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H.E.S.S. VHE Gamma-ray sources without identified counterparts

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Abstract: Scan-based observations of the Galactic plane and continuing re-observations of known very-high-energy (VHE) gamma-ray sources with the H.E.S.S. system of imaging atmospheric Cherenkov telescopes have revealed a wide variety of new VHE objects. While in many cases these objects can be associated with known sources in the X-ray, radio, or optical wavebands, a subset of them currently have no obvious cataloged lower-energy counterpart. An analysis of 8 such unidentified sources is presented here.

Introduction

The current generation of Imaging Atmospheric Cherenkov Telescopes (IACTs) have provided an unprecedented level of sensitivity to the field of VHE (E =100 GeV–100 TeV) astronomy. In particular, the H.E.S.S. instrument and the ongoing H.E.S.S. Galactic Plane Survey of the inner Galaxy [1], has increased the number of known VHE sources by nearly an order of magnitude. While many of the new VHE sources discovered in the survey can be associated through multi-wavelength data with previously identified objects (e.g. shell-type supernova remnants, pulsar-wind nebulae, or X-ray binaries), a growing population of VHE sources have yet to be identified. Since at least weak X-ray and radio emission is predicted by most common VHE emission models, the lack of lower-energy detections may provide substantial model constraints and may even point to a new class of objects which emit primarily in the VHE energy range.

The results presented here should be considered preliminary; further details (sky maps and spectra) and final results will be available shortly in a refereed article.

Technique

H.E.S.S. (the High Energy Stereoscopic System) is an array of four atmospheric Cherenkov telescopes located in the Khomas highland of Namibia at an altitude of $1800\ \mathrm{m}$ above sea-level. Each telescope consists of a $107\mathrm{m}^2$ optical reflector made up of segmented mirrors that focus light into a camera of 960 photo-multiplier tube pixels [2]. The telescopes image the UV/blue flashes of Cherenkov light emitted by the secondary particles produced in gamma-ray-induced air-showers. Stereoscopic shower observations using the *imaging atmospheric Cherenkov technique* (e.g. [3, 4, 5]) allow for accurate reconstruction of the direction and energy of the primary gamma rays as well as for the rejection of background events from air showers of cosmic ray origin. H.E.S.S. is sensitive to gamma rays above a post-cuts threshold energy of approximately 150 GeV and has an average energy resolution of $\sim 16\%$ [6].

The data discussed here were taken as part of the H.E.S.S. Galactic Plane Survey, which covers the band $-50^\circ < l < 60^\circ$ in galactic longitude and $-3^\circ < b < 3^\circ$ in latitude. Data are taken as a series of 28-minute "runs", each centered on regular grid points along the survey region, or in case of re-observed sources, in *wobble-mode*, where the runs are taken at alternating offsets from the source position (typically $0.7°$). The data are analyzed using the standard H.E.S.S. analysis and calibration techniques described in [6]. The predefined *hard* gamma-ray selection cuts were applied to the data, which provide better gamma-hadron separation (and are thus better for source detection) at the expense of a higher analysis energy threshold. For source detection and morphology studies, the *ring-background* technique [7] was used for background subtraction with an on-source integration radius of 0.22° and an off-source annulus with typical radius $0.7°$ (standard for H.E.S.S. scan sources).

Source Selection

The VHE sources discussed here include all new sources discovered (with post-trials significances over 6σ) in the H.E.S.S. Galactic Plane Survey for which there is no obvious cataloged counterpart at lower wavelengths, according to the criteria cited below. Additionally, two sources meeting these criteria that were previously published in [1] are included due to a substantial increase in exposure time. A search for counterparts to the VHE emission was made by first looking in source catalogs for objects which are of a type known to produce VHE photons, including the ATNF pulsar catalog [8], the Green's supernova remnant catalog [9], and the High-Mass X-ray binary (HMXB) catalog by [10]. We also checked the Low-Mass X-ray binary (LMXB) catalog by [11], the INTEGRAL source catalog [12], and the SIMBAD database. Additionally, publicly available images for lower-wavelength survey data in the radio and X-ray wavebands, from the Molonglo [13, 14], NRAO VLA [15], ROSAT [16], ASCA [17] Galactic plane surveys, were compared with the H.E.S.S. excess maps.

To reduce the possibility of chance coincidences, some minimal selection criteria were applied to the possible candidates. For pulsar wind nebulae, only pulsars with spin-down fluxes $\dot{E}/D^2 > 10^{33}\,\mathrm{erg\,sec^{-1}\,kpc^{-2}}$ (e.g. ones which would require $< 100\%$ spin-down power to gamma ray conversion efficiency) were considered. For shell-type SNRs, only those that reasonably match the morphology (size and position) of the VHE emission, and for XRBs (which have so far not been observed to produce extended emission), only those with small offsets from the VHE source were considered plausible candidates.

