LAPP
Laboratoire d'Annecy de Physique des Particules

The gamma-ray sky at very high energy

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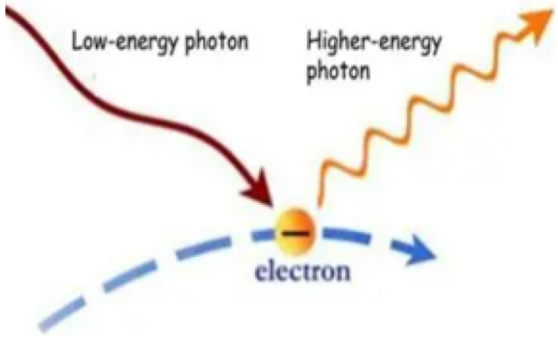
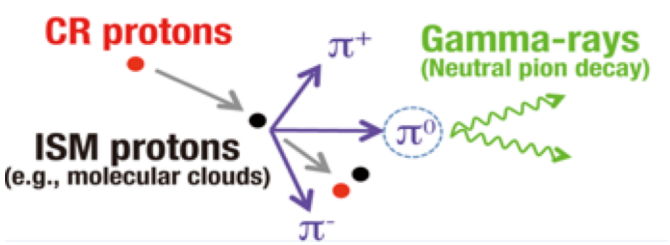
Why gamma-ray matters?

- Probe the most extreme non-thermal processes in the Universe.
- And reveals particle acceleration in action.
- Direct window on cosmic accelerators and fundamental physics.

