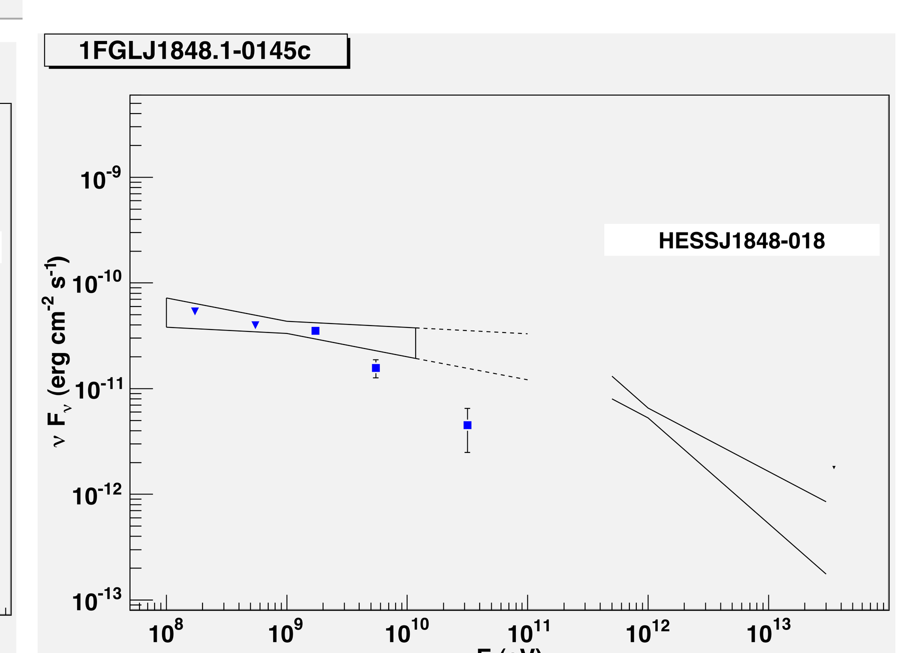


Figure
The 100 MeV to multi-TeV spectra of coincident 1FGL/VHE source pairs that do not seem to be well fit by a single spectral component. The flux in the five energy bands in [2] are plotted together with the best-fit power law in the VHE range. 1FGL J1848.1-0145c has a 0FGL counterpart whose best-fit power law is also shown.

Conclusion

We found five VHE sources that are spatially coincident with a 1FGL source but the GeV-TeV spectra are incompatible with a single spectral component: HESS J0852-463, HESS J1614-518, HESS J1702-420, HESS J1809-193, and HESS J1848-018.

The cases presented here might represent a group of GeV/TeV sources where the spectral miss-matches indicate different radiations working at different energies or that radiation comes from different parts of the γ-ray source. Further studies of these spectral mis-match GeV/TeV spatially coincident cases are encouraged.

References

[1] Tam, P. H. T., Wagner, S., Tibolla, O., Chaves, R., A&A, 2010, 518, A8
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