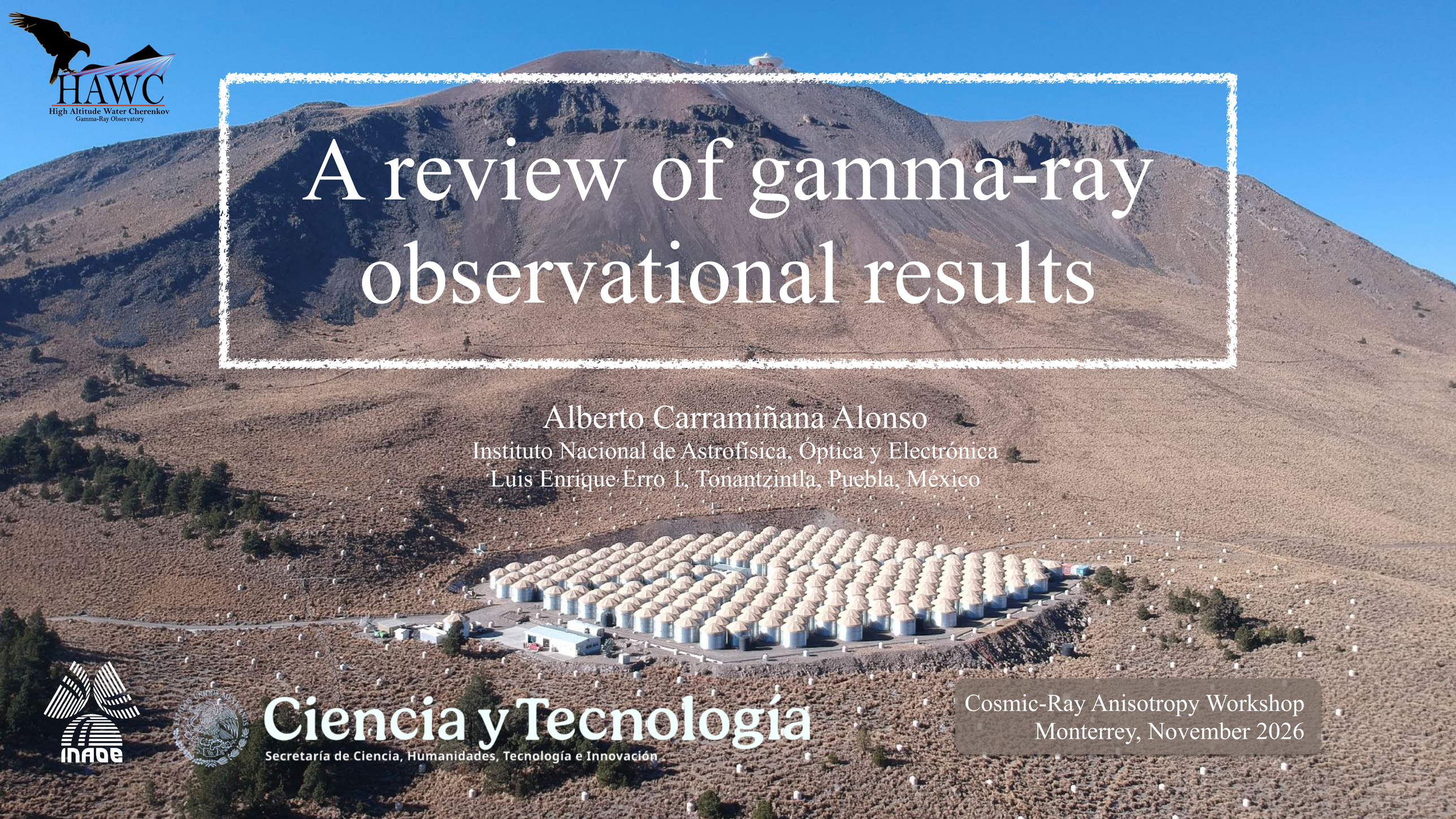
A review of gamma-ray observational results

Alberto Carramiñana Alonso
Instituto Nacional de Astrofísica, Óptica y Electrónica
Luis Enrique Erro 1, Tonantzintla, Puebla, México



Ciencia y Tecnología
Secretaría de Ciencia, Humanidades, Tecnología e Innovación

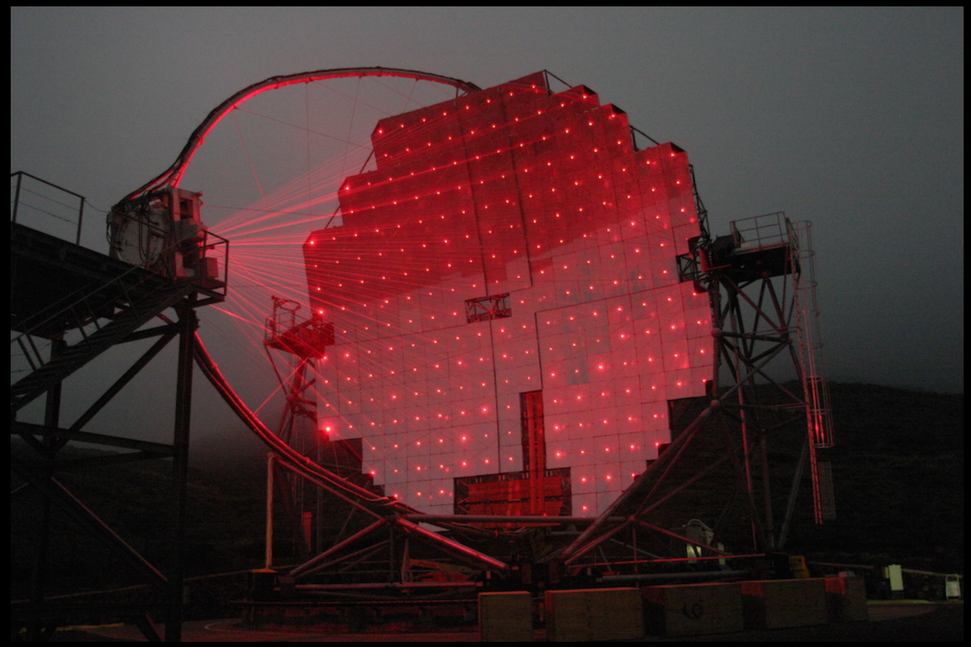
Cosmic-Ray Anisotropy Workshop
Monterrey, November 2026

Layout

- Gamma-ray telescopes → FL16Y
- A little taste of LHAASO.
- HAWC & recent results.

γ ray astronomy: a quest to identify particle accelerators in the Universe.







MeV → GeV

GeV → TeV

TeV → PeV

We could also use neutrinos…

fermi.gsfc.nasa.gov/ssc/

Fermi LAT catalogs

Type	Catalog	Range
General	0FGL → 4FGL → FL16Y (→ 5FGL)	50 MeV - 1 TeV
Hard sources	1FHL → 4FHL	50 GeV - 2 TeV
Low energy	1FLE → 2FLE	20 - 200 MeV
Active galaxies	1LAC → 4LAC	50 MeV - 1 TeV
Pulsars	1PC → 3PC	50 MeV - 1 TeV
Supernova remnants	2 SC	1 - 100 GeV
GRBs	2 GRB	100 MeV - 100 GeV

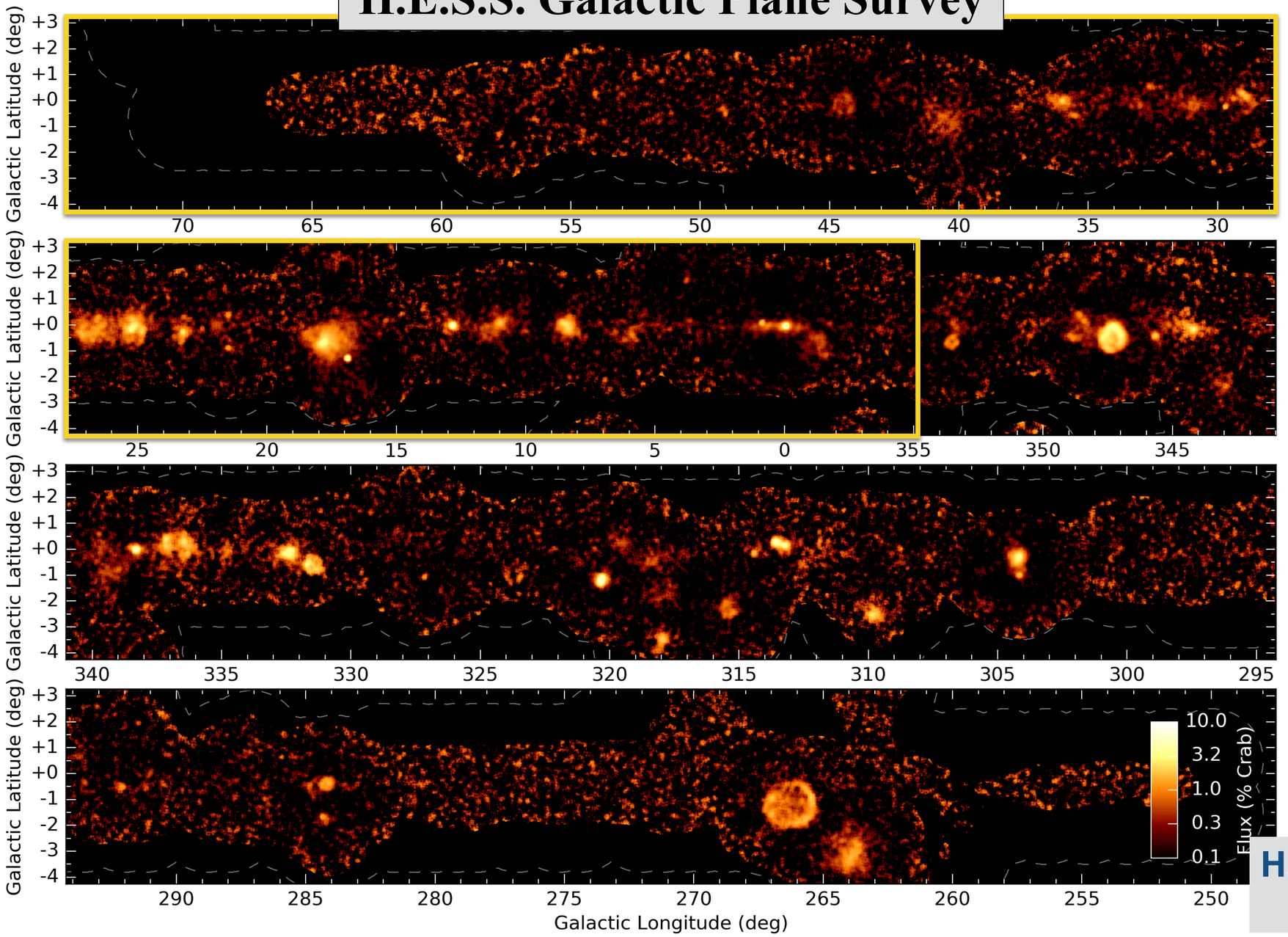
+ weekly light curves, FAVA, GBM-TGF, FLSF…

LAT FL16Y - 7220 sources at GeV energies

PSR + psr	140 + 5	BLL + **bll**	22 + 1803
MSP + msp	167 + 31	FSRQ + **fsrq**	44 + 791
PWN + pwn	12 + 8	RDG + rdg	6 + 75
SNR + snr	26 + 17	BCU + **bcu**	1 + 1512
SPP + **spp**	6 + 128	NLSY1 + nlsy1	4 + 2
SFR + sfr	3 + 25	SBG + sbg	0 + 8
Other Galactic	17 + 68	Other extragal.	3 + 17
Galactic	**371 + 282**	**Extragalatic**	**80 + 4208**
UNK + **unk**	3 + 161	**Unassociated**	2114

H.E.S.S. Galactic Plane Survey

HAWC

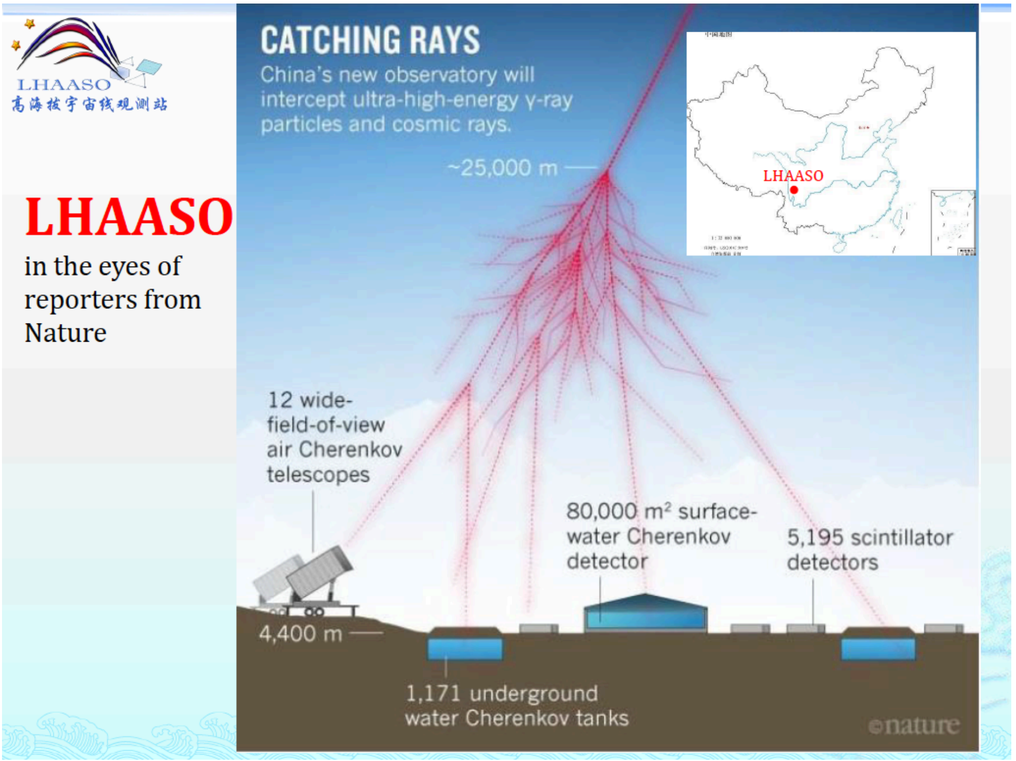


H.E.S.S. Collaboration, A&A 612, A1 (2018)

LHAASO - September 2022

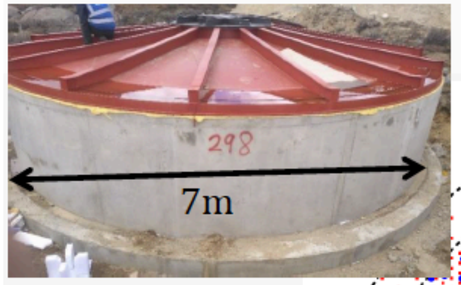
Copyright©2002-2024 LHAASO Team

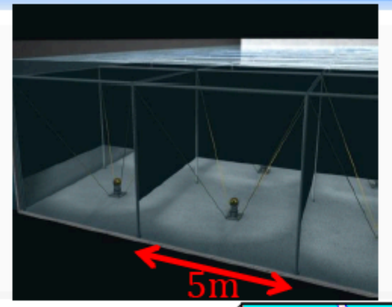




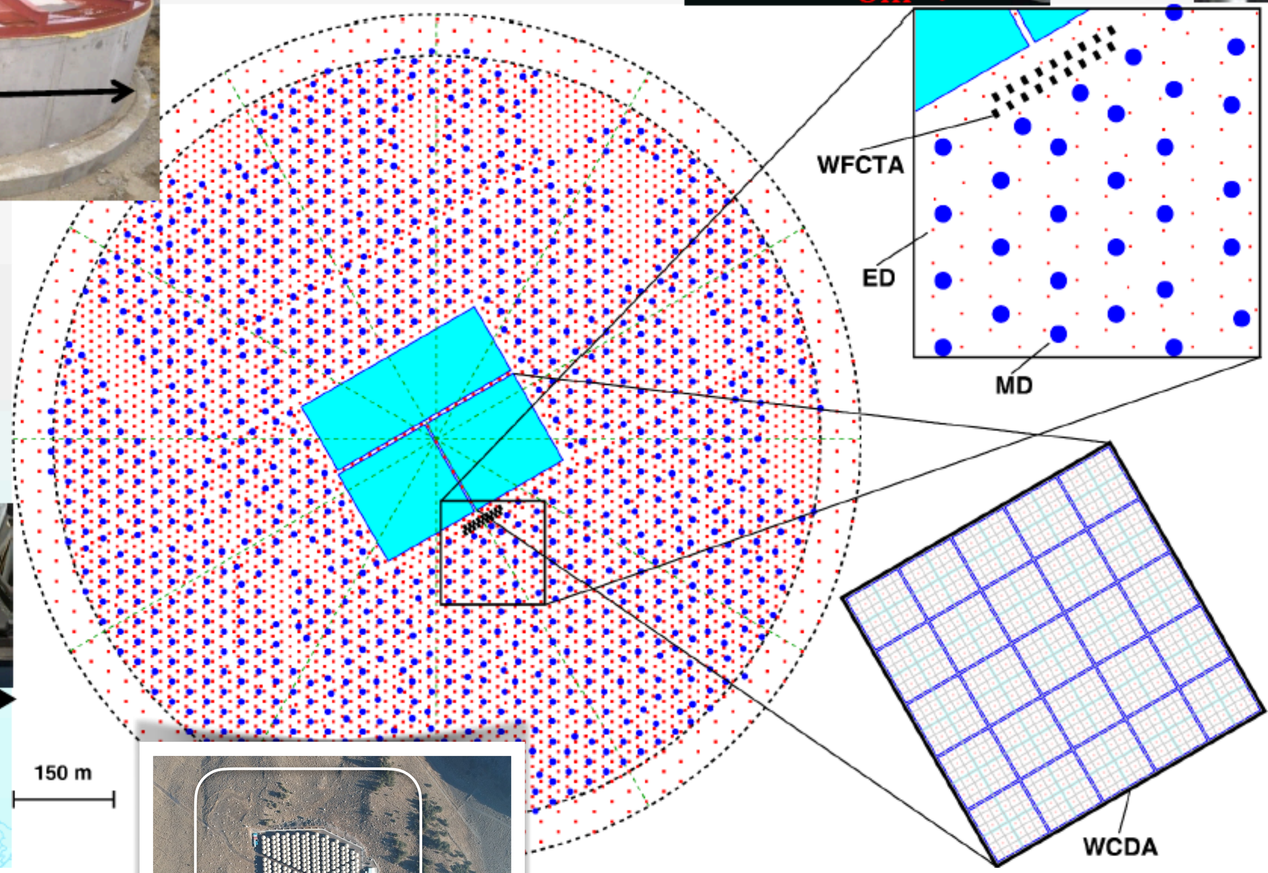
LHAASO
in the eyes of reporters from Nature

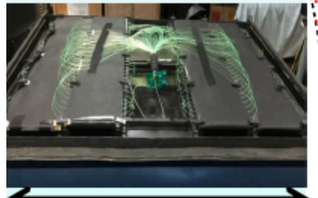
Detector Layout in LHAASO













- Surface array: 5195 EM + 1171 muon detectors;
- Water Cherenkov: 3120 cells × 2 PMTs / cell;
- Array of 12 atmospheric Cherenkov telescopes.