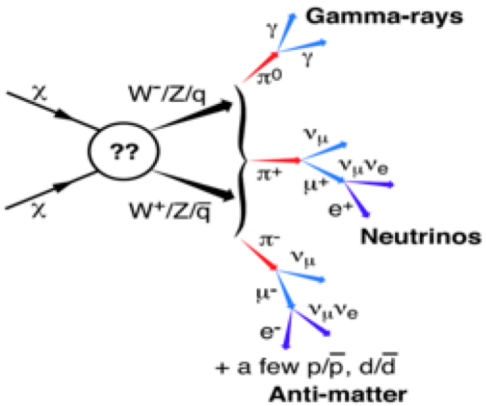
Leptonic origin



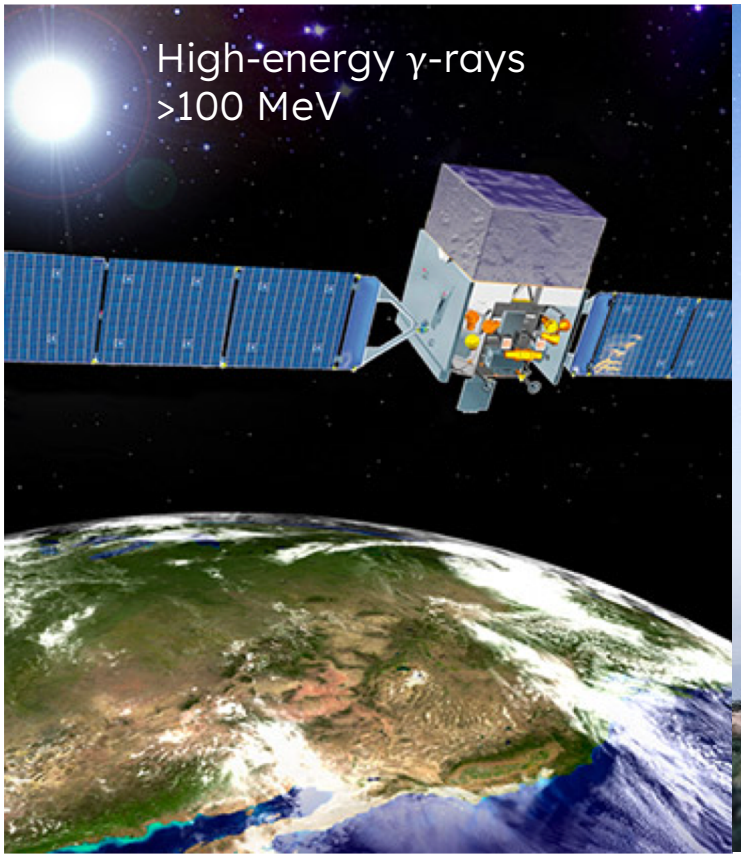
Hadronic origin

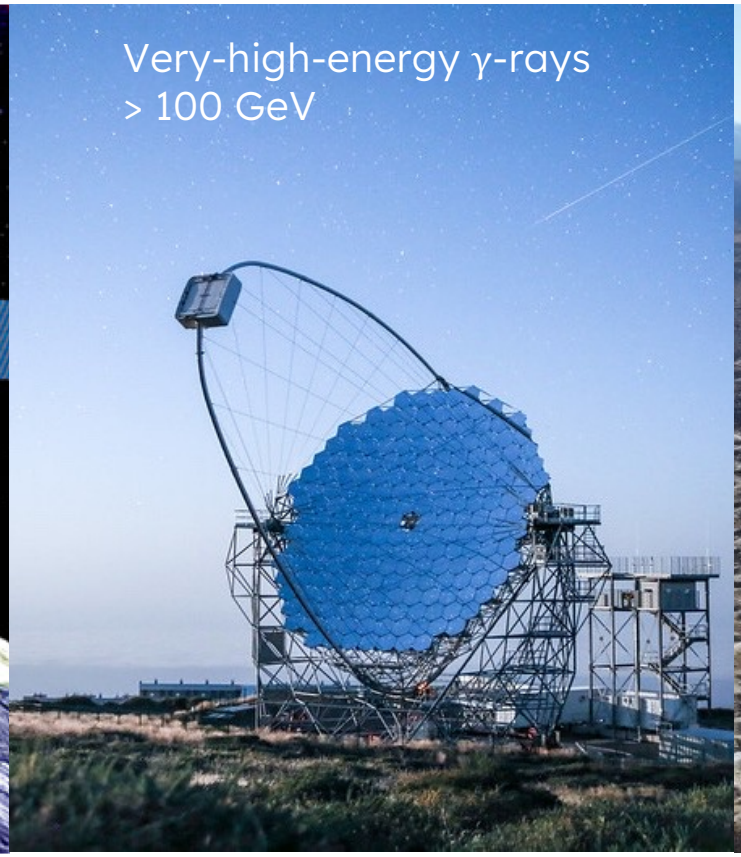


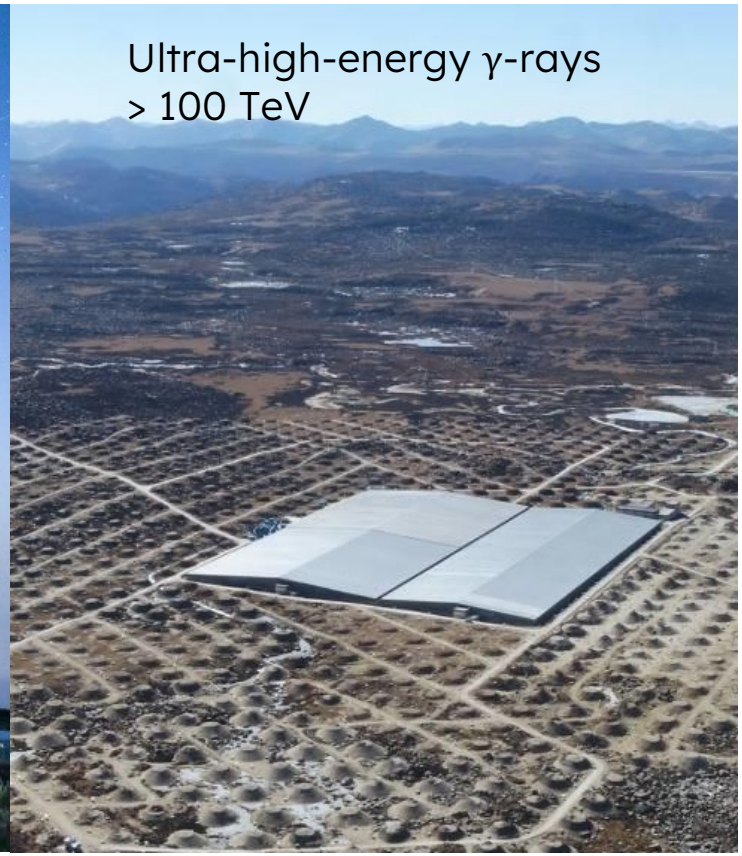
Exotic origin



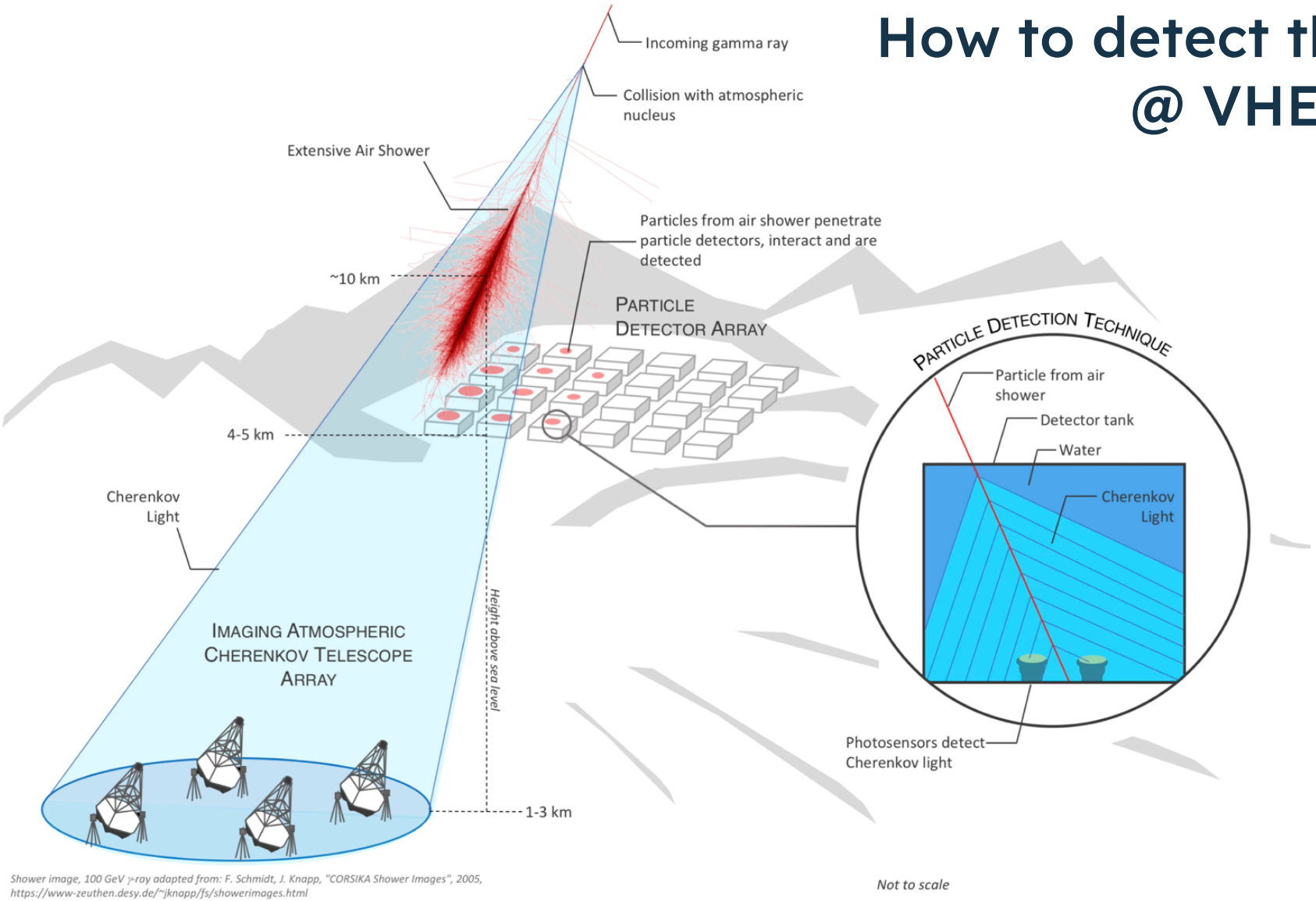
How to detect them ?