Source	R.A.	Dec
HESS J1303-631‡	$13^{\rm h}03^{\rm m}00^{\rm s}$	$-63°11'55"$
HESS J1614-518‡	$16^{\rm h}14^{\rm m}19^{\rm s}$	$-51°49'12"$
HESS J1632-478	$16^{\rm h}32^{\rm m}09^{\rm s}$	$-47°49'12"$
HESS J1634-472	$16^{\rm h}34^{\rm m}58^{\rm s}$	$-47°16'12"$
HESS J1745-303	$17^{\rm h}45^{\rm m}02^{\rm s}$	$30°22'12"$
HESS J1837-069	$18^{\rm h}37^{\rm m}38^{\rm s}$	$-6°57'00"$
TeV J2032+4130‡	$20^{\rm h}32^{\rm m}57^{\rm s}$	$41°29'57"$

Table 2: Previously published unidentified VHE sources, not discussed here. Coordinates are in J2000 epoch. Sources with ‡ have no obvious lower-wavelength counterpart. For other sources, possible counterpars exist, which are however unidentified themselves or did not yet permit an identification of the VHE source. Results are from [18], [1], and [19].

Results

The details of the six new and two updated unidentified H.E.S.S. VHE sources are presented in Table 1, while previously published unidentified VHE sources are listed in 2 for reference. The results of a simple two-dimensional Gaussian function convolved with the H.E.S.S. point-spread function to the uncorrelated excess event maps is given in Table 3. This gives a rough impression of the size of each object, however as the emission is in most cases not Gaussian.

Discussion

Though the general characteristics (size, location, flux) of the eight unidentified sources described here are similar to previously identified galactic VHE sources (e.g. PWNe), they have so far no clear counterpart in lower wavebands and further multi-wavelength study is required to understand the emission mechanisms powering them. Therefore, follow-up observations with higher-

Source	R. A.	Dec	$l(^\circ)$	$b(^\circ)$	T (hrs)	S (σ)	Counts
HESS J1427−608	$14^{\mathrm{h}}27^{\mathrm{m}}2^{\mathrm{s}}$	−60°51′00”	314.409	-0.145	21	7.3	197
HESS J1626−490	$16^{\mathrm{h}}26^{\mathrm{m}}04^{\mathrm{s}}$	−49°05′13”	334.772	0.045	12	7.5	153
HESS J1702−420†	$17^{\mathrm{h}}02^{\mathrm{m}}44^{\mathrm{s}}$	−42°00′57”	344.304	-0.184	9	12.8	412
HESS J1708−410†	$17^{\mathrm{h}}08^{\mathrm{m}}24^{\mathrm{s}}$	−41°05′24”	345.683	-0.469	39	10.7	513
HESS J1731−347	$17^{\mathrm{h}}31^{\mathrm{m}}55^{\mathrm{s}}$	−34°42′36”	353.565	-0.622	14	8.1	218
HESS J1841−055	$18^{\mathrm{h}}40^{\mathrm{m}}55^{\mathrm{s}}$	−05°33′00”	26.795	-0.197	26	10.6	346
HESS J1857+026	$18^{\mathrm{h}}57^{\mathrm{m}}11^{\mathrm{s}}$	02°40′00”	35.972	-0.056	21	8.7	223
HESS J1858+020	$18^{\mathrm{h}}58^{\mathrm{m}}20^{\mathrm{s}}$	02°05′24”	35.578	-0.581	25	7.0	168

Table 1: Positions in equatorial (J2000 epoch) and Galactic (l,b) coordinates along with the detection significances of unidentified sources in the H.E.S.S. Galactic Plane scan discussed in this proceeding. S is the significance (number of standard deviations above the background level) of the source using a fixed integration radius of 0.22°, which was used for selecting the sources from the scan data. The position of each source is based on a model fit to the background-subtracted gamma-ray maps. The fit positions have an average statistical error of 0.05 degrees. Sources marked with a † are previously published in [1] and have been updated with new data. The exposure time is corrected for the off-axis sensitivity of the telescope system and accounts for instrumental readout dead-time.

sensitivity X-ray and GeV gamma-ray telescopes will be beneficial. Since most VHE sources are predicted to emit X-ray and radio emission, a non-detection of lower-wavelength emission with current-generation experiments for some of these objects may indicate a new VHE source class (as suggested in [20]), and may provide new insight into high-energy processes within our Galaxy.

Source	σ_1 (°)	σ_2 (°)	ϕ (°)
HESS J1427−608	0.04 ± 0.02	0.08 ± 0.03	80 ± 17
HESS J1626−490	0.07 ± 0.02	0.10 ± 0.05	3 ± 40
HESS J1702−420	0.30 ± 0.02	0.15 ± 0.01	68 ± 7
HESS J1708−410	0.06 ± 0.01	0.08 ± 0.01	-20 ± 23
HESS J1731−347	0.18 ± 0.07	0.11 ± 0.03	-89 ± 21
HESS J1841−055	0.41 ± 0.04	0.25 ± 0.02	39 ± 6
HESS J1857+026	0.11 ± 0.08	0.08 ± 0.03	-3 ± 49
HESS J1858+020	0.08 ± 0.02	0.02 ± 0.04	4 ± 17

Table 3: Results from an elongated 2-D Gaussian model fit to the gamma-ray excess for each source. σ_1 and σ_2 are the intrinsic semi-major and semi-minor axes (in degrees on the sky), with the effect of the point-spread function removed. The errors are statistical. The position angle (ϕ) is measured counter-clockwise in degrees relative to the RA axis.