LHAASO Collaboration, Nature, May 2021

Article

Table 1 | UHE γ-ray sources

Source name		RA (°)	dec. (°)	Significance above 100 TeV (×σ)	E_{max} (PeV)	Flux at 100 TeV (CU)
LHAASO J0534+2202	Crab	83.55	22.05	17.8	0.88 ± 0.11	1.00(0.14)
LHAASO J1825-1326		276.45	−13.45	16.4	0.42 ± 0.16	3.57(0.52)
LHAASO J1839-0545		279.95	−5.75	7.7	0.21 ± 0.05	0.70(0.18)
LHAASO J1843-0338		280.75	−3.65	8.5	$0.26 - 0.10^{+0.16}$	0.73(0.17)
LHAASO J1849-0003		282.35	−0.05	10.4	0.35 ± 0.07	0.74(0.15)
LHAASO J1908+0621	MGRO	287.05	6.35	17.2	0.44 ± 0.05	1.36(0.18)
LHAASO J1929+1745		292.25	17.75	7.4	$0.71 - 0.07^{+0.16}$	0.38(0.09)
LHAASO J1956+2845		299.05	28.75	7.4	0.42 ± 0.03	0.41(0.09)
LHAASO J2018+3651	Cygnus	304.75	36.85	10.4	0.27 ± 0.02	0.50(0.10)
LHAASO J2032+4102		308.05	41.05	10.5	1.42 ± 0.13	0.54(0.10)
LHAASO J2108+5157		317.15	51.95	8.3	0.43 ± 0.05	0.38(0.09)
LHAASO J2226+6057	Boomerang	336.75	60.95	13.6	0.57 ± 0.19	1.05(0.16)

Celestial coordinates (RA, dec.); statistical significance of detection above 100 TeV (calculated using a point-like template for the Crab Nebula and LHAASO J2108+5157 and 0.3° extension templates for the other sources); the corresponding differential photon fluxes at 100 TeV; and detected highest photon energies. Errors are estimated as the boundary values of the area that contains ±34.14% of events with respect to the most probable value of the event distribution. In most cases, the distribution is a Gaussian and the error is 1σ.

The Astrophysical Journal Supplement Series, 271:25 (26pp), 2024 March

1st LHAASO catalog

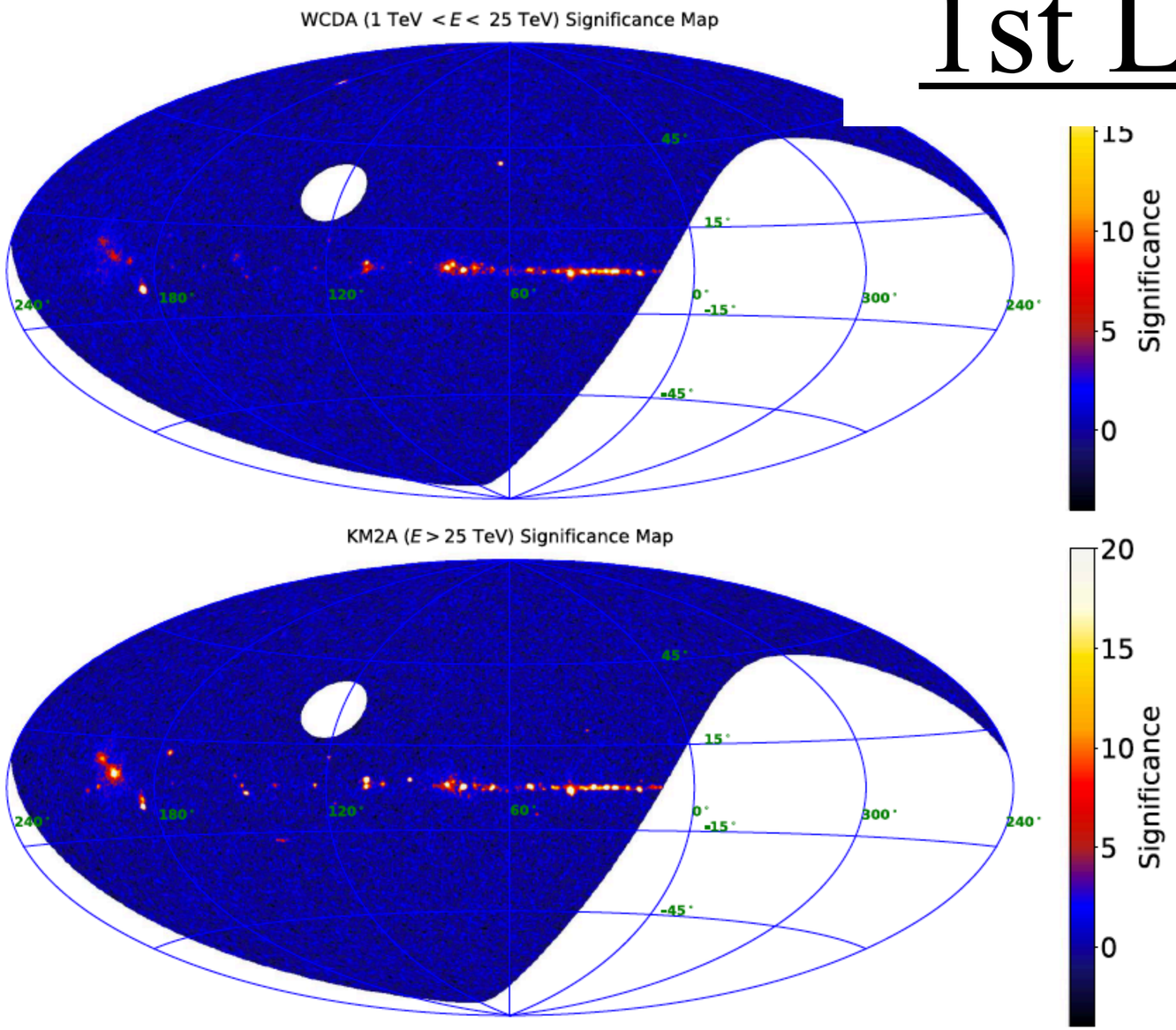


Figure 1. Significance maps of the region monitored by LHAASO. A point test source with a spectral index of 2.6 for WCDA data and 3.0 for KM2A data is used.

WCDA 508 days + KM2A 933 days

$\Longrightarrow$ 90 sources,

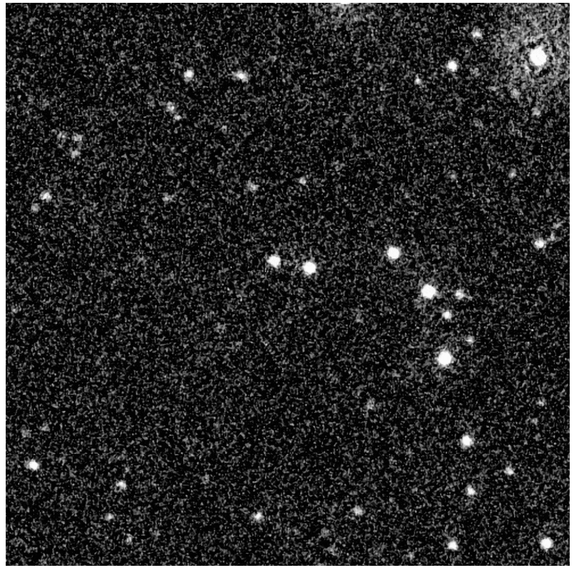
43 E>100 TeV, 32 new.

22 1LHAASO sources not in 4HWC

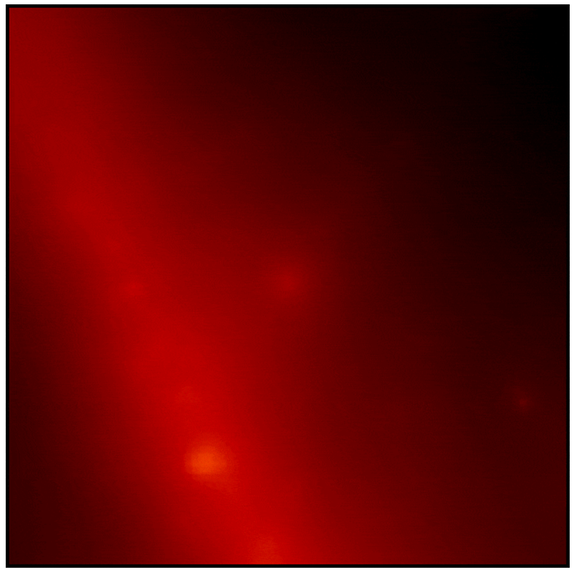
LHAASO Col., ApJSS 271, 25 (2024)

- Cygnus OB2 - 2.5 PeV photon… (Sci. Bull. 69, 449, 2024)
- More recent: LS I +61 303 (Cao et al., 2510.23345)
- Much more tomorrow…