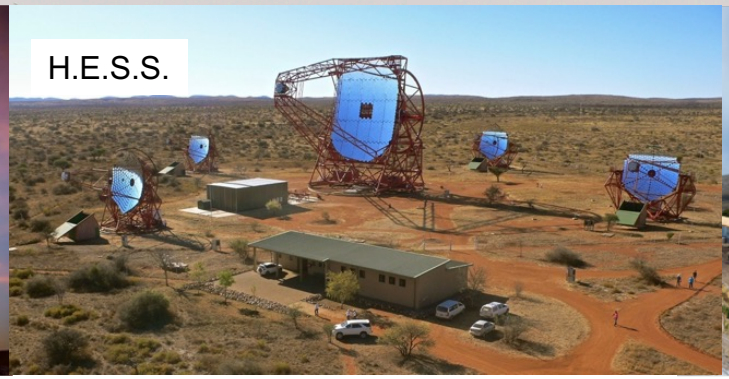


How to detect them ? @ VHE/UHE

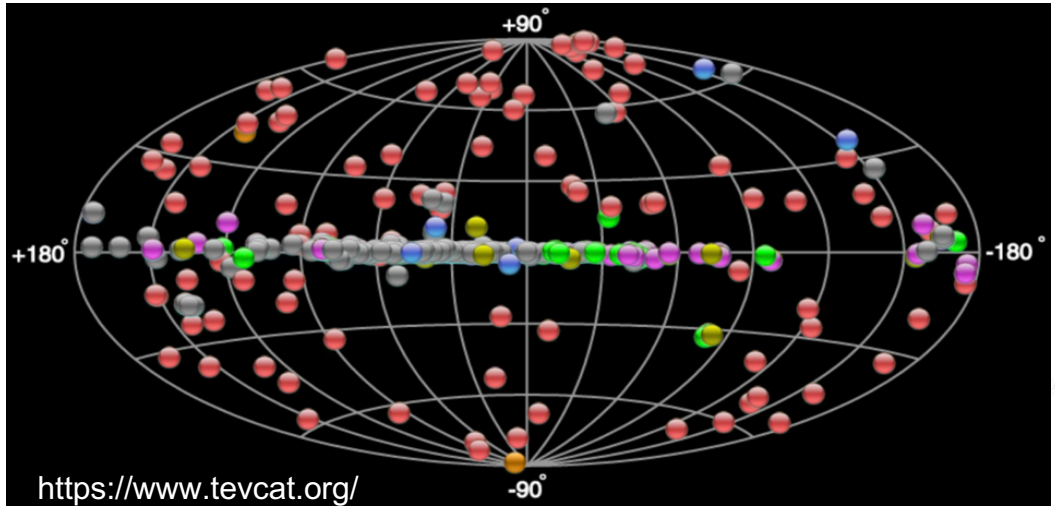


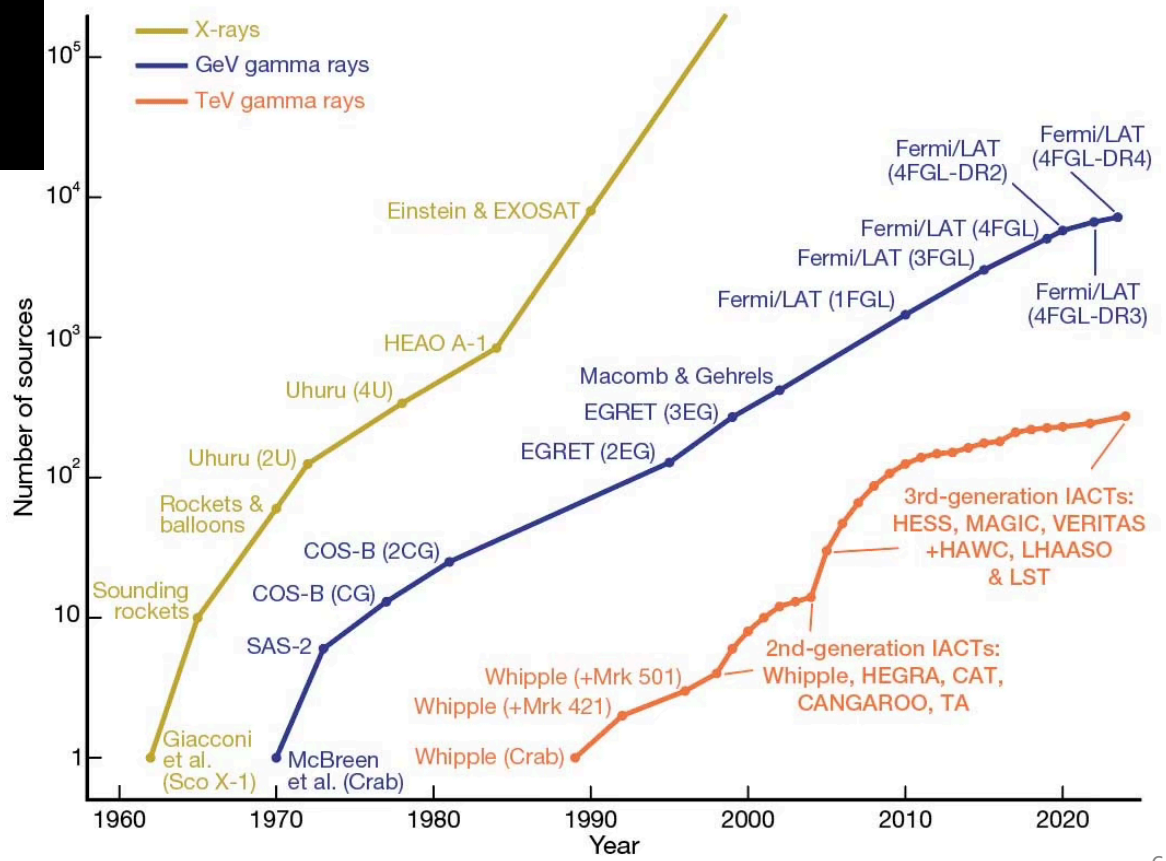
Schoorlemmer et al. 2019

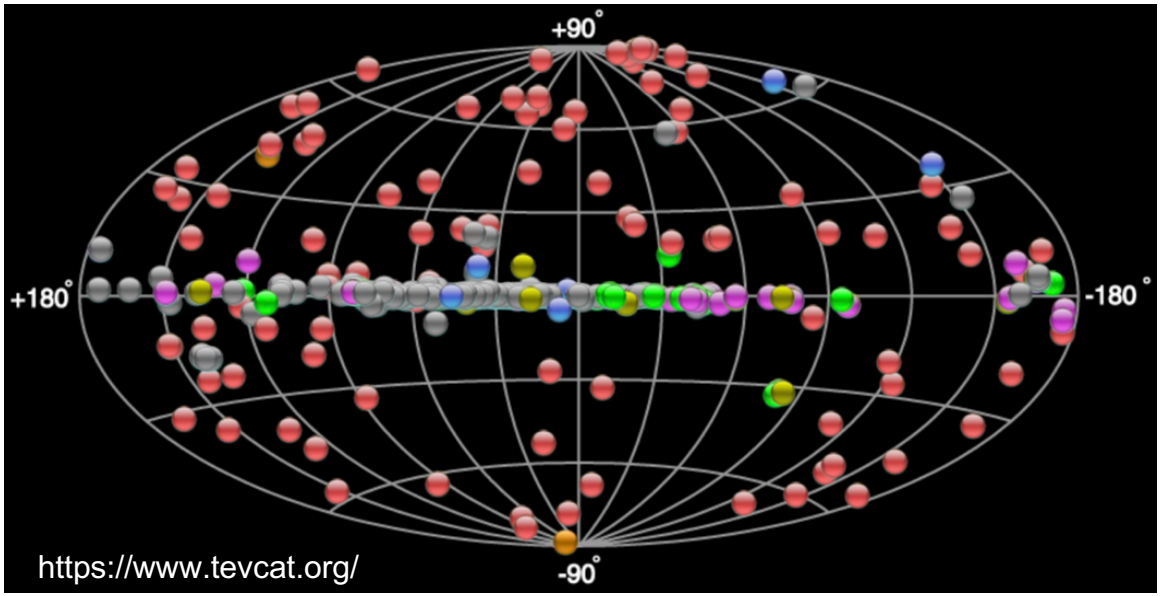
Current ground-based instruments



Is it successful?

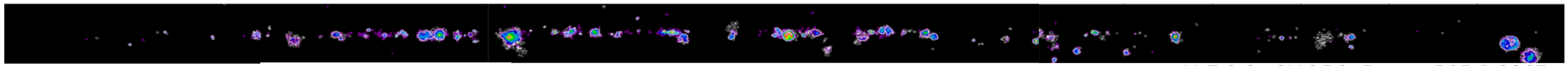






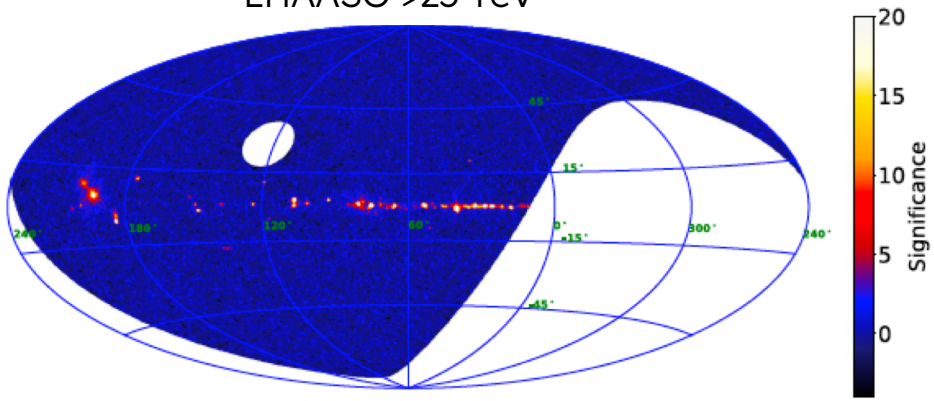
What do we observe?

- Galactic population growing steadily (SNRs, PWNe, binaries, SF regions).
- Extragalactic: mainly blazars, radio galaxies
- Rising number of transient detections.