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References

[1] F. A. Aharonian et al. (HEGRA Collaboration), The H.E.S.S. Survey of the Inner Galaxy in Very High Energy Gamma Rays, ApJ636 (2006) 777–797.

[2] B. et al., The optical system of the H.E.S.S. imaging atmospheric Cherenkov telescopes. Part I: layout and components of the system, Astroparticle Physics 20 (2003) 111–128.

[3] A. M. Hillas, Differences between Gamma-Ray and Hadronic Showers, Space Science Reviews 75 (1996) 17–30.

[4] T. C. Weekes, The Atmospheric Cherenkov Technique in Very High Energy Gamma-Ray Astronomy, Space Science Reviews 75 (1996) 1–15.

[5] A. Daum et al., First results on the performance of the HEGRA IACT array, Astroparticle Physics 8 (1997) 1–2.

[6] F. A. Aharonian et al. (HEGRA Collaboration), Observations of the Crab nebula with HESS, A&A457 (2006) 899–915.

[7] D. Berge, S. Funk, J. Hinton, Background modelling in very-high-energy gamma-ray astronomy, A&A466 (2007) 1219–1229.

[8] R. N. Manchester, G. B. Hobbs, A. Teoh, M. Hobbs, The Australia Telescope National Facility Pulsar Catalogue, AJ129 (2005) 1993–2006.

[9] D. A. Green, Galactic supernova remnants: an updated catalogue and some statistics., Bulletin of the Astronomical Society of India 32 (2004) 335–370.

[10] Q. Z. Liu, J. van Paradijs, E. P. J. van den Heuvel, Catalogue of high-mass X-ray binaries in the Galaxy (4th edition), A&A455 (2006) 1165–1168.

[11] Q. Z. Liu, J. van Paradijs, E. P. J. van den Heuvel, A catalogue of low-mass X-ray binaries in the Galaxy, LMC, and SMC (Fourth edition), A&A469 (2007) 807–810.

[12] A. J. Bird, A. Malizia, A. Bazzano, E. J. Barlow, L. Bassani, A. B. Hill, G. Bélanger, F. Capitanio, D. J. Clark, A. J. Dean, M. Fiocchi, D. Götz, F. Lebrun, M. Molina, N. Produit, M. Renaud, V. Sguera, J. B. Stephen, R. Terrier, P. Ubertini, R. Walter, C. Winkler, J. Zurita, The Third IBIS/ISGRI Soft Gamma-Ray Survey Catalog, ApJS170 (2007) 175–186.

[13] A. J. Green, L. E. Cram, M. I. Large, T. Ye, The Molonglo Galactic Plane Survey. I. Overview and Images, ApJS122 (1999) 207–219.

[14] T. Mauch, T. Murphy, H. J. Buttery, J. Curran, R. W. Hunstead, B. Piestrzynski, J. G. Robertson, E. M. Sadler, SUMSS: a wide-field radio imaging survey of the southern sky - II. The source catalogue, MNRAS342 (2003) 1117–1130.

[15] J. J. Condon, W. D. Cotton, E. W. Greisen, Q. F. Yin, R. A. Perley, G. B. Taylor, J. J. Broderick, The NRAO VLA Sky Survey, AJ115 (1998) 1693–1716.

[16] W. Voges, B. Aschenbach, T. Boller, H. Brauninger, U. Briel, W. Burkert, K. Dennerl, J. Englhauser, R. Gruber, F. Haberl, G. Hartner, G. Hasinger, E. Pfeffermann, W. Pietsch, P. Predehl, J. Schmitt, J. Trumper, U. Zimmermann, Rosat All-Sky Survey Faint Source Catalogue, IAU Circ7432 (2000) 3–+.

[17] Y. Tanaka, H. Inoue, S. S. Holt, The X-ray astronomy satellite ASCA, PASJ46 (1994) L37–L41.

[18] F. A. Aharonian et al. (H.E.S.S. Collaboration), Serendipitous discovery of the unidentified extended TeV γ-ray source HESS J1303-631, A&A439 (2005) 1013–1021.

[19] F. A. Aharonian et al. (HEGRA Collaboration), The unidentified TeV source (TeV J2032+4130) and surrounding field: Final HEGRA IACT-System results, A&A431 (2005) 197–202.

[20] F. A. Aharonian et al. (H.E.S.S. Collaboration), A New Population of Very High Energy Gamma-Ray Sources in the Milky Way, Science 307 (2005) 1938–1942.