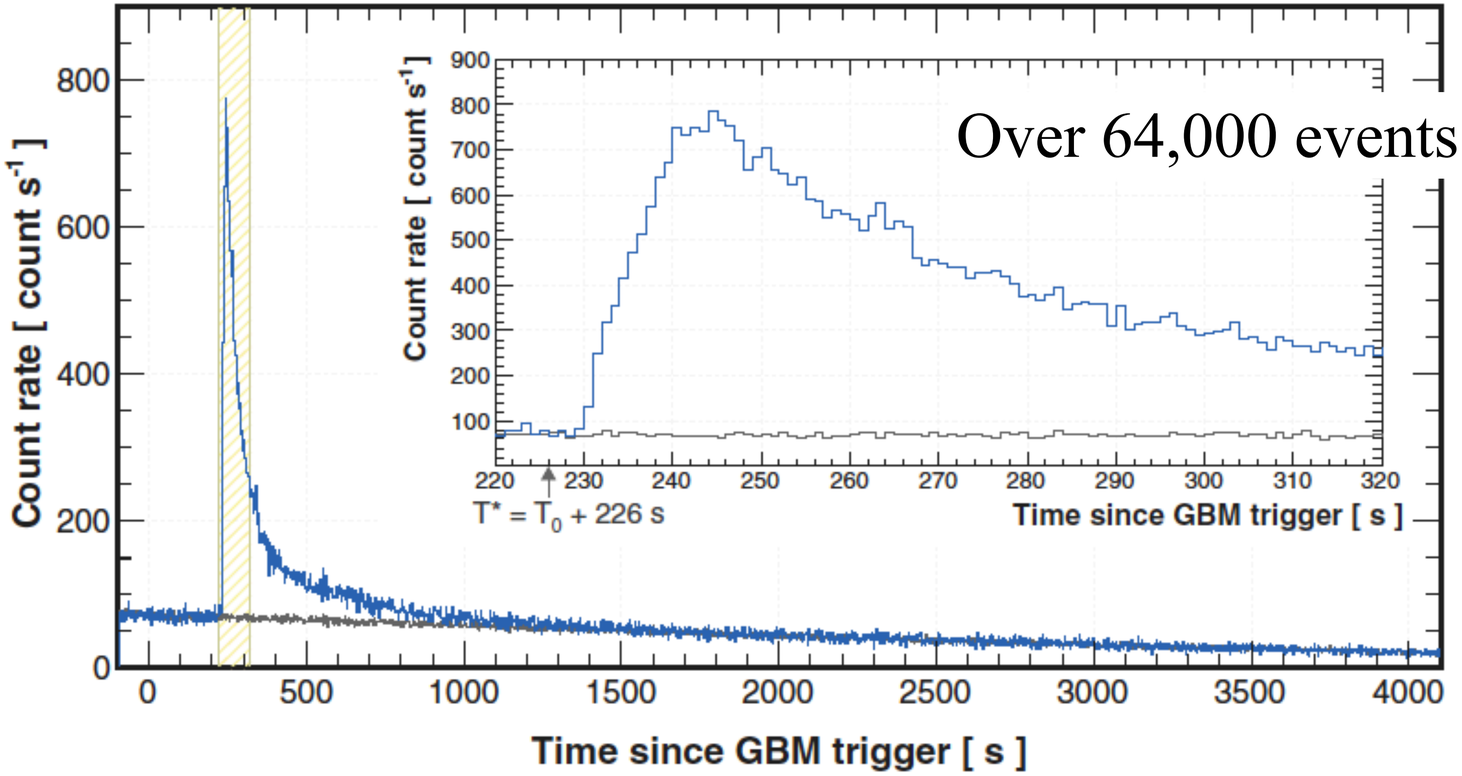
GRB 221009A



Swift-UVOT



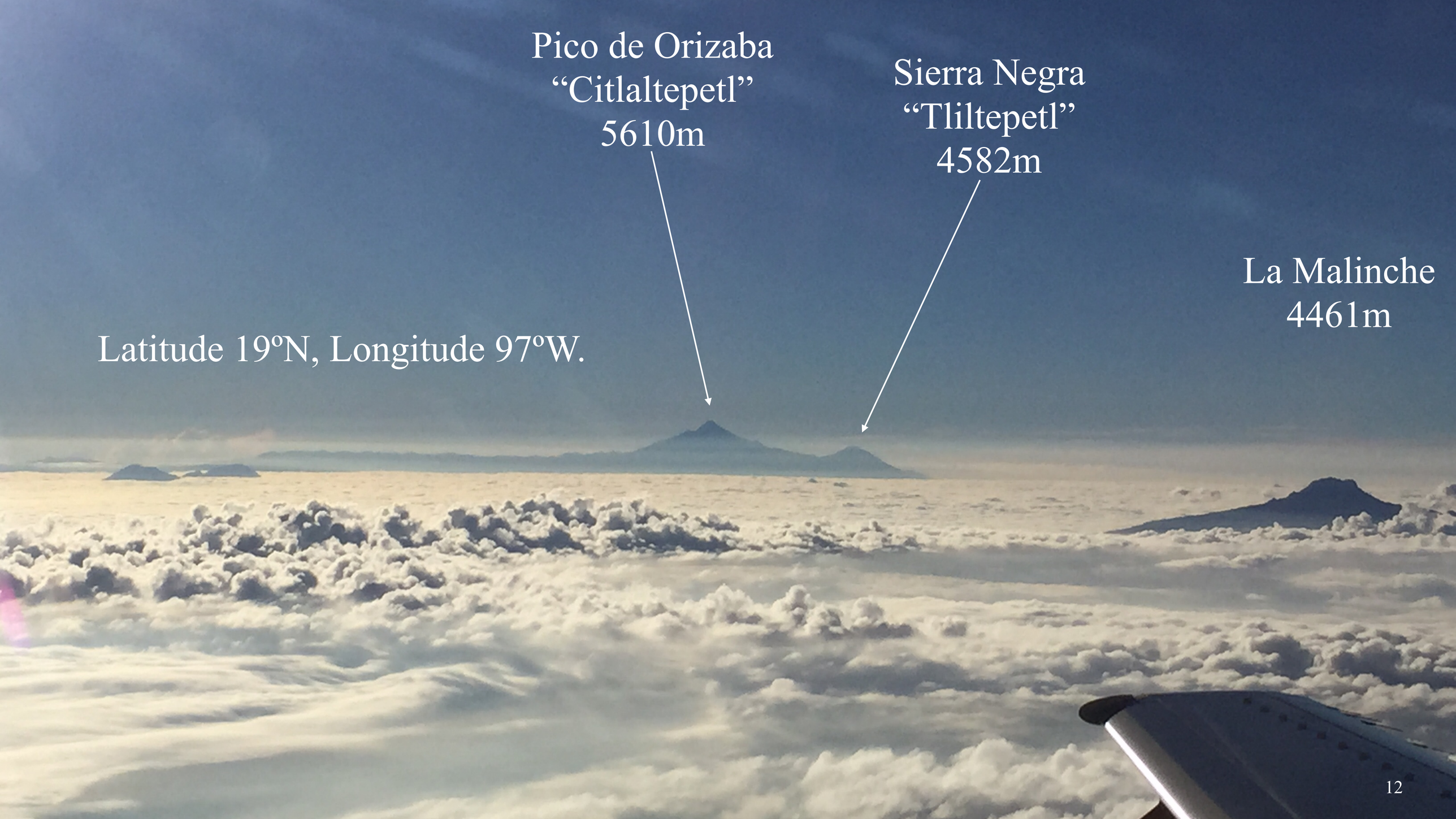
Fermi-LAT

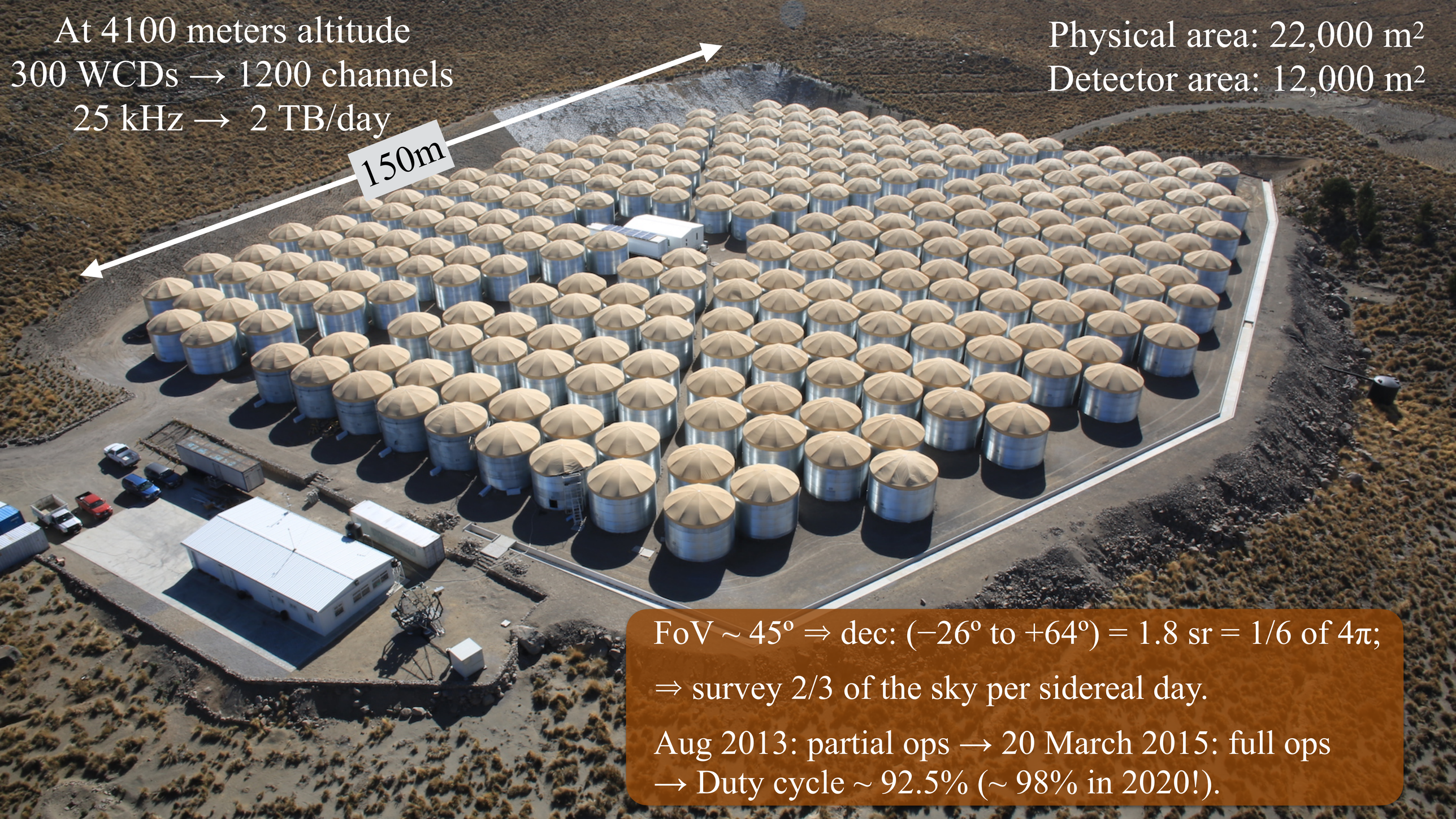


Over 64,000 events in WCDA…

Fig. 1. Count rate light curve of GRB 221009A observed by LHAASO-WCDA. The energy range of photons observed is ~0.2 to 7 TeV. The inset panel shows a zoomed-in view of the light curve during 220 to 320 s (yellow shaded zone) after the GBM trigger (T_0), with the arrow indicating the reference time $T^* = T_0 + 226$ s for our light curve analysis (see text). Blue histograms are the data, and black histograms are the estimated background.

LHAASO Collaboration, Science 380, 1390 (2023)

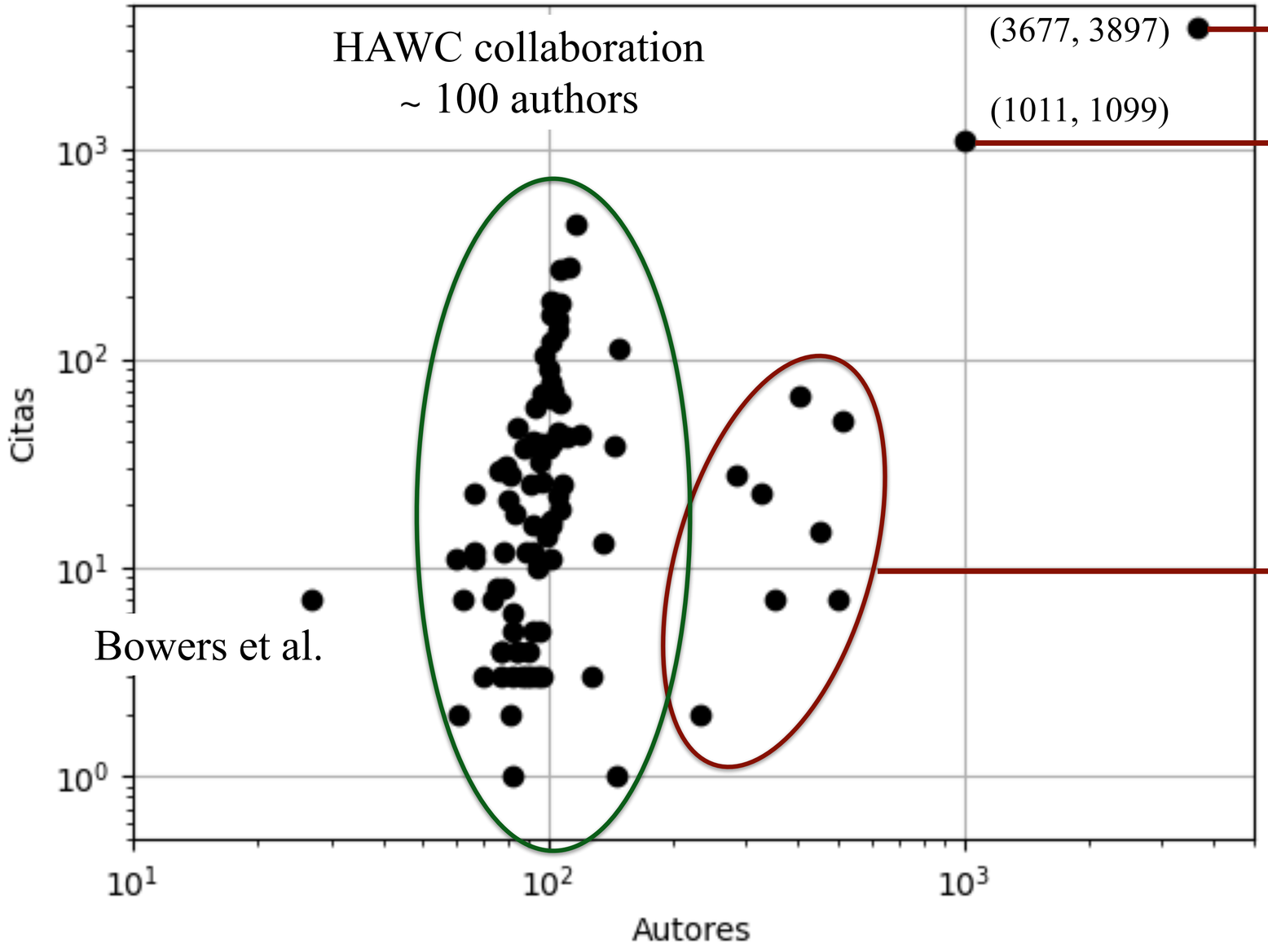

Pico de Orizaba
“Citlaltepetl”
5610m
Sierra Negra
“Tliltepetl”
4582m
La Malinche
4461m
Latitude 19ºN, Longitude 97ºW.


At 4100 meters altitude
300 WCDs → 1200 channels
25 kHz → 2 TB/day
150m
Physical area: 22,000 m²
Detector area: 12,000 m²
FoV ~ 45º ⇒ dec: (−26º to +64º) = 1.8 sr = 1/6 of 4π;
⇒ survey 2/3 of the sky per sidereal day.
Aug 2013: partial ops → 20 March 2015: full ops
→ Duty cycle ~ 92.5% (~ 98% in 2020!).

Outrigger array
installed 2018
→ Pass 6
(work in progress…)



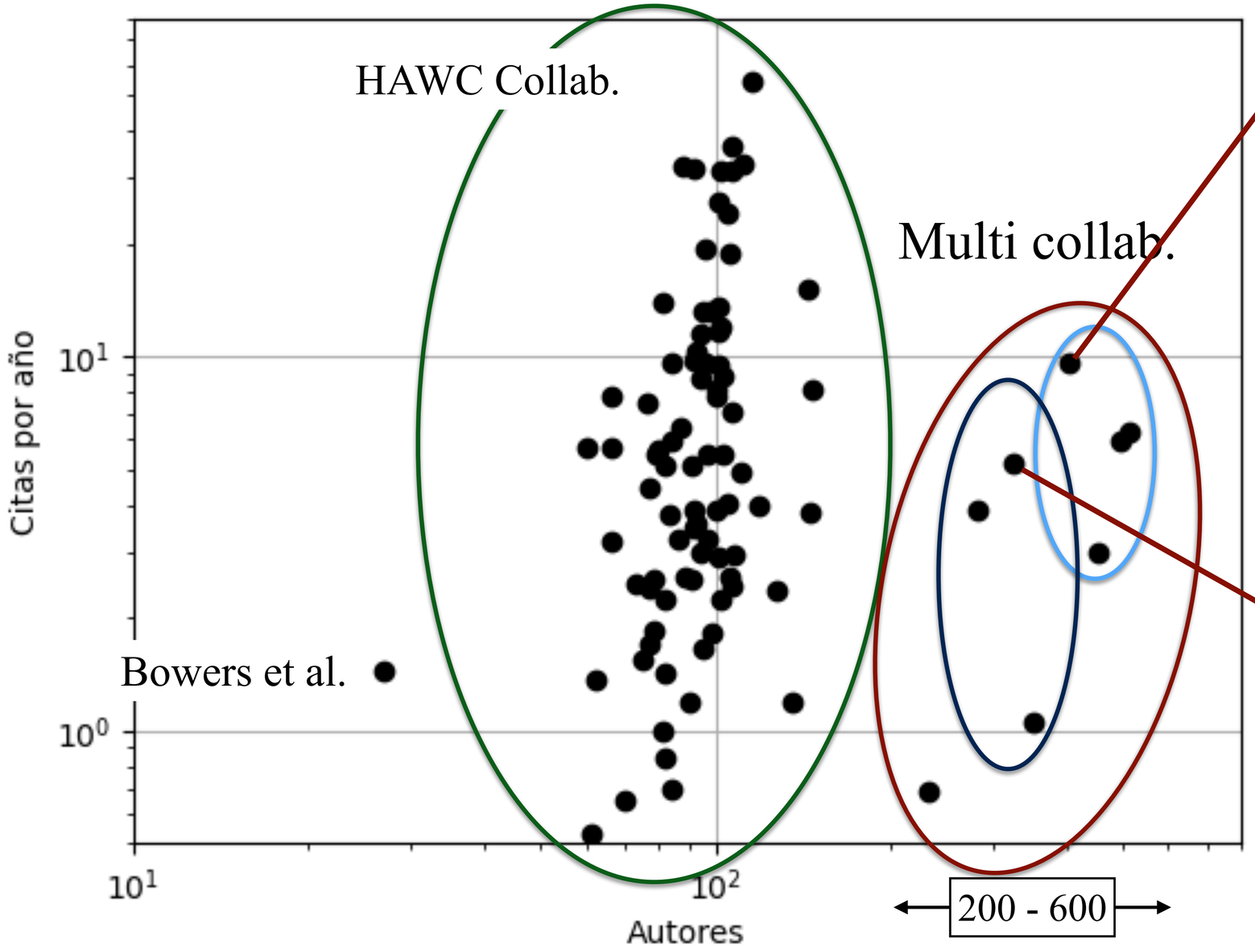
100,000 m^2



GW 170817 = GRB 170817A

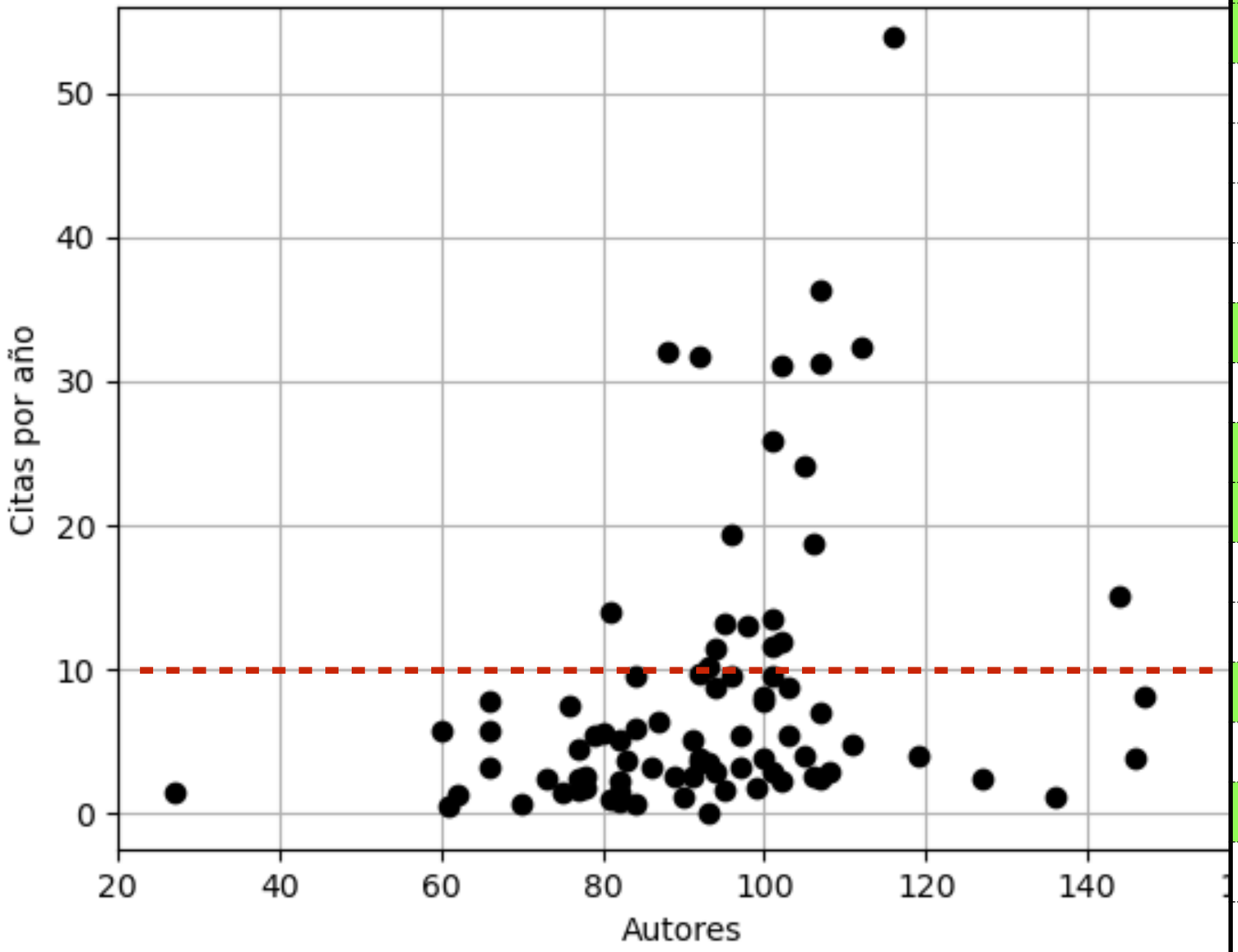
IC 170922A = TXS 0506+056

Two or three collaborations
CR, MW, MM, follow-up…
~ 200 - 500 authors



Paper	Aut.	Citas	
IC+HAWC all-sky CR anisotropy	404	67	9.6/año
IC neutrino triplet	513	51	6.2/año
IC-sub threshold coincidences	453	15	3.0/año
Search for joint MM - HAWC & IC	496	7	5.9/año
γ-ray neutrino coincidences ANTARES	233	2	0.7/año
Galactic Plane HAWC and H.E.S.S.	324	23	5.2/año
VERITAS and LAT follow up HAWC	282	28	3.9/año
MAGIC and LAT follow up on HAWC	353	7	1.0/año