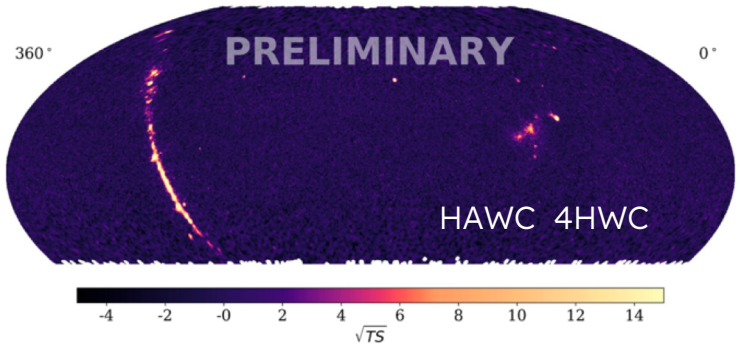


H.E.S.S., 2HGPS, Remy, ICRC 2023

LHAASO >25 TeV

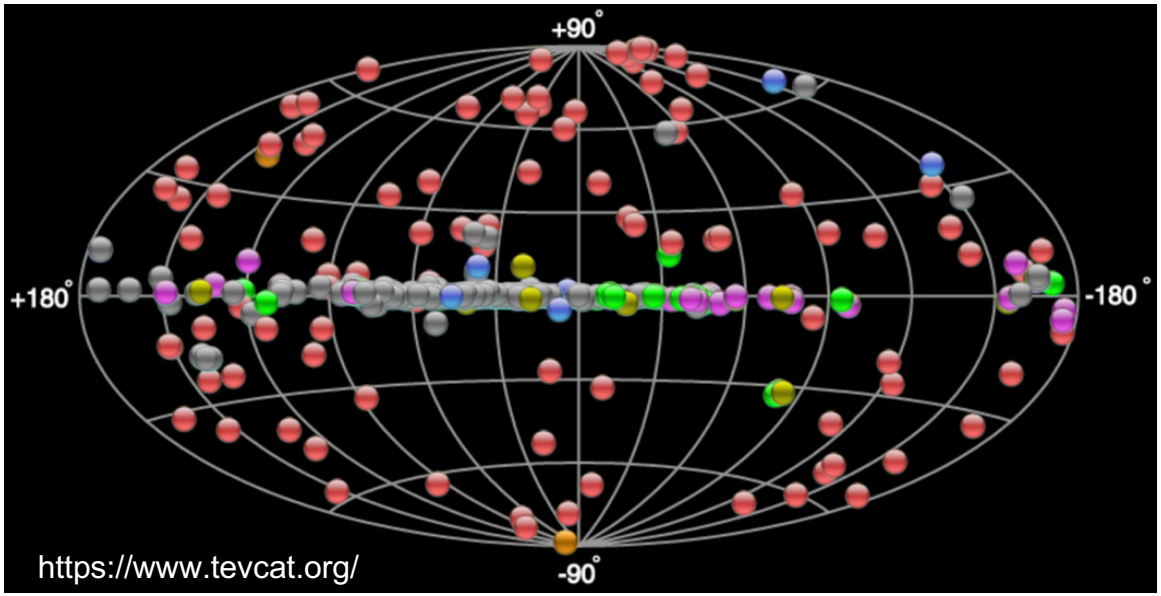


LHAASO 2024 ApJS 271 25

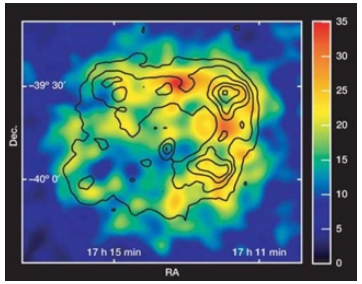


HAWC ICRC 2025

What do we observe?

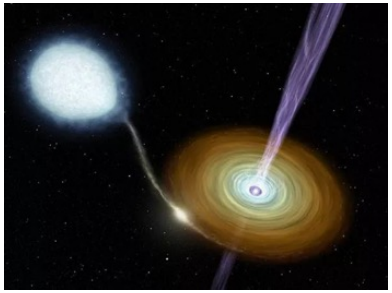


SNR

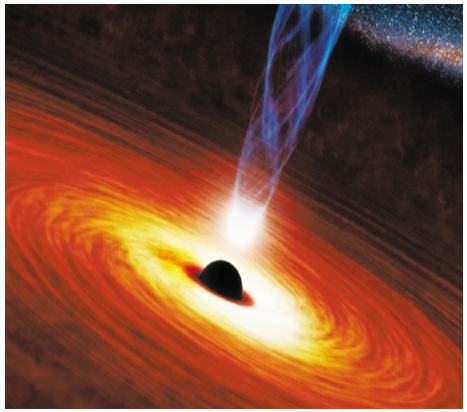


Pulsar and PWN

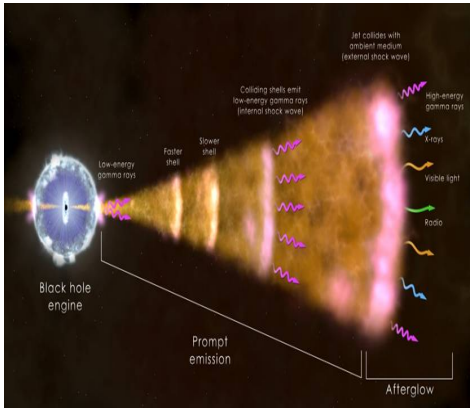
Binary systems



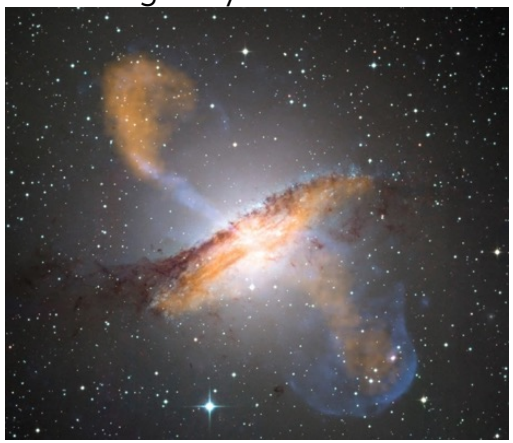
AGN



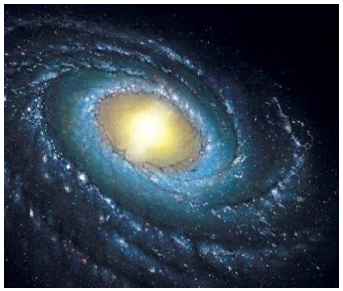
GRB



Radio galaxy

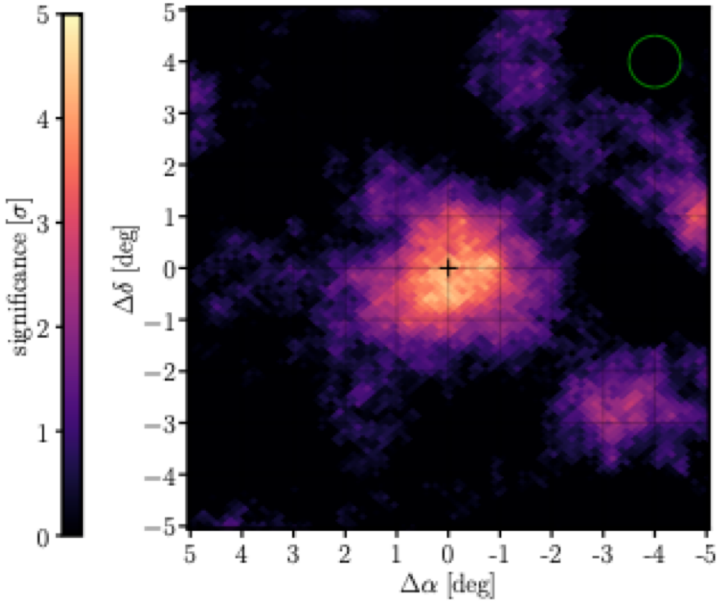


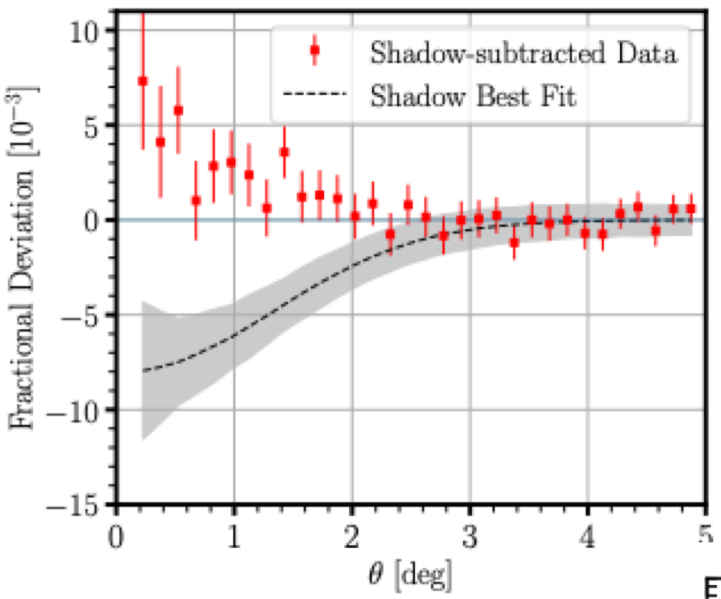
Galactic center



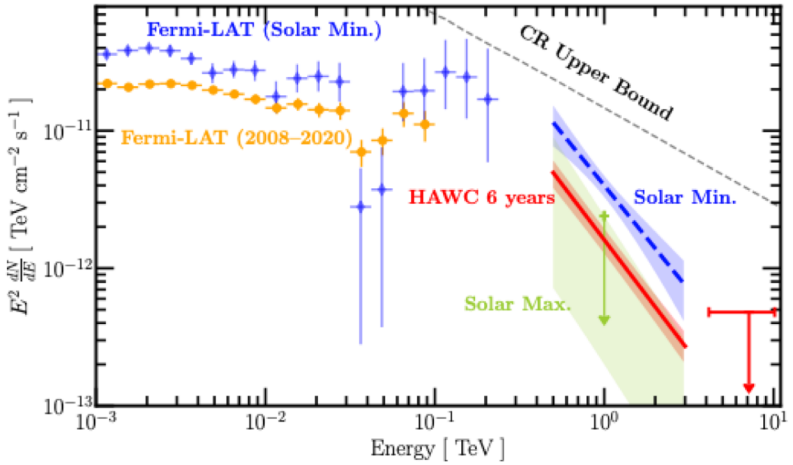
(…)