HAWC Collaboration



Paper	Aut.	Citas	
Geminga (Science 2017)	116	**440**	53.8/año
3HWC (ApJ 2020)	107	**185**	36.3/año
2HWC (ApJ 2017)	112	**276**	32.4/año
V4641 Sgr (Nature 2024)	92	40	31.7/año
Crab (ApJ 2017)	107	**266**	31.2/año
Multi >56 TeV (PRL 2020)	102	**187**	31.1/año
Cygnus Cocoon (NA 2021)	101	**121**	25.9/año
Crab (ApJ 2019)	105	**155**	24.1/año
Crab - perform. (ApJ 2024)	96	26	19.3/año
SS 433 jets (Nature 2018)	106	**136**	18.7/año
HAWC obs (NIM 2023)	144	38	15.1/año
Source sens. (APh 2013)	101	**164**	13.6/año
Quiescent Sun (PRL 2023)	95	32	13.2/año
DM limit dwarfs (ApJ 2018)	98	**104**	13.1/año
Galactic Center (ApJ 2024)	102	16	11.9/año
J2227+610 (ApJ 2020)	101	65	11.6/año
LIV constraints (PRL2020)	93	59	10.2/año

Revista Mexicana de Astronomía y Astrofísica, 61, 261-299, (2025)
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OPEN ACCESS https://doi.org/10.22201/ia.01851101p.2025.61.03.13

The first 10 years of the HAWC Gamma-Ray Observatory: science results

A. Albert [19], R. Alfaro [1], C. Alvarez [2], A. Andrés [3], E. Anita-Rangel [3], M. Araya [4], J. C. Arteaga-Velázquez [5], K. P Arunbabu [34], D. Avila Rojas [3], H. A. Ayala Solares [6], R. Babu [7], P. Bangale [8], E. Belmont-Moreno [1], S. BenZvi [41], A. Bernal [3], C. Brisbois [16], K. S. Caballero-Mora [2], J.I. Cabrera Martínez [46, 48], T. Capistrán [3], A. Carramiñana [9], F. Carreón [3], S. Casanova [10], P. Colín-Farias [22], A.L. Colmenero-Cesar [5], U. Cotti [5], J. Cotzomi [11], S. Coutiño de León [35], E. De la Fuente [13], C. de León [5], R. DeLay [16], D. Depaoli [14], P. Desiati [12], N. Di Lalla [15], R. Diaz Hernandez [9], B. L. Dingus [19], M. A. DuVernois [12], J. C. Díaz-Vélez [12], R.W. Ellsworth [16], K. Engel [16], T. Ergin [7], C. Espinoza [1], K. L. Fan [16], K. Fang [12], H. Fleischhack [33], N. Fraija [3], S. Fraija [3], J. A. García-González [17], F. Garfias [3], N. Ghosh [18], H. Goksu [14], A. Gonzalez Muñoz [1], M. M. González [3], J. A. González [5], J. A. Goodman [16], S. Groetsch [18], J. Gyeong [30], J. P. Harding [19], S. Hernandez Cadena [31], I. Herzog [7], D. Huang [16], F. Hueyotl-Zahuantitla [2], P. Hüntemeyer [18], A. Iriarte [3], S. Kaufmann [20], N. Kelley-Hoskins [18], D. Kieda [21], A. Lara [22], R. Lauer [27], K. Leavitt [18], W. H. Lee [3], J. Lee [23], H. León Vargas [1], T. Lewis [18], J. T. Linnemann [7], A. L. Longinotti [3], G. Luis-Raya [20], K. Malone [19], A. Marinelli [43,44,45], S. Marinelli [7], O. Martinez [11], I. Martinez-Castellanos [24], J. Martínez-Castro [25], H. Martínez-Huerta [26], J. A. Matthews [27], J. McEnery [24], P. Miranda-Romagnoli [28], P. E. Mirón-Enriquez [3], T. Montaruli [42], J. A. Morales-Soto [5], E. Moreno [11], M. Mostafá [8], M. Najafi [18], A. Nayerhoda [10], L. Nellen [29], M. U. Nisa [7], R. Noriega-Papaqui [28], N. Omodei [15], M. Osorio-Archila [3], E. Ponce [11], Y. Pérez Araujo [1], E. G. Pérez-Pérez [20], J. Pretz [6], C. D. Rho [30], A. Rodriguez Parra [5], D. Rosa-González [9], M. Roth [19], E. Ruiz-Velasco [14], J. Ryan [49], H. Salazar [11], D. Salazar-Gallegos [7], F. Salesa Greus [10,35], A. Sandoval [1], M. Schneider [16], G. Schwefer [14], J. Serna-Franco [1], A. J. Smith [16], Y. Son [23], R. W. Springer [21], I. Taboada [37], O. Tibolla [20], K. Tollefson [7], I. Torres [9], R. Torres-Escobedo [31], R. Turner [18], F. Ureña-Mena [9], E. Varela [11], M. Vargas-Magaña [1], O. W. Vázquez Estrada [38], G. Vianello [36], L. Villaseñor [11], X. Wang [47], Z. Wang [47], I. J. Watson [23], I. Wisher [12], J. Wood [32], H. Wu [12], T. Yapici [41], S. Yu [6], S. Yun-Cárcamo [16], D. Zaborov [40] and H. Zhou [23]

[1] *Instituto de Fisica, Universidad Nacional Autónoma de México, Ciudad de México, México. The remaining affiliations are listed at the end of the paper.*

Keywords: *acceleration of particles, (ISM:) cosmic rays, gamma-rays: general, astroparticle physics*

The Crab Pulsar Wind Nebula

THE ASTROPHYSICAL JOURNAL, 881:134 (13pp), 2019 August 20

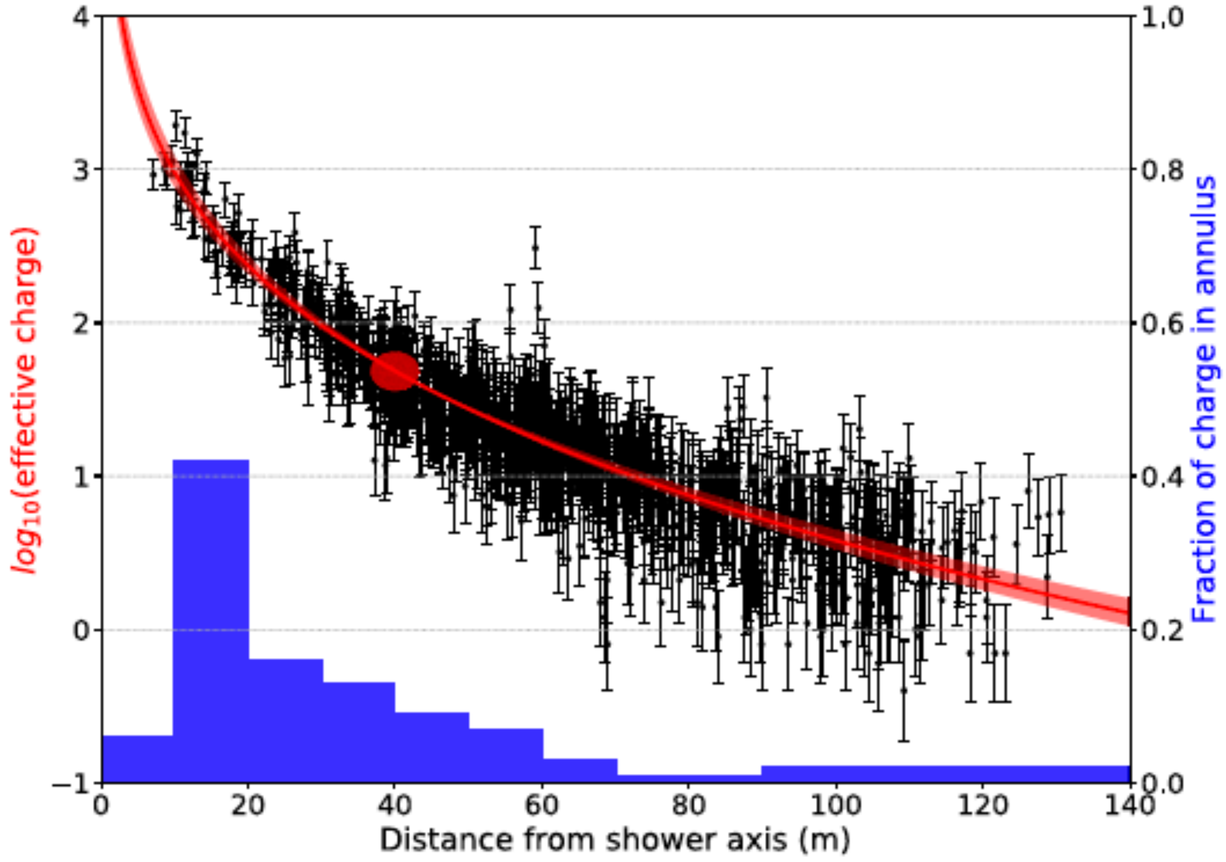


Figure 2. Depiction of the information used by the two energy estimators. The black points show, for a single event, the log of the effective charge measured

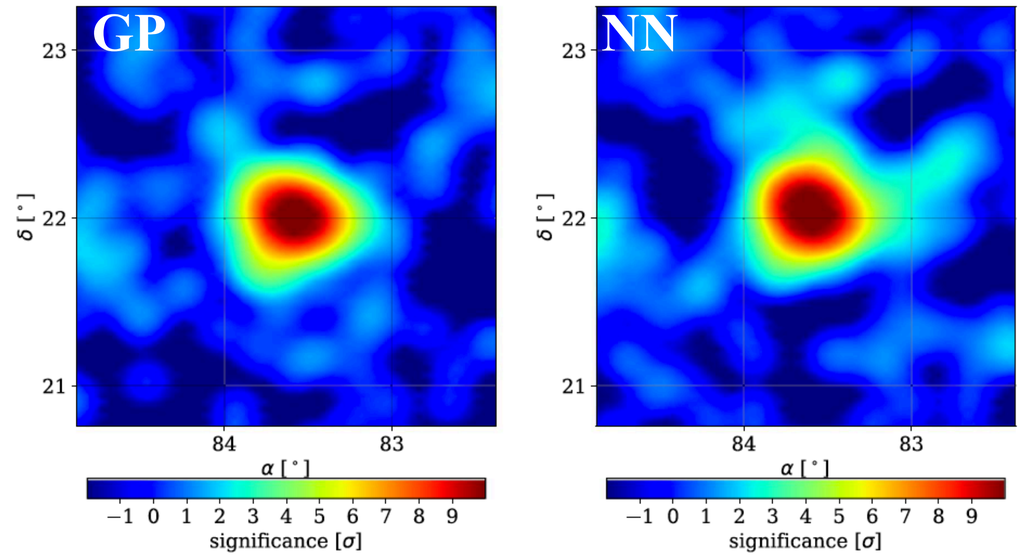


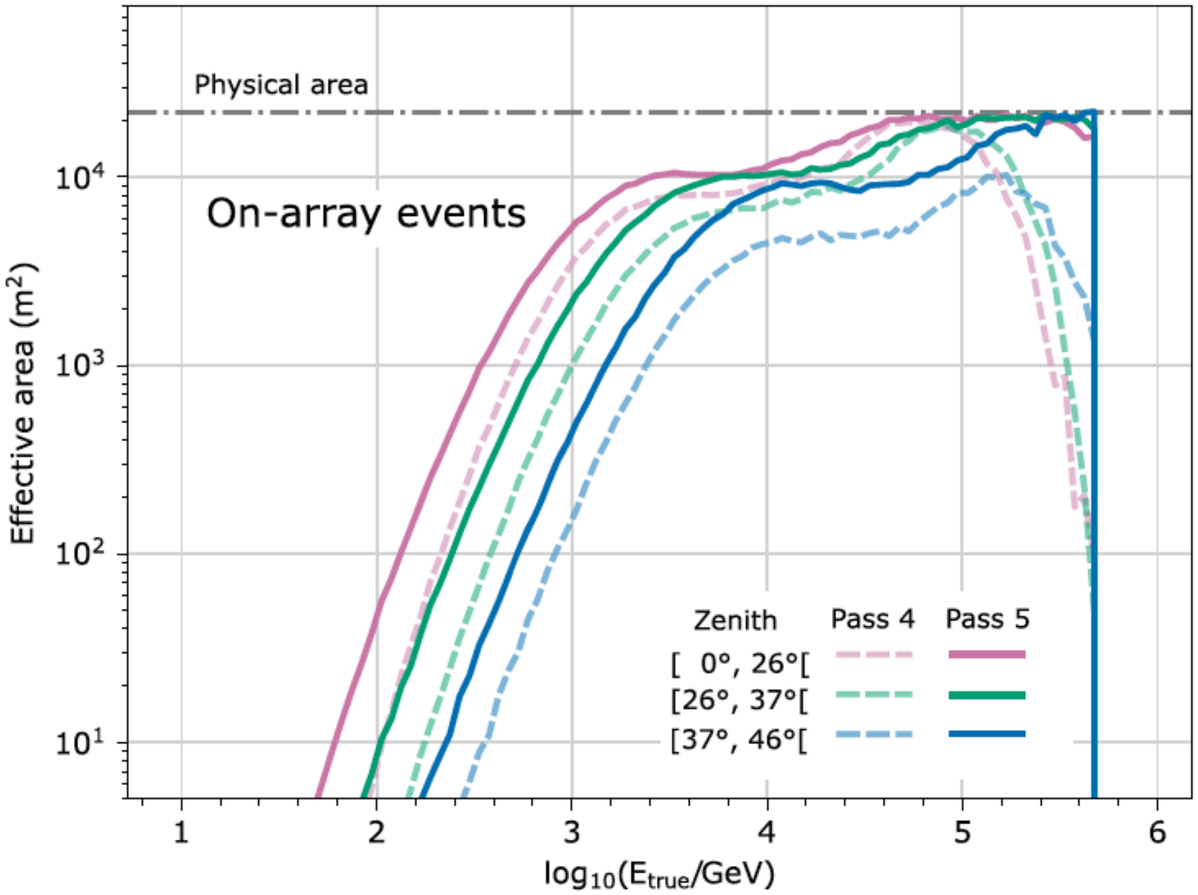
Figure 12. Significance map above 56 TeV in reconstructed energy for the GP (left) and NN (right). The maximum significance is 11.2σ for the GP and 11.6σ for the NN. Both significance maps have been smoothed for presentation purposes.

→ HAWC validation (ApJ 843, 13, 2017)

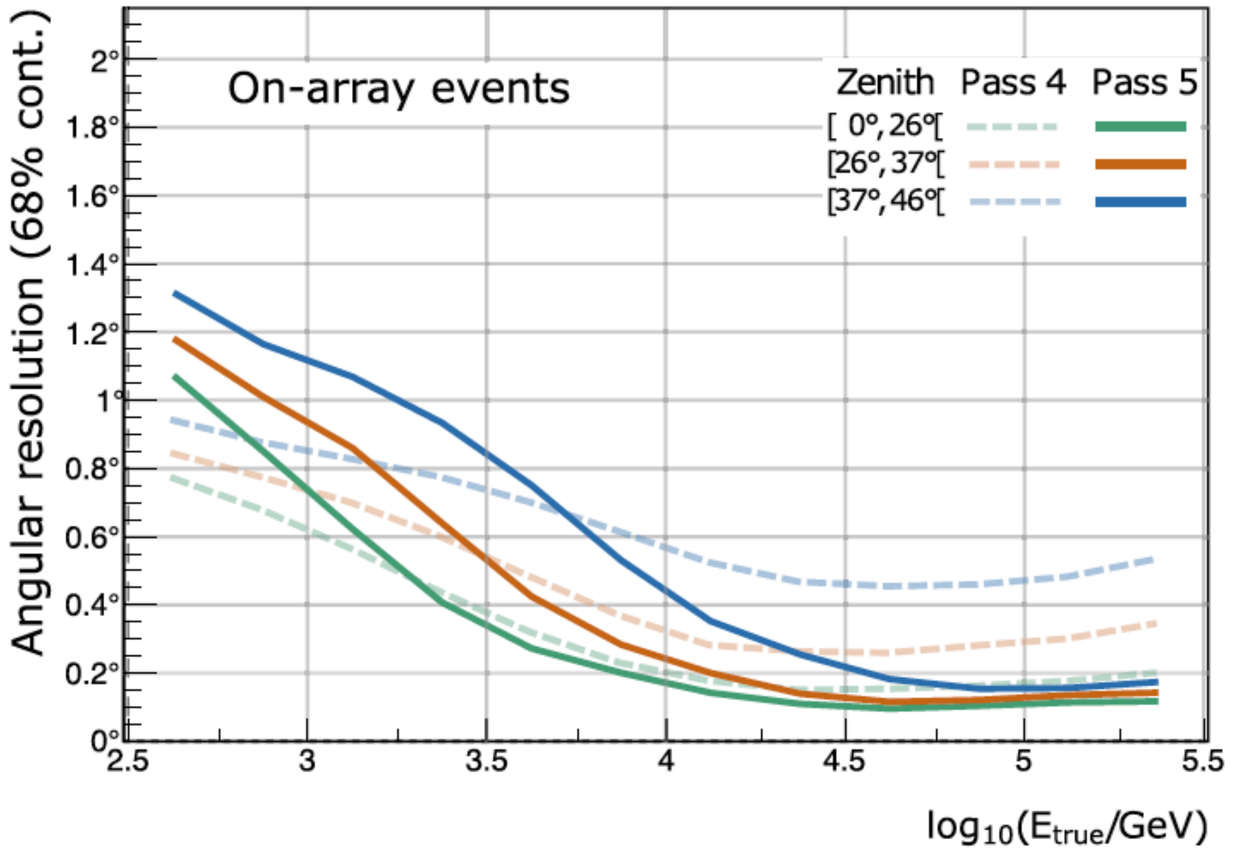
→ Energy estimators - Pass 4 (ApJ 881, 134, 2019)