Solar gamma rays up to TeV





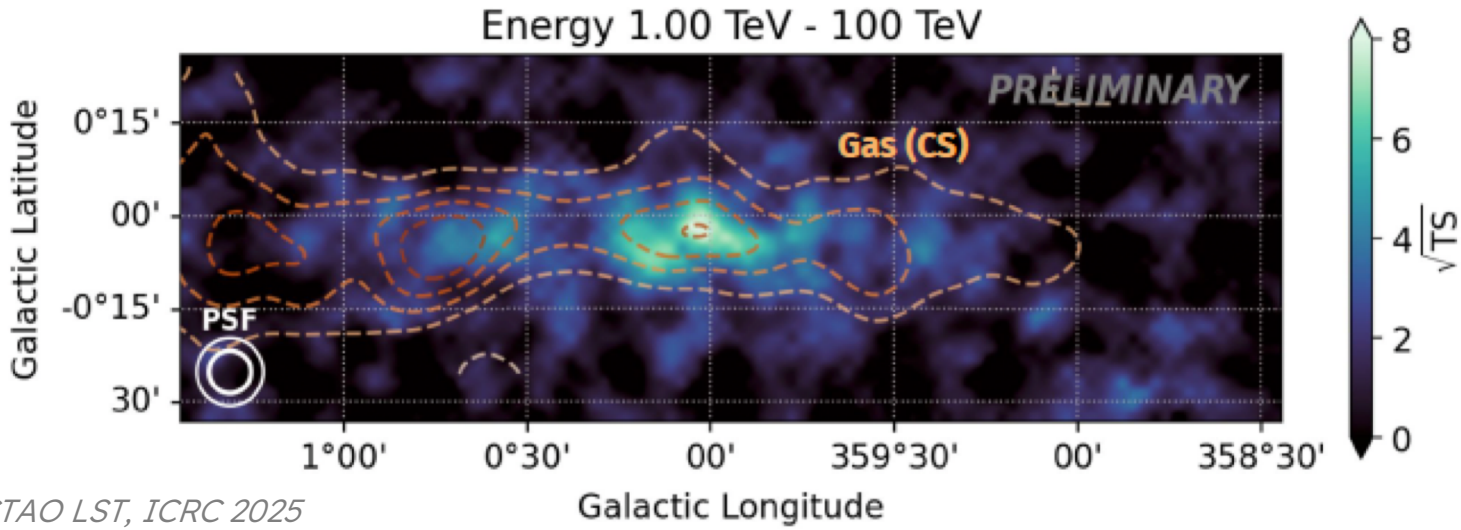
HAWC, 2023, PhysRevLett.131.051201



- Confirmed emission from the Sun up to ~1 TeV by HAWC.
- 20% of the max expected flux if all CR mirrored
- Steeper spectral index than lower energies

⇒ Challenging models

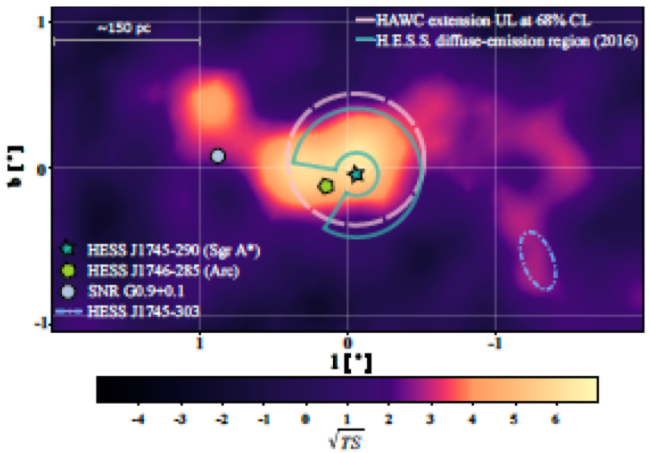
Our galaxy center



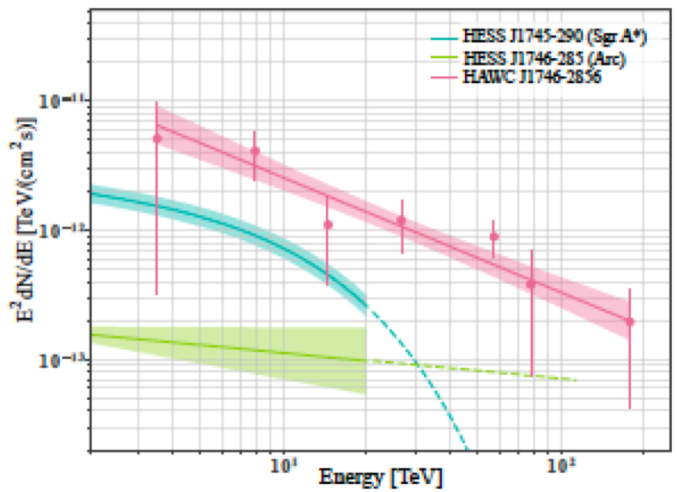
CTAO LST, ICRC 2025

Confirmation of a hadronic Pevatron presence at the Galaxy center

No evidence of spectral cutoff up to 100 TeV



HAWC 2024 ApJL 973 L34

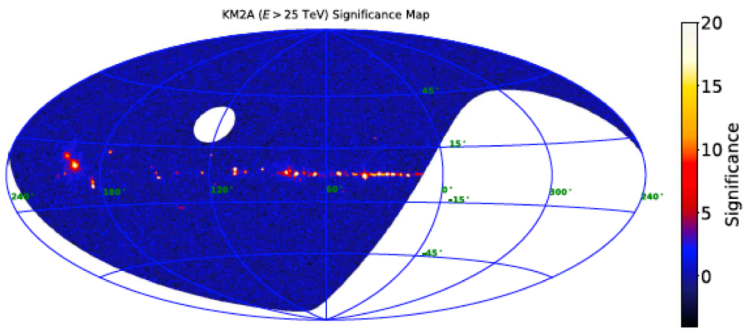


Our galaxy at VHE/UHE

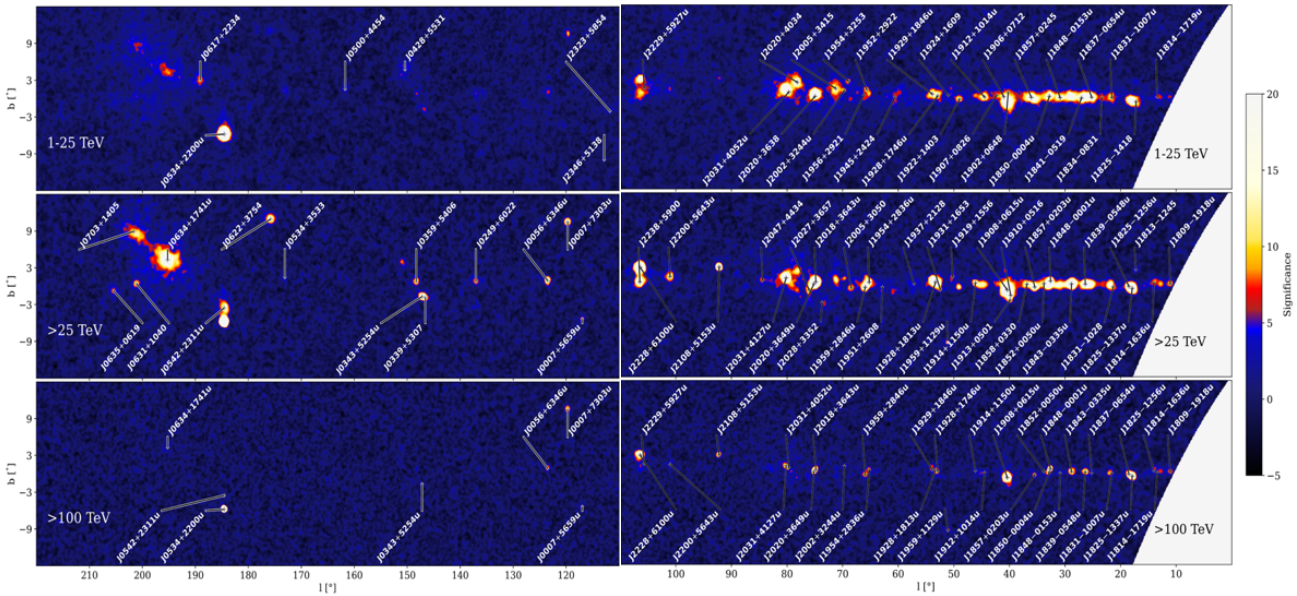
1st LHAASO source catalog released

⇒ 90 VHE sources including 43 >100 TeV sources

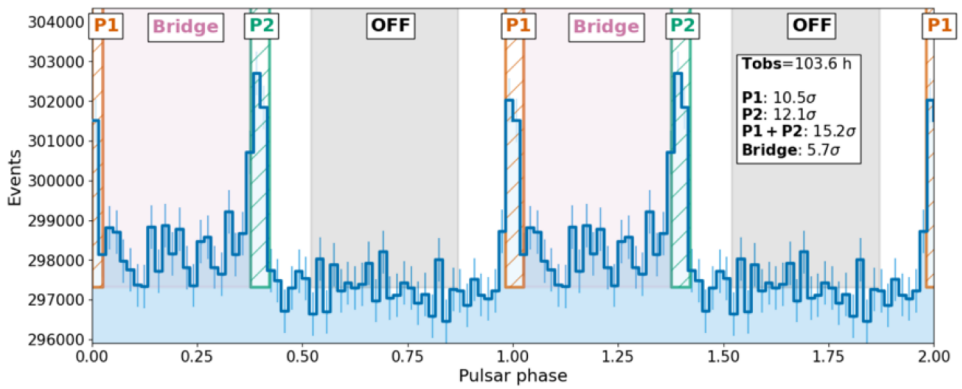
⇒ Mostly associated with Pulsar Wind Nebulae but some without counterparts