→ Pass 5 (ApJ 972, 144, 2024)

HAWC performance



(b) Gamma/hadron cuts



Pass 5 Crab validation -
Albert et al. (ApJ 972, 144, 2024)

3HWC → 4HWC (Alfaro et al. ArXiV 2602.00263)

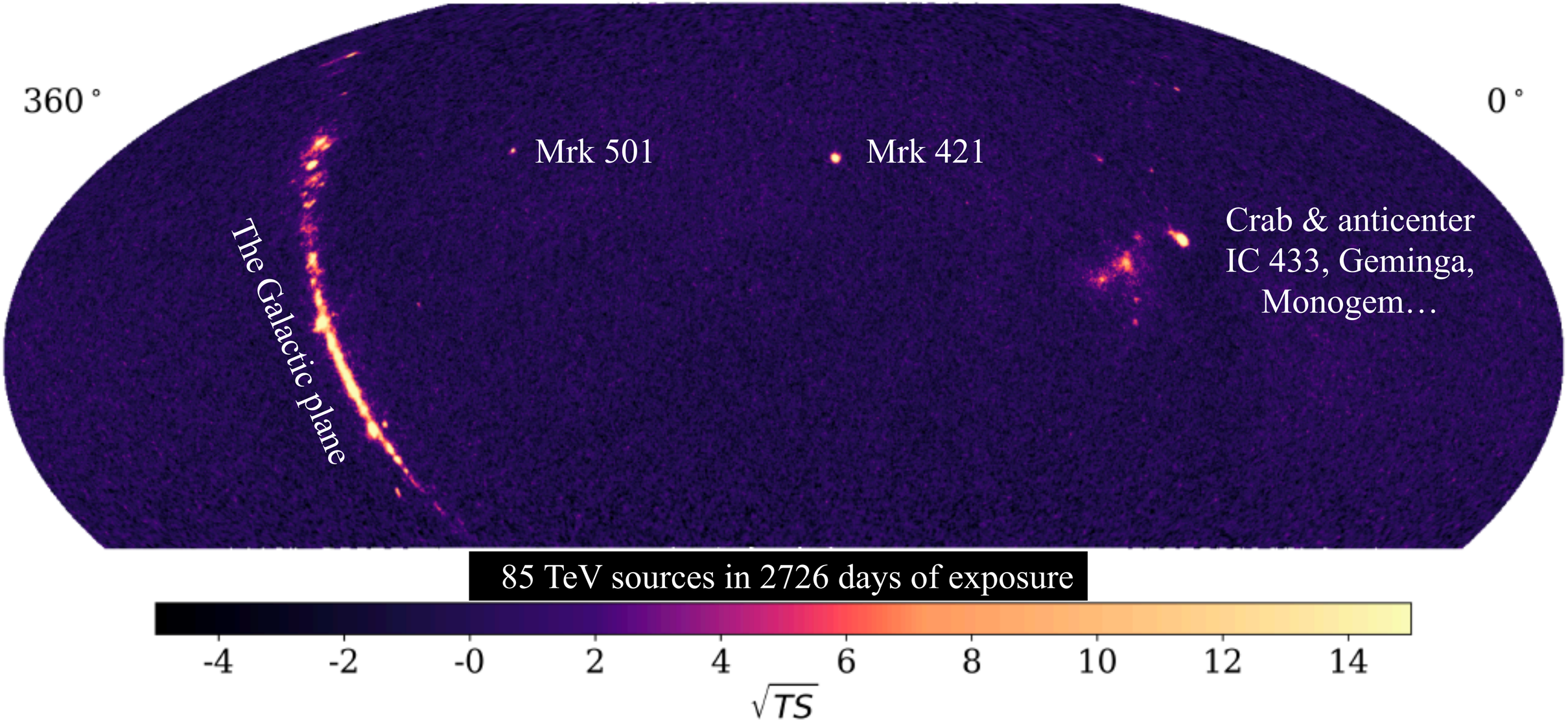


Figure 1. The full all-sky significance map from the HAWC map used to create the 4HWC catalog. This map is in celestial coordinates, and the significance shown is calculated using a point-source assumption with a fixed −2.6 power-law index.

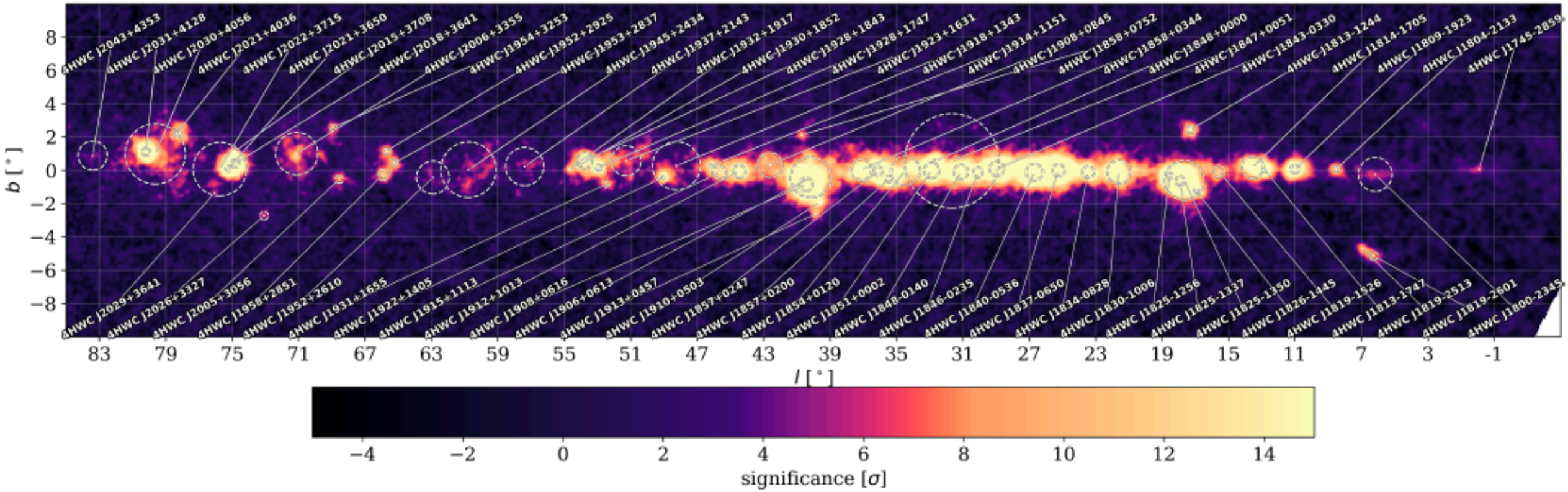


Figure 2. The inner Galactic Plane from the 4HWC catalog (paper to be submitted). The source locations and sizes are labeled. Dashed circle size corresponds to the 1σ width of the symmetric Gaussian model, where applicable.

Pass 5 has allowed the detection of sources with culmination zenith angles > 45º.

Galactic Center PeVatron

- Previously observed up to 20 TeV by H.E.S.S. (2016): Sgr A✶ & HESS J1746-285 (Galactic radio arc).
- Culminates at 48º for HAWC
  - Pass 5!!
- HAWC J1746-2856 detected at 6.5σ, at 6-114 TeV, with 2546 days of data.

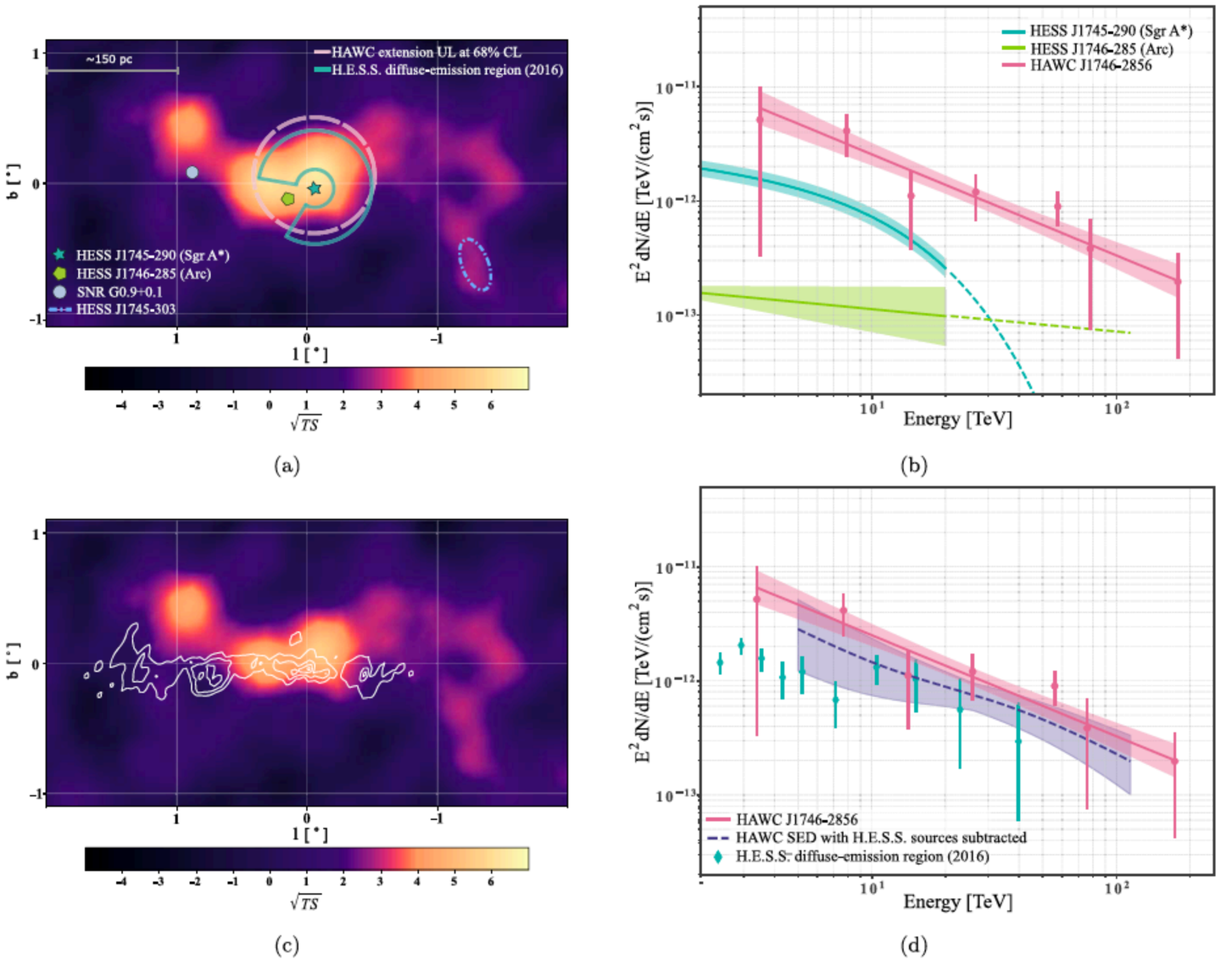


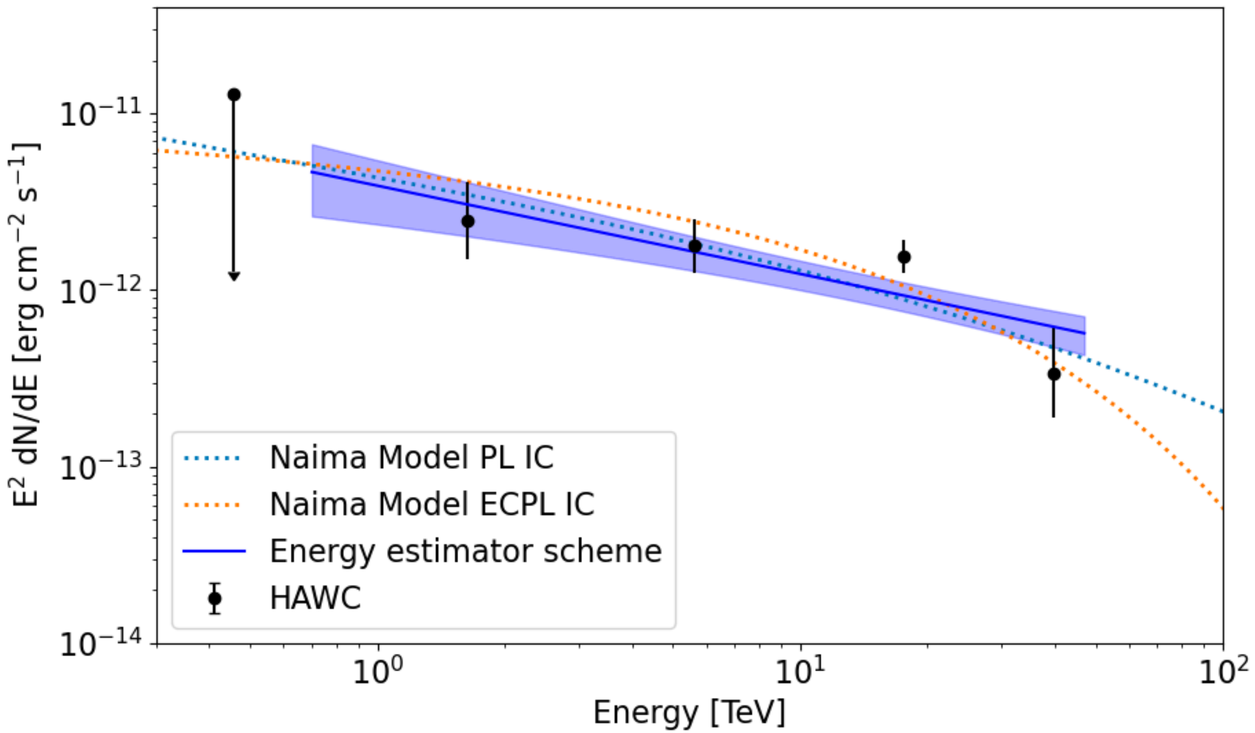
Figure 1. GC analysis results. (a) Significance map obtained using the HAWC neural network energy estimator (on- and off-array events; A. U. Abeysekara et al. 2019) and the position of the three main point sources and one extended source in the GC region as measured by H.E.S.S.. The dashed circle outlines the extension UL at the 68% CL. We also include the diffuse region used in the H.E.S.S. analysis (H.E.S.S. Collaboration et al. 2016). (b) Spectra of the two H.E.S.S. sources, along with the best-fit spectrum of HAWC J1746-2856. The dashed lines for the H.E.S.S. sources show the extrapolation of their best fit to the HAWC energy

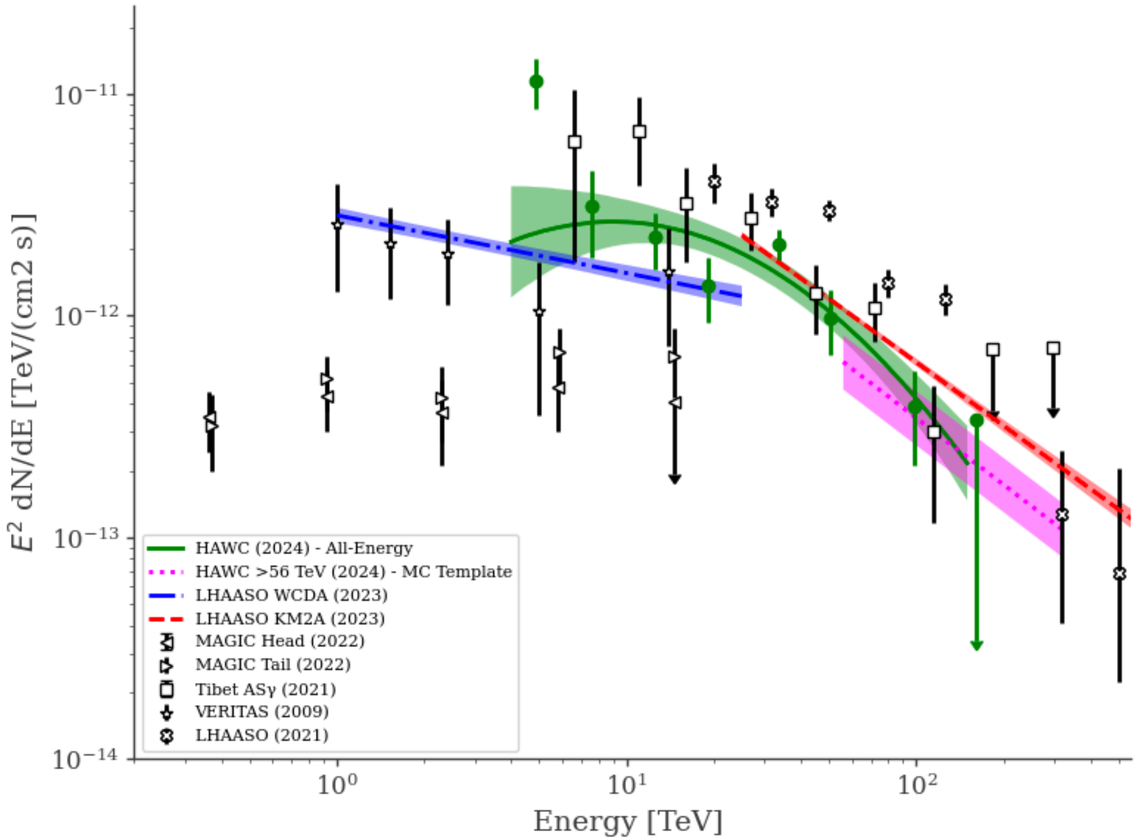
Supernovae and pulsars

- Fermi (1949) proved that shocks can produce high energy particles with a power-law energy distribution. Supernova remnants meet easily the energetics with predicted spectral index 2 (Fermi 1954).
  - Fermi didn't live enough to see the discovery of neutron stars…
- **SNR:** IC 433 (up to 30 TeV); SNR G106.3+2.7 (beyond 100 TeV); SNR G40.5-0.5 and HAWC J1907+063 (Pevatron); HESS J1809-193 (Pevatron) next to SNR G11.1+0.1 and G11.0-0.0; HAWC J1844-034 with PSR J1844-0346 and SNR G28.6-0.1; γ Cygni.
- **PWN:** leptonic? hadronic? Young to middle-aged, composite… Boomerang G106.3+2.7 & PSR J2229+6114 (LAT, VERITAS, MAGIC, HAWC, Tibet ASg and LHAASO); HAWC J2006+341 (Cygnus region), HAWC J2031+415; G32.64+0.53.
- **TeV halos!**