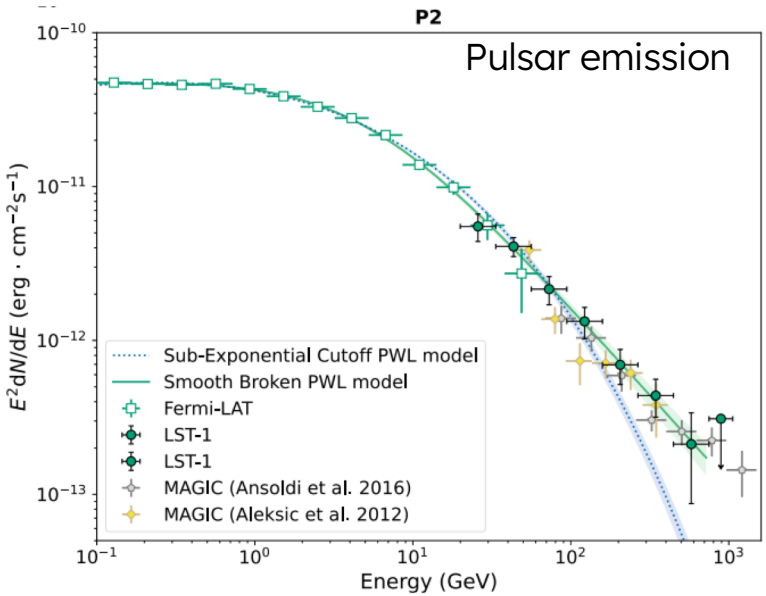


LHAASO 2024 ApJS 271 25

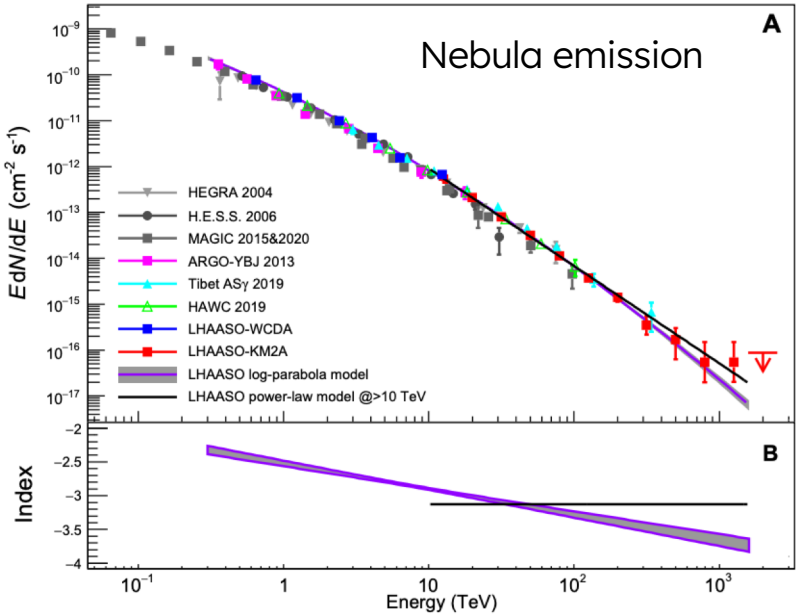


The Crab region





CTAO LST, 2024, A&A, 690, A167



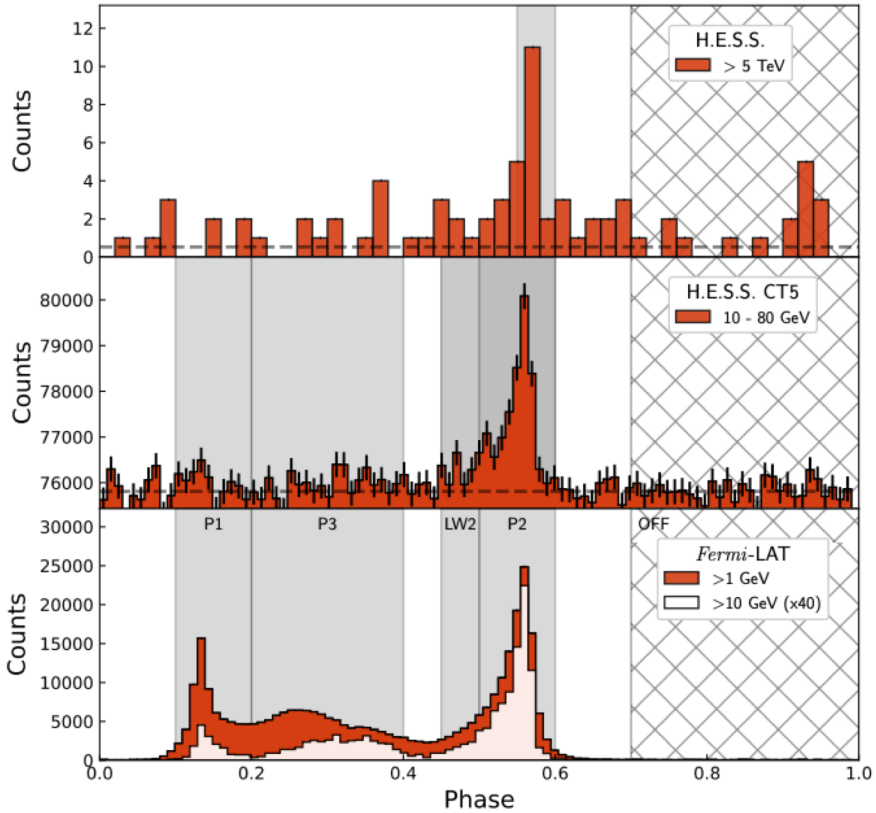
LHAASO, 2021, CPC, 45, 025002

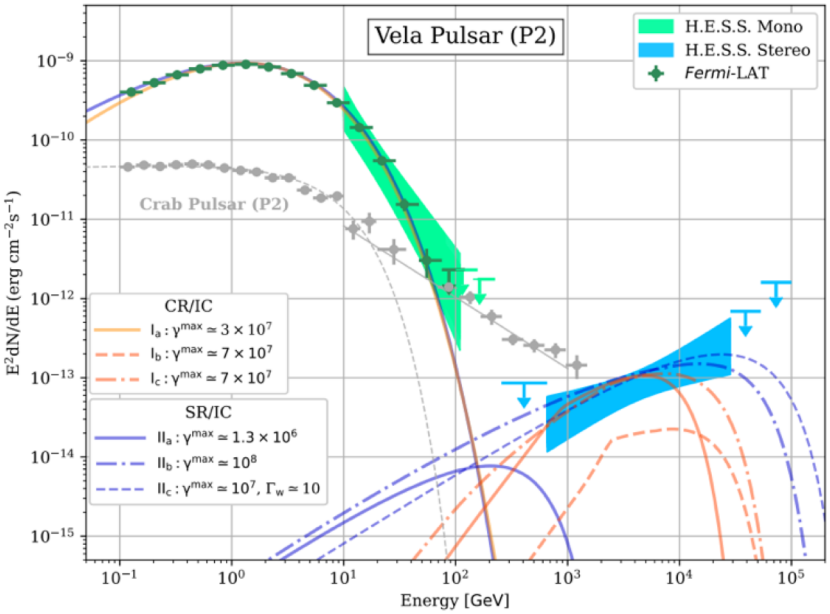
Promising measurement of pulsed emission around TeV energies

Nebula emission extend up to >100 TeV

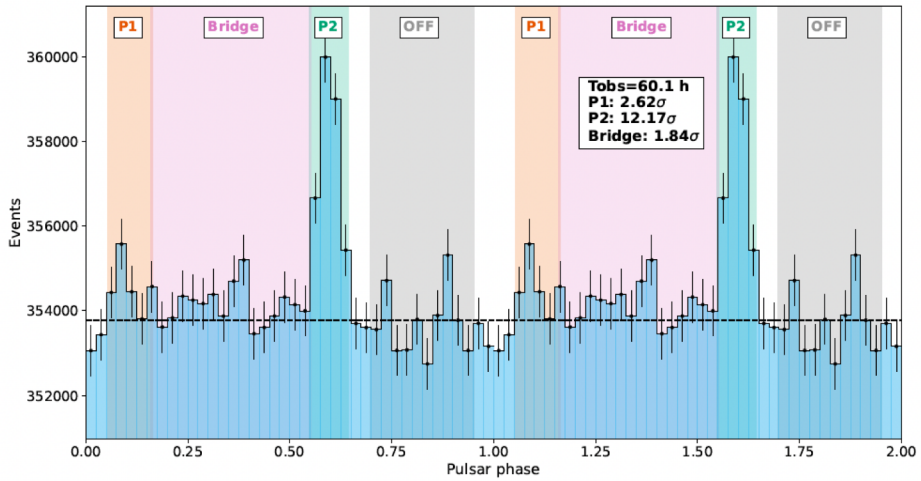
Pulsars

H.E.S.S., 2023, Nature 7 1341





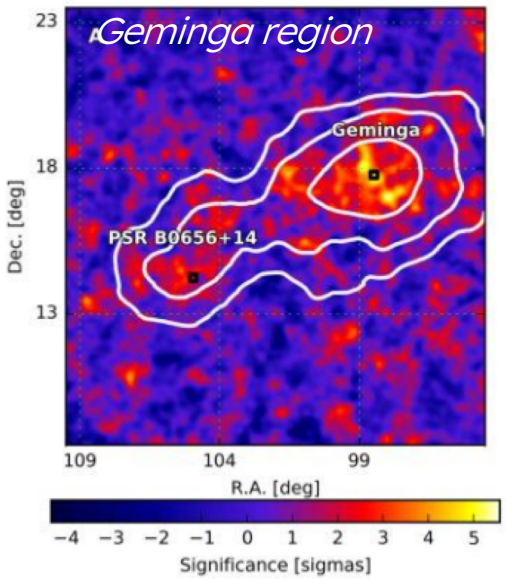
CTAO LST, 2024, A&A 698 A283



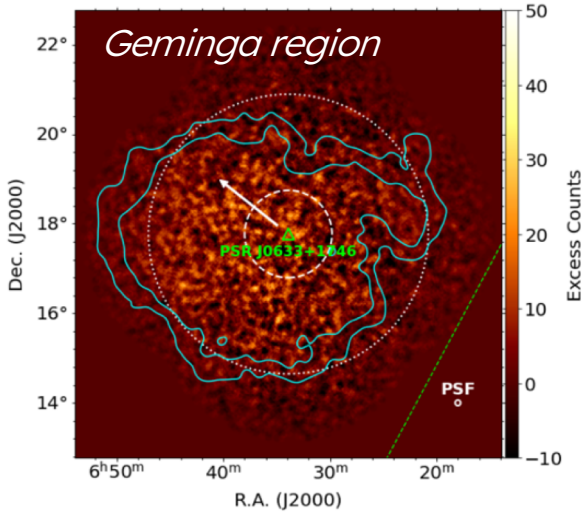
- A few pulsed emission detected at VHE energies
- Emission up to 10 TeV detected from Vela