Supernova remnants

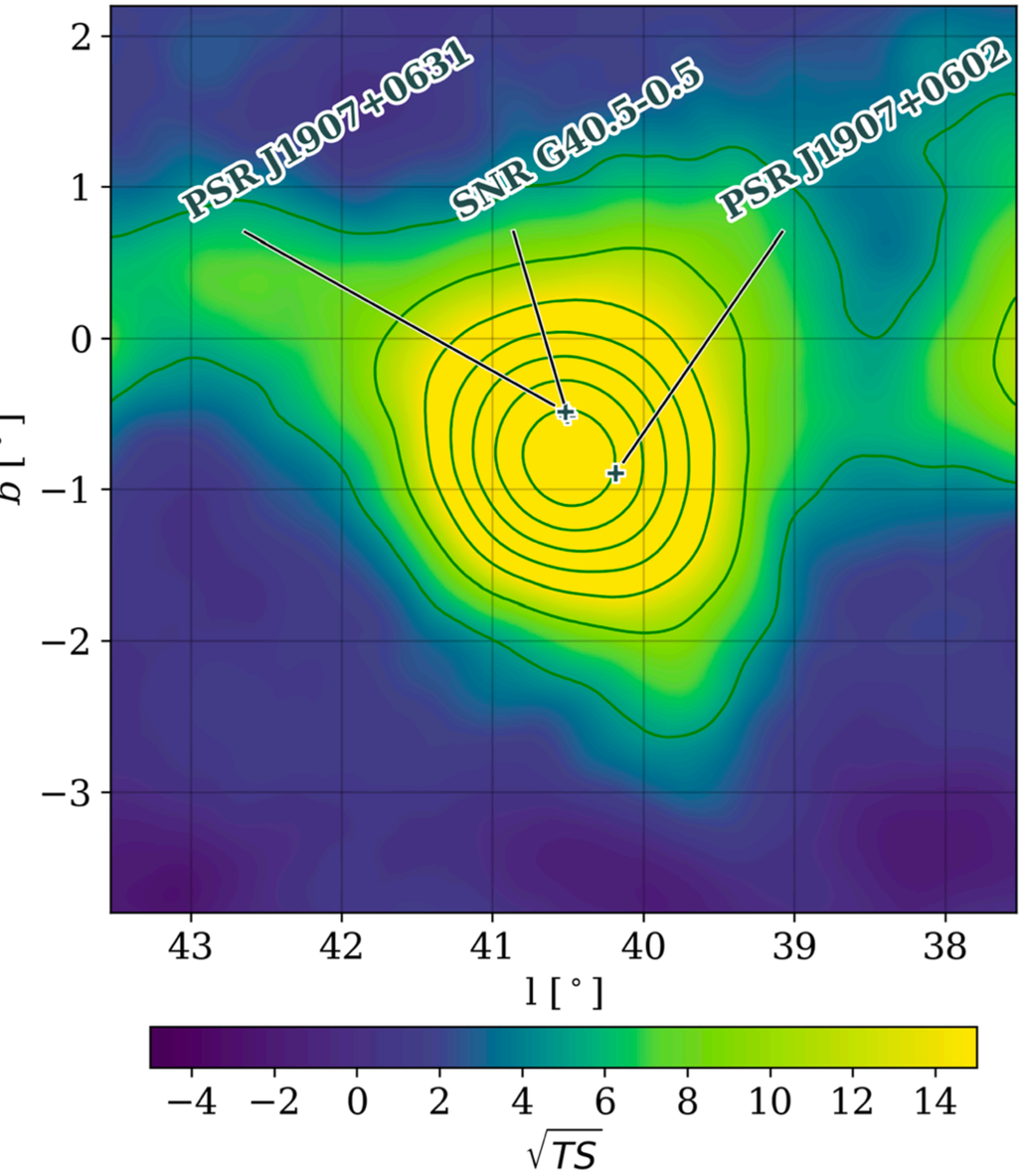
IC 433 (Alfaro et al. ApJ 992, 22, 2025)



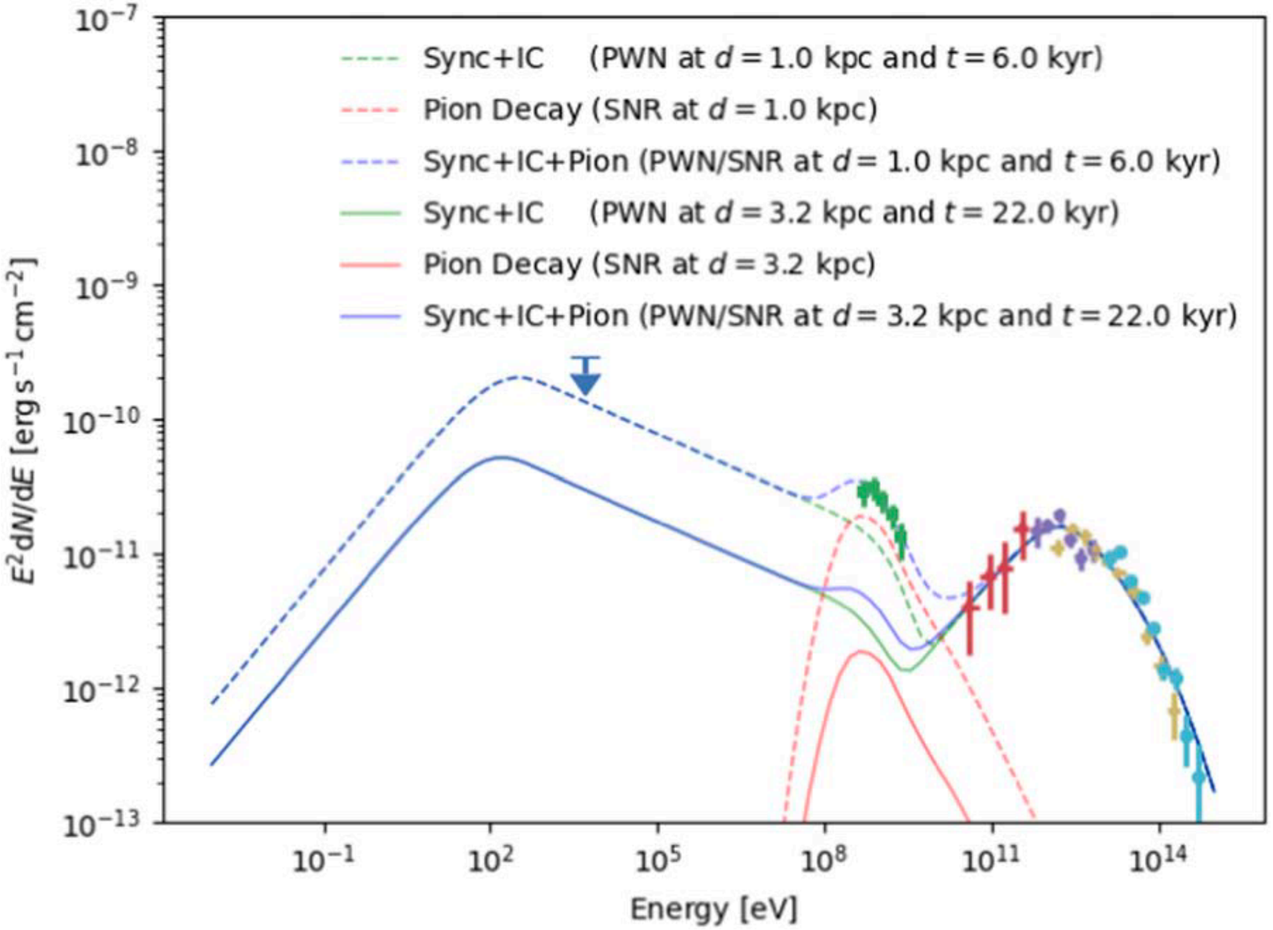


Boomerang: SNR, molecular cloud & PWN system SNR G106.3+2.7 and PSR J2229+6114 (Alfaro et al. A&A 691, A89, 2024).

PWNe



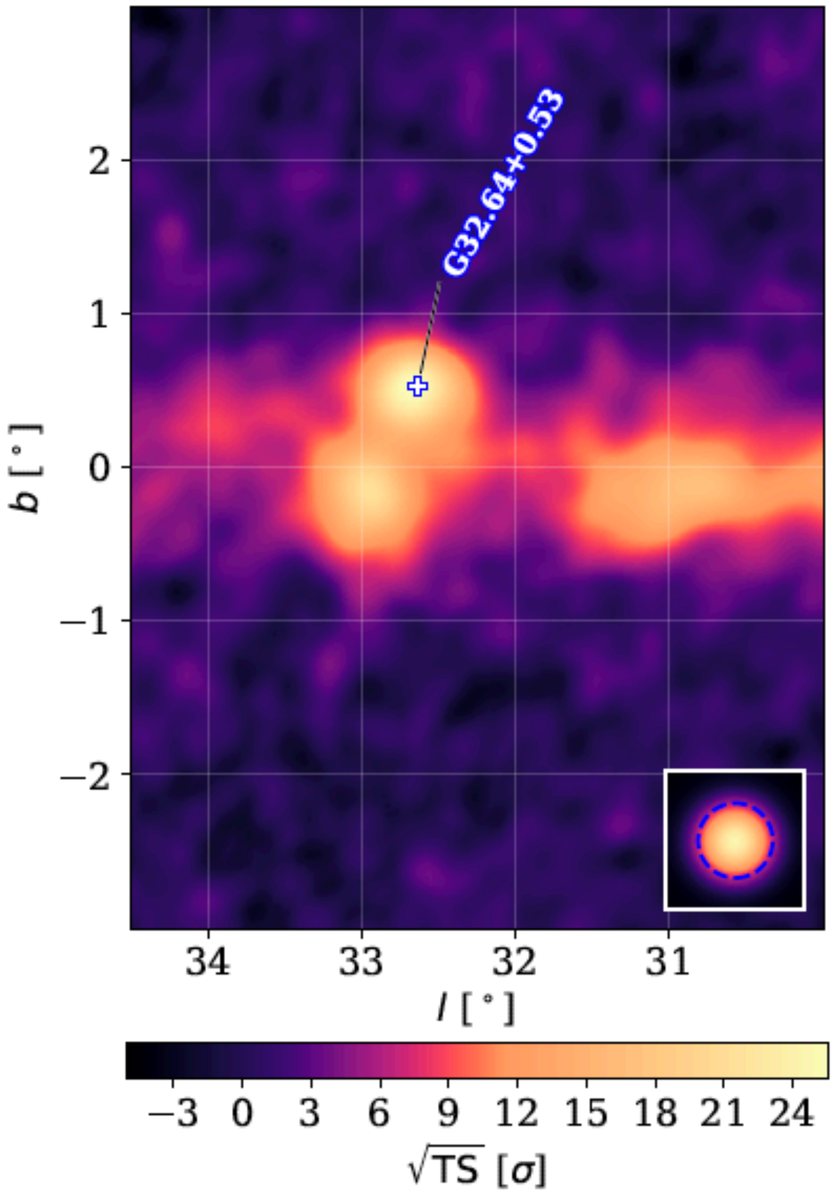
MGRO J1908+06 with HAWC
Albert et al. ApJ 928, 116, 2022

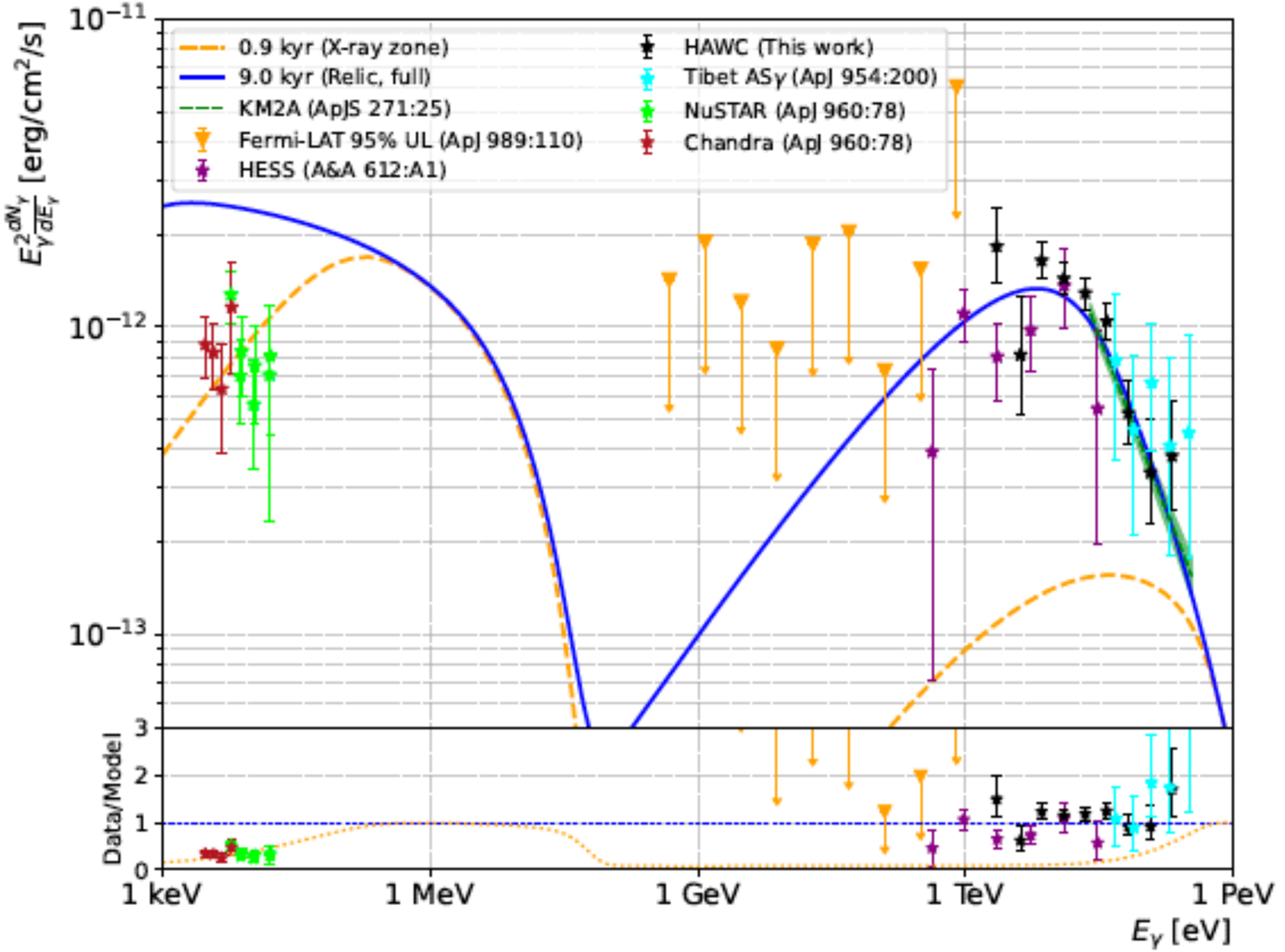


MGRO J1908+06 Fermi-LAT, VERITAS & HAWC
Acharyya et al. ApJ 974, 61, 2024

THE ASTROPHYSICAL JOURNAL, 1009:47 (11pp), 2026 September 20

eHWC J1850+001 → PSR J1849-0001 & G32.64+0.53





Two zone leptonic model (Alfaro et al. ApJ 1009, 47, 2026)

TeV halos

- Geminga and Monogem: further observations (Albert et al. ApJ 974, 246, 2024);
  - x-ray extension around B0656+14 with eROSITA (Niu et al. ApJ 997, 324).
- “Extended TeV halos may commonly exist around middle-aged pulsars” (Albert et al. PRL 134, 1005, 2025);
  - Stacking analysis around 36 pulsars
- But… “Absence around ms pulsars” (Abeysekara PRD 111, 3014, 2025); limits on the spider ms-pulsar (Alfaro et al. PRD 113, 3016, 2026).
- Constrains on the TeV halo pop of M31 (Andrés et al.; ICRC 2024).

TeV halos

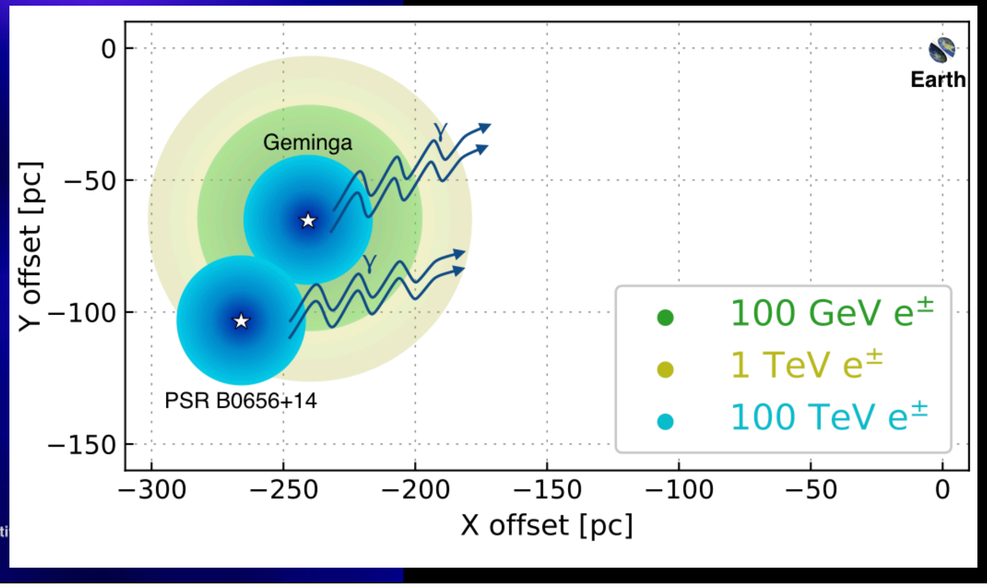
La Luna (misma escala)

Geminga

PSR B0656+14

Abeysekara et al.
Science 358, 911 (2017)

Slow diffusion of TeV $e^{\pm}$ around middle aged pulsars



“Precise Measurements of TeV Halos around Geminga and Monogem Pulsars with HAWC”

THE ASTROPHYSICAL JOURNAL, 974:246 (13pp), 2024 October 20

Albert et al.

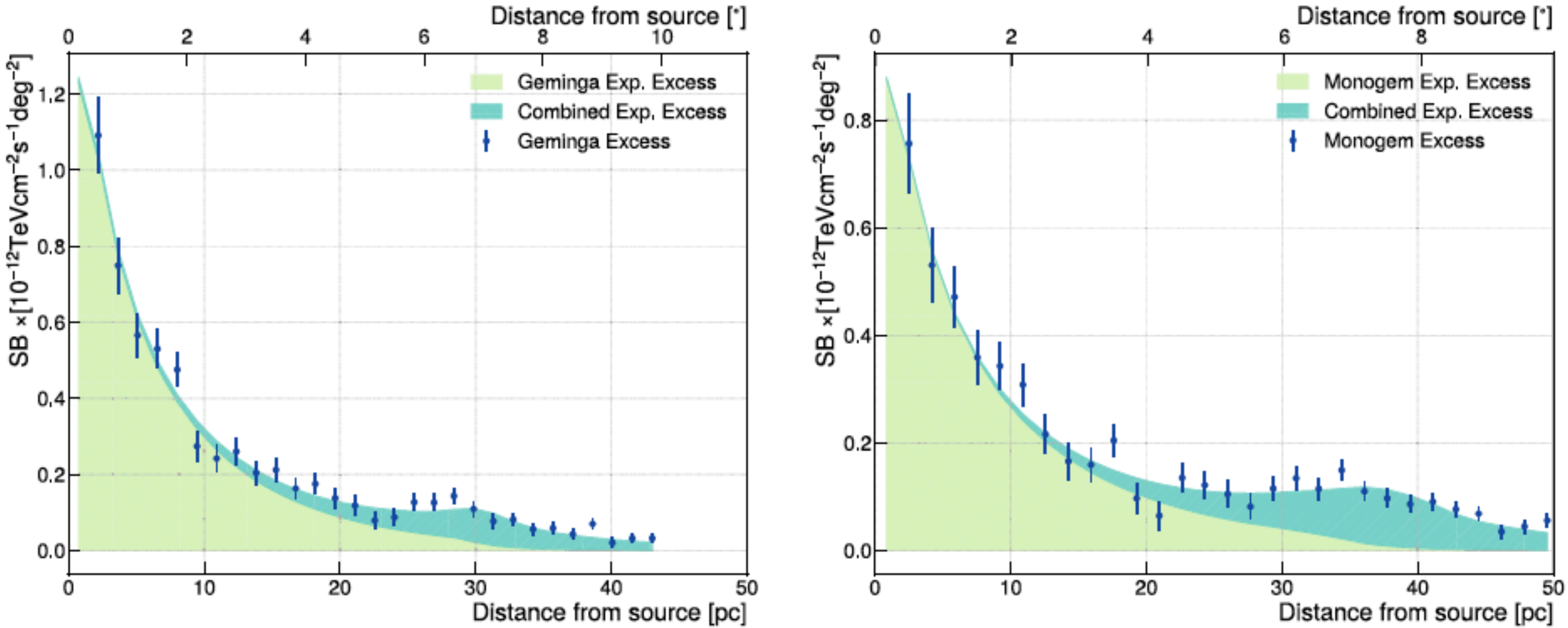
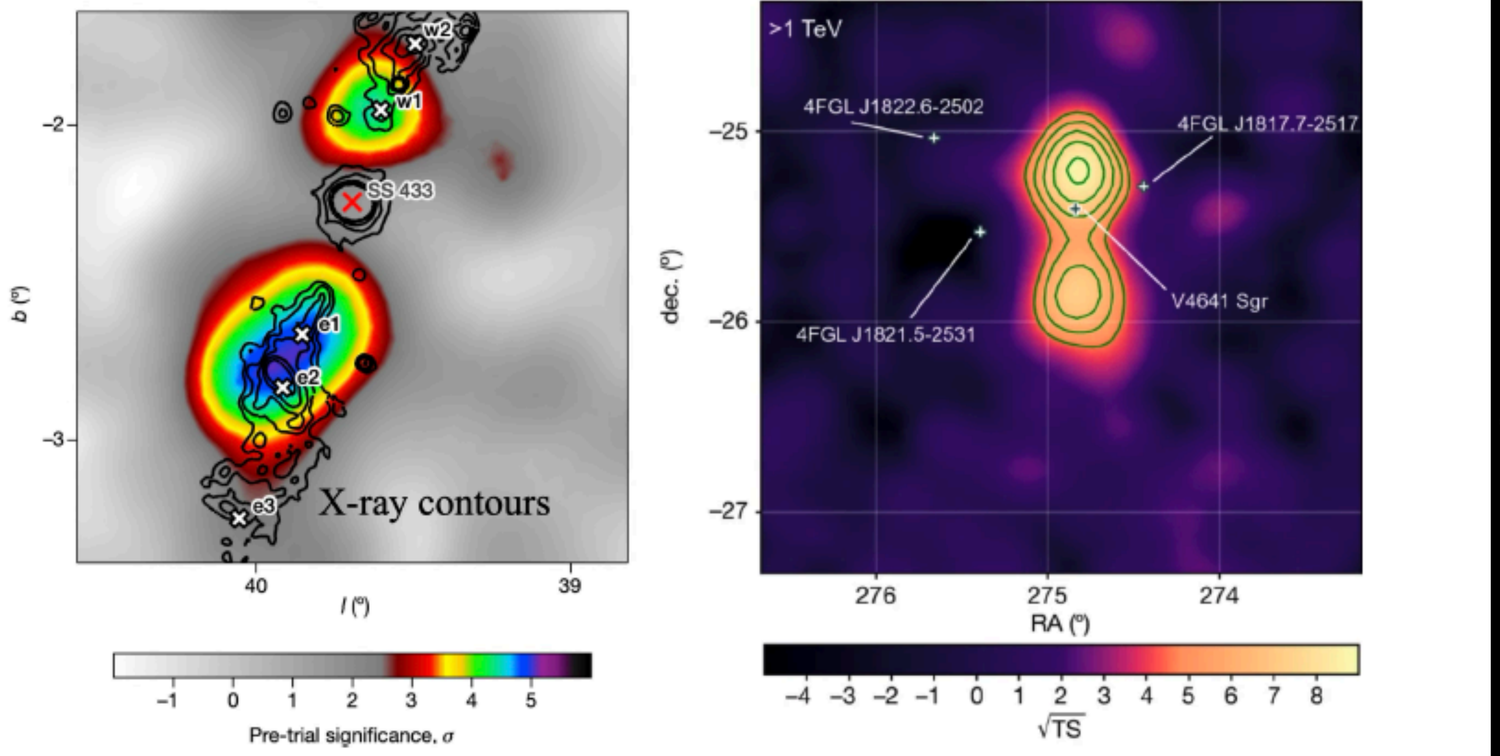


Figure 5. Surface brightness profiles of multi-TeV γ-ray emission in units of TeV cm^{-2} s^{-1} deg^{-2} as a function of distance for Geminga (left panel) and Monogem (right panel) for energy range of 5.4 to 68 TeV. The green color band shows the individual emission and the blue band shows the excess emission from its neighboring source.

Microquasars

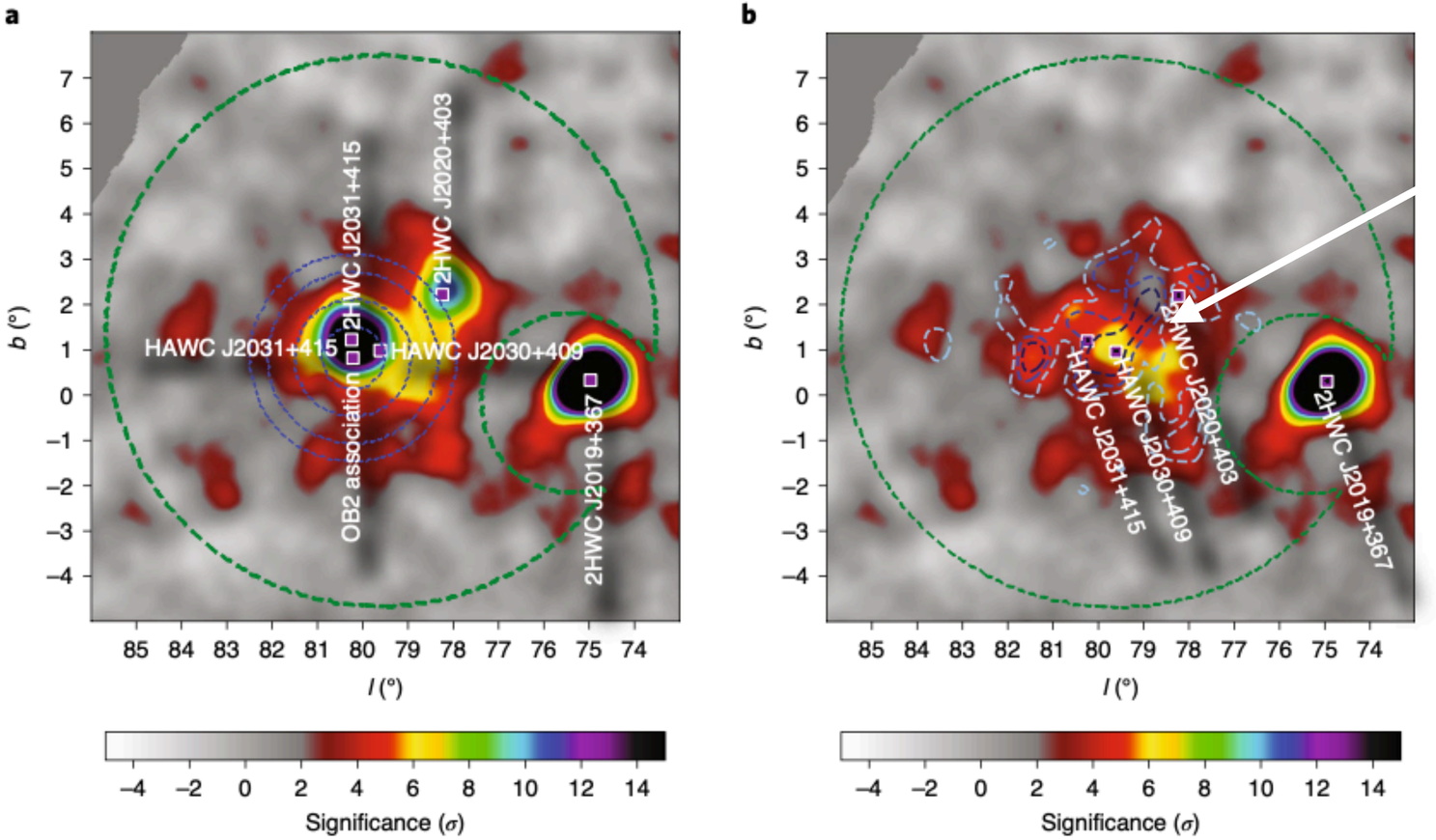


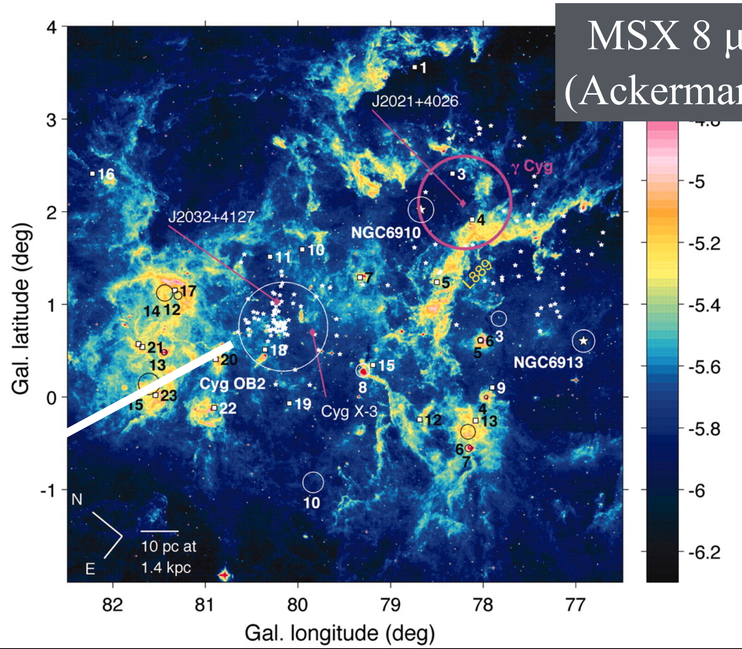
Left Panel: The HAWC TeV image of the SS 433/W50 region in Galactic coordinates, reproduced from Abeysekara & HA
tion (2018) Nature, Volume 562, Issue 7725, p.82–85, 2018, Springer Nature. The statistical significance in the color sc
ed before accounting for statistical trials. The gamma-ray excess in SS 433 was measured after fitting and subtracting

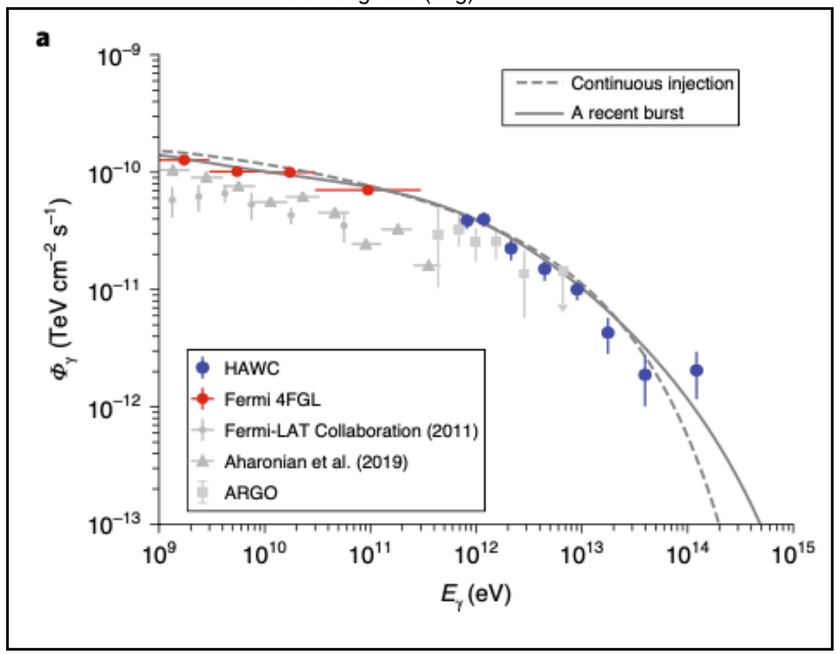
- SS 433: spectral studies; above 120 TeV (ApJ 2024).
- LS 5039 up to 200 TeV and orbital modulation (Alfaro et al. 2025).
- V4641 Sgr (bubble beyond 200 TeV; leptonic/hadronic? Nature 2024);
  - recent X-ray jets by XMM (arxiv 2610.02966)

The Cygnus Cocoon

> 100 TeV gamma-rays in high-mass **star forming region**



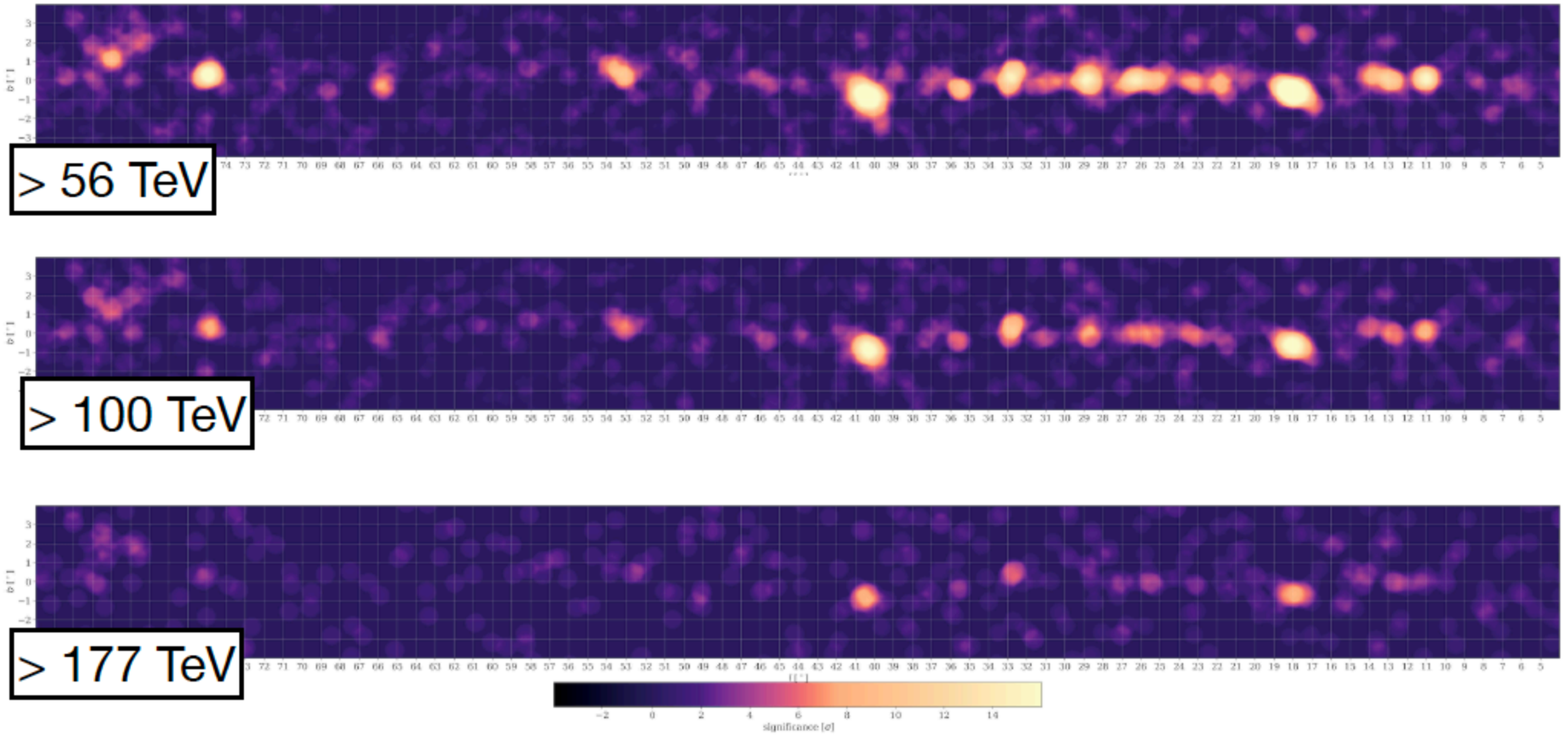




Abeysekara et al., Nature Astron. 5, 465 (2021).

HAWC's UHE catalog today: ~2800 days of data

- With more data and updated algorithms, we now detect ~30 sources > 56 TeV, ~15 of which extend above 100 TeV and ~3 extend above 177 TeV (paper in progress, preliminary results presented at ICRC last year)
- More classes of sources than previously thought extend to high energies



1eHWC (Abeysekara et al. 2020) → Malone - Tevpa 2024 → 2 eHWC

Active galaxies: the Markarians and beyond

The first 10 years of the HAWC Gamma-Ray Observatory: science results — HAWC Collaboration

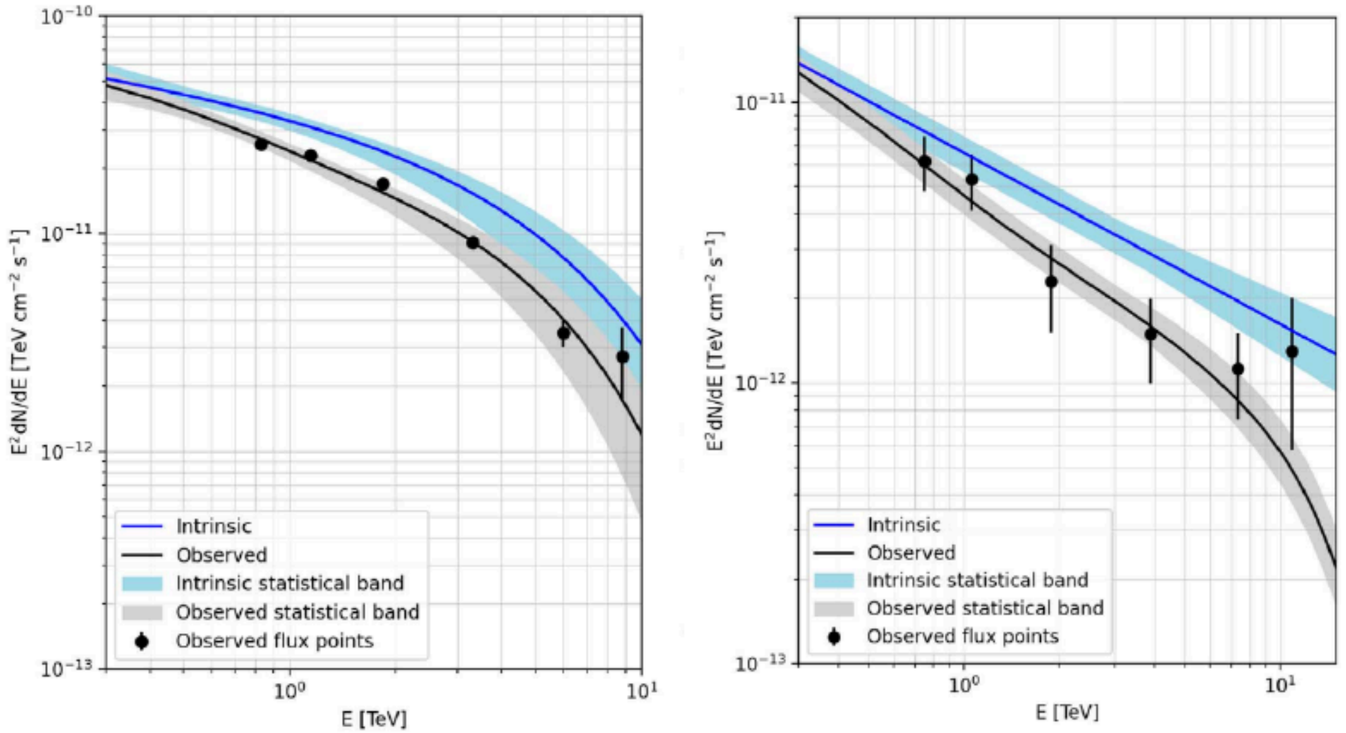
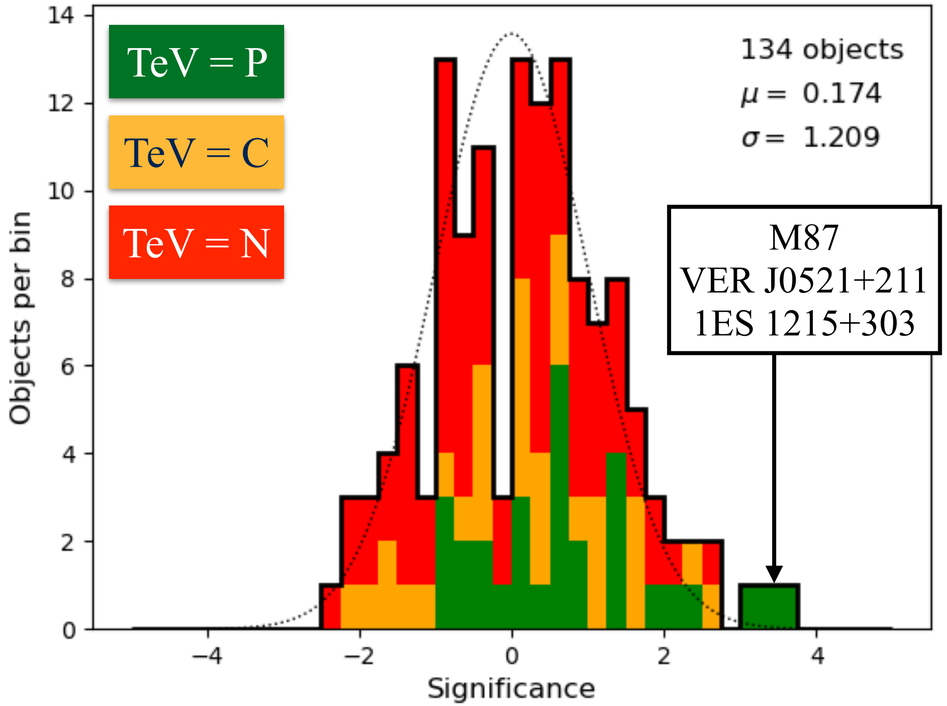


Figure 8. HAWC spectra of the blazars Mrk 421 (**left**) and Mrk 501 (**right**), ©AAS. Reproduced with permission from Albert et al. (2022a). Black circles indicate the observed flux points. The blue and black lines mark, respectively, the intrinsic and observed spectra with their statistical uncertainties in corresponding colors.



Albert et al. (2021; ApJ 907, 67)

Pos (ICRC 2023) 805

Detections ($> 5\sigma$)	TS	Marginal detections ($3\sigma - 5\sigma$)	TS
BL Lac objects:		**BL Lac objects**:	
Mrk 421	10265.12	ZS 0214+083	14.28
Mrk 501	558.08	PKS 0422+00	9.90
1ES 1215+303	26.28	VER J0521+211	16.32
Radio Galaxies:		RX J0648.7+1516	11.78
M87	29.87	RX J1100.3+4019	13.54
		PG 1218+304	23.72
		W Comae	10.08
		Radio Galaxies:	
		3C 264	9.56

Table 1: AGNs in our sample with $TS > 9$ in the $\alpha = 2.5$ study.

Table 1. List of objects above the detection threshold.

H.E.S.S. name	Association	RA	Dec	Type	Redshift	Reference
HESS J0013-189	SHBL J001355.9-185406	$00^h\,13^m\,56.04^s$	$-18°\,54'\,06.7''$	BL Lac / HSP	0.095	1
HESS J0047-253	NGC 253	$00^h\,47^m\,33.13^s$	$-25°\,17'\,19.7''$	Starburst	0.000864	2,3
HESS J0152+017	RGB J0152+017	$01^h\,52^m\,39.61^s$	$+01°\,47'\,17.4''$	BL Lac / HSP	0.080	4
HESS J0232+202	1ES 0229+200	$02^h\,32^m\,48.61^s$	$+20°\,17'\,17.5''$	BL Lac / HSP	0.140	5
HESS J0303-241	PKS 0301-243	$03^h\,03^m\,26.50^s$	$-24°\,07'\,11.4''$	BL Lac / HSP	0.266	6
HESS J0349-119	1ES 0347-121	$03^h\,49^m\,23.19^s$	$-11°\,59'\,27.4''$	BL Lac / HSP	0.188	7
HESS J0416+010	1ES 0414+009	$04^h\,16^m\,52.49^s$	$+01°\,05'\,23.9''$	BL Lac / HSP	0.287	8
HESS J0449-438	PKS 0447-439	$04^h\,49^m\,24.70^s$	$-43°\,50'\,09.0''$	BL Lac / HSP	0.343	9
HESS J0550-322	PKS 0548-322	$05^h\,50^m\,40.57^s$	$-32°\,16'\,16.5''$	BL Lac / -	0.069	10
HESS J0627-354	PKS 0625-354	$06^h\,27^m\,06.73^s$	$-35°\,29'\,15.4''$	RG	0.055	11
HESS J1010-313	1RXS J101015.9-311909	$10^h\,10^m\,15.98^s$	$-31°\,19'\,08.4''$	BL Lac / HSP	0.143	12
HESS J1103-234	1ES 1101-232	$11^h\,03^m\,37.62^s$	$-23°\,29'\,31.2''$	BL Lac / HSP	0.186	13
HESS J1230+123	M 87	$12^h\,30^m\,49.42^s$	$+12°\,23'\,28.0''$	RG	0.0044	14,15
HESS J1315-426	1ES 1312-423	$13^h\,15^m\,03.39^s$	$-42°\,36'\,49.8''$	BL Lac / HSP	0.105	16
HESS J1325-430	Centaurus A	$13^h\,25^m\,27.62^s$	$-43°\,01'\,08.8''$	RG	0.00183	17,18
HESS J1444-391	PKS 1440-389	$14^h\,43^m\,57.20^s$	$-39°\,08'\,40.1''$	BL Lac / HSP	0.139	19
HESS J1512-090	PKS 1510-089	$15^h\,12^m\,50.53^s$	$-09°\,05'\,59.8''$	FSRQ/ LSP	0.361	20
HESS J1517-243	AP Librae	$15^h\,17^m\,41.81^s$	$-24°\,22'\,19.5''$	BL Lac / ISP	0.049	21
HESS J1555+111	PG 1553+113	$15^h\,55^m\,43.04^s$	$+11°\,11'\,24.4''$	BL Lac / HSP	0.433	22,23
HESS J2009-488	PKS 2005-489	$20^h\,09^m\,25.39^s$	$-48°\,49'\,53.7''$	BL Lac / HSP	0.071	24,25
HESS J2158-302	PKS 2155-304	$21^h\,58^m\,52.07^s$	$-30°\,13'\,32.1''$	BL Lac / HSP	0.117	26,27
HESS J2324-406	1ES 2322-409	$23^h\,24^m\,44.67^s$	$-40°\,40'\,49.4''$	BL Lac / HSP	0.174	28
HESS J2359-306	H 2356-309	$23^h\,59^m\,07.90^s$	$-30°\,37'\,40.7''$	BL Lac / HSP	0.165	

H.E.S.S. extragalactic survey (ArXiV 2504.21221)

The sky gets increasingly opaque with energy…

HAWC → SWGO

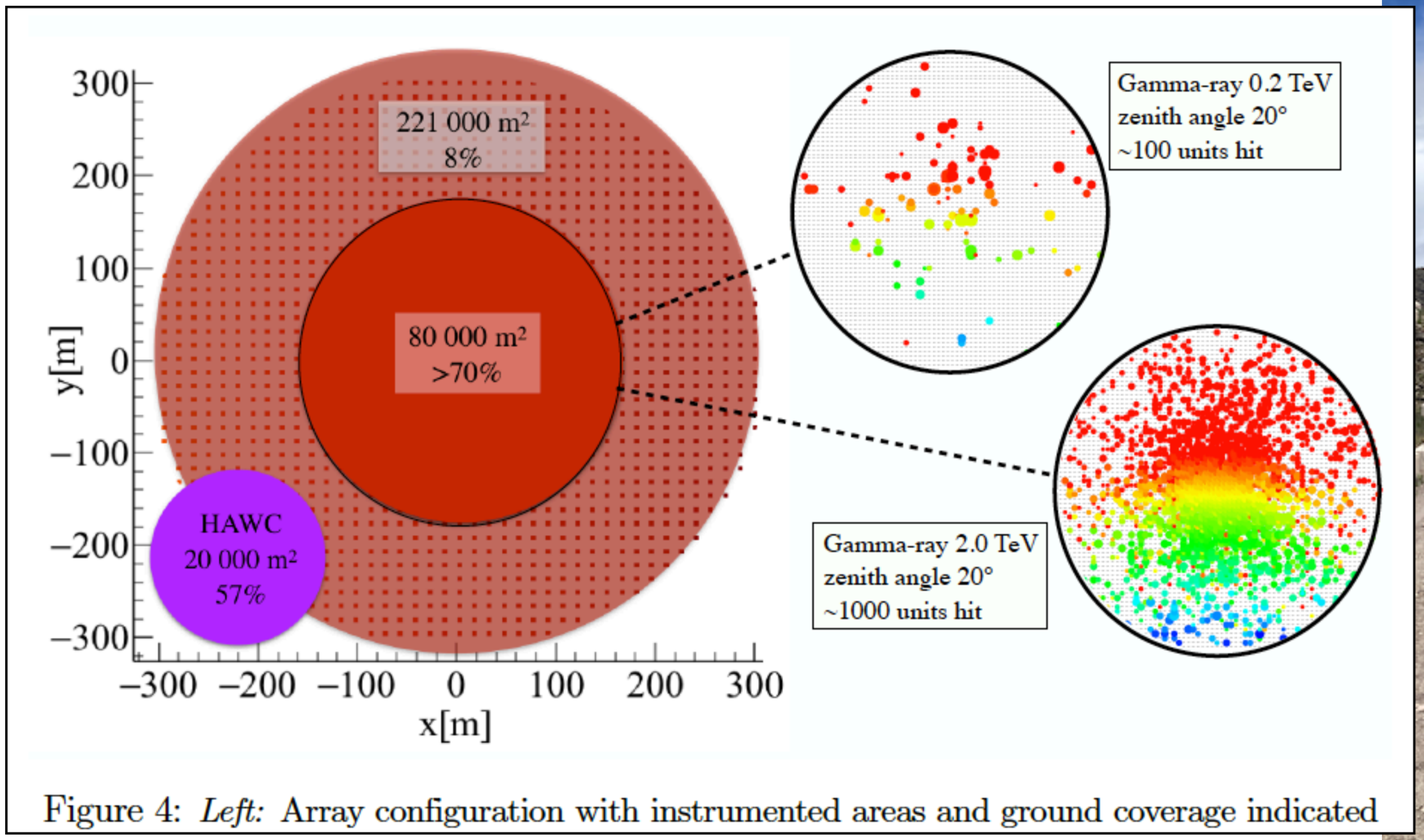


Figure 4: *Left:* Array configuration with instrumented areas and ground coverage indicated



Friday talk by Ibrahim Torres

If you don’t look, you don’t see!