TeV halo around pulsars

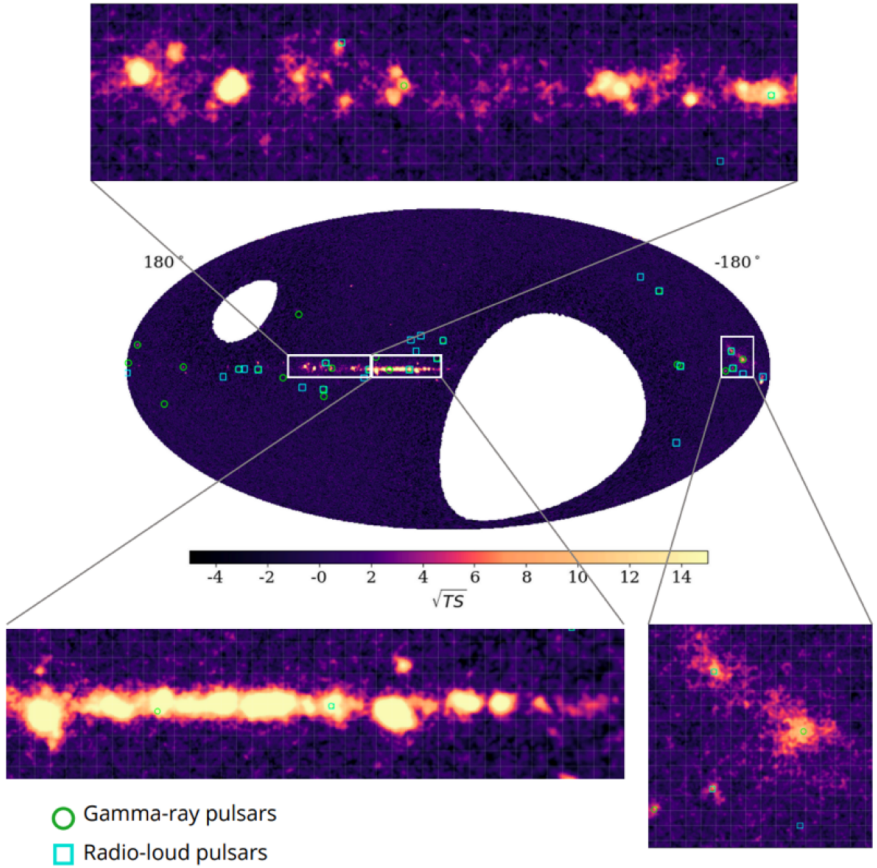
HAWC, 2023, ApJ 974 246



H.E.S.S., 2023, A&A 673 A148

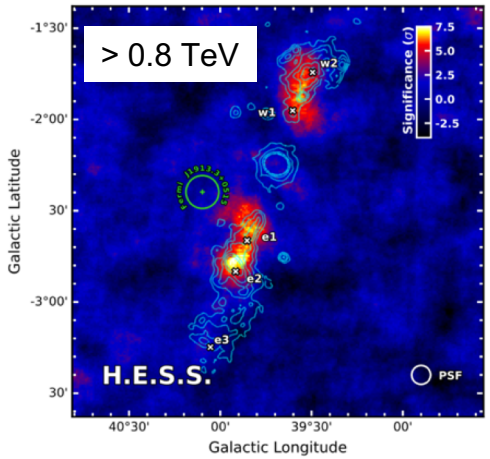


- Extended emission beyond PWN detected around several pulsars by HAWC, LHAASO and recently HESS
- Stacking analysis by HAWC suggests this could be a common feature for middle aged pulsars

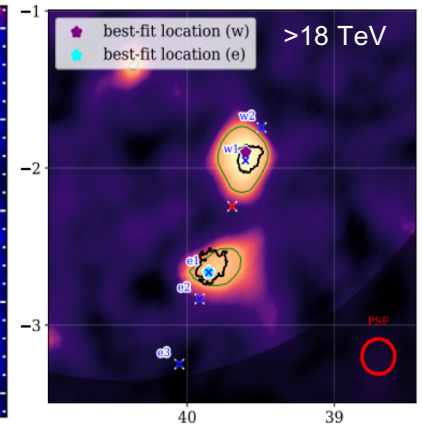


HAWC 2025, PRL 134 171005

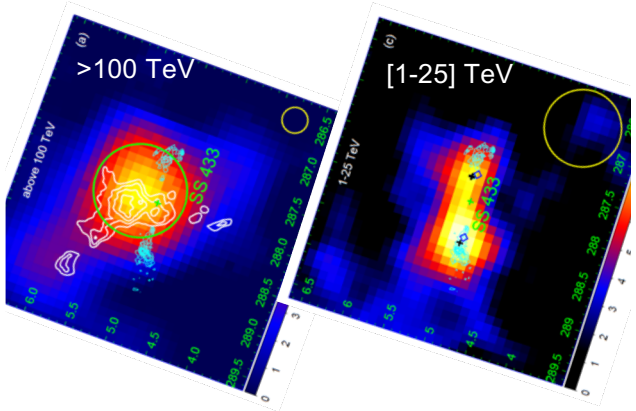
Microquasar – SS 433



H.E.S.S., 2024, Science 383 6681



HAWC, 2023, ApJ 976 30



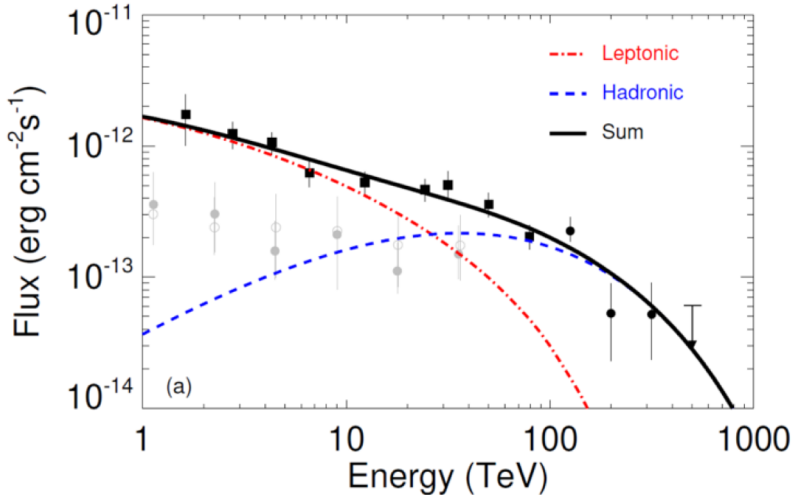
LHAASO, 2024, arXiv:2410.08988

- HAWC discovered a TeV emission, confirmed by H.E.S.S up to 50 TeV

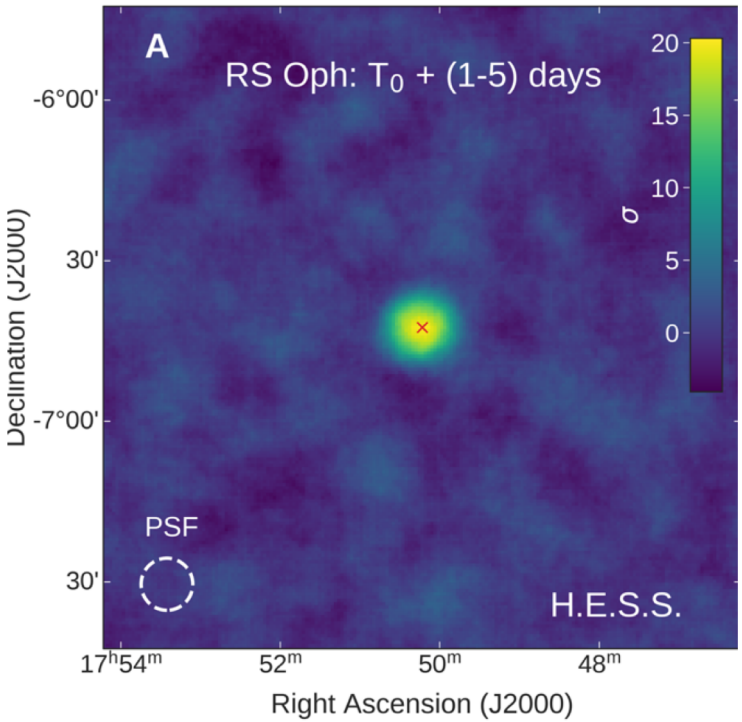
⇒ Electrons accelerated up to 200 TeV

- Detection above 100 TeV by LHAASO

⇒ hadronic origin of UHE emission from the central region



RS Ophuichi - the first TeV nova

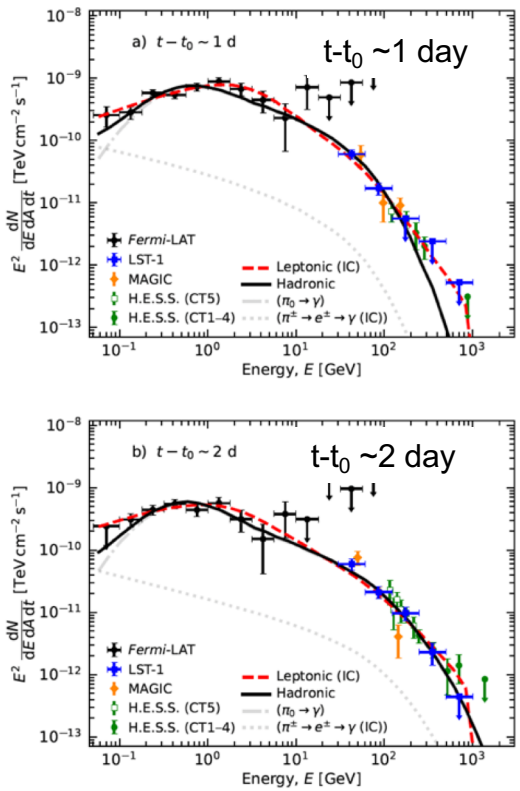


H.E.S.S., 2022, Science 376 6588

Recurrent symbiotic nova
- period ~15 years
- White dwarf embedded in a red giant wind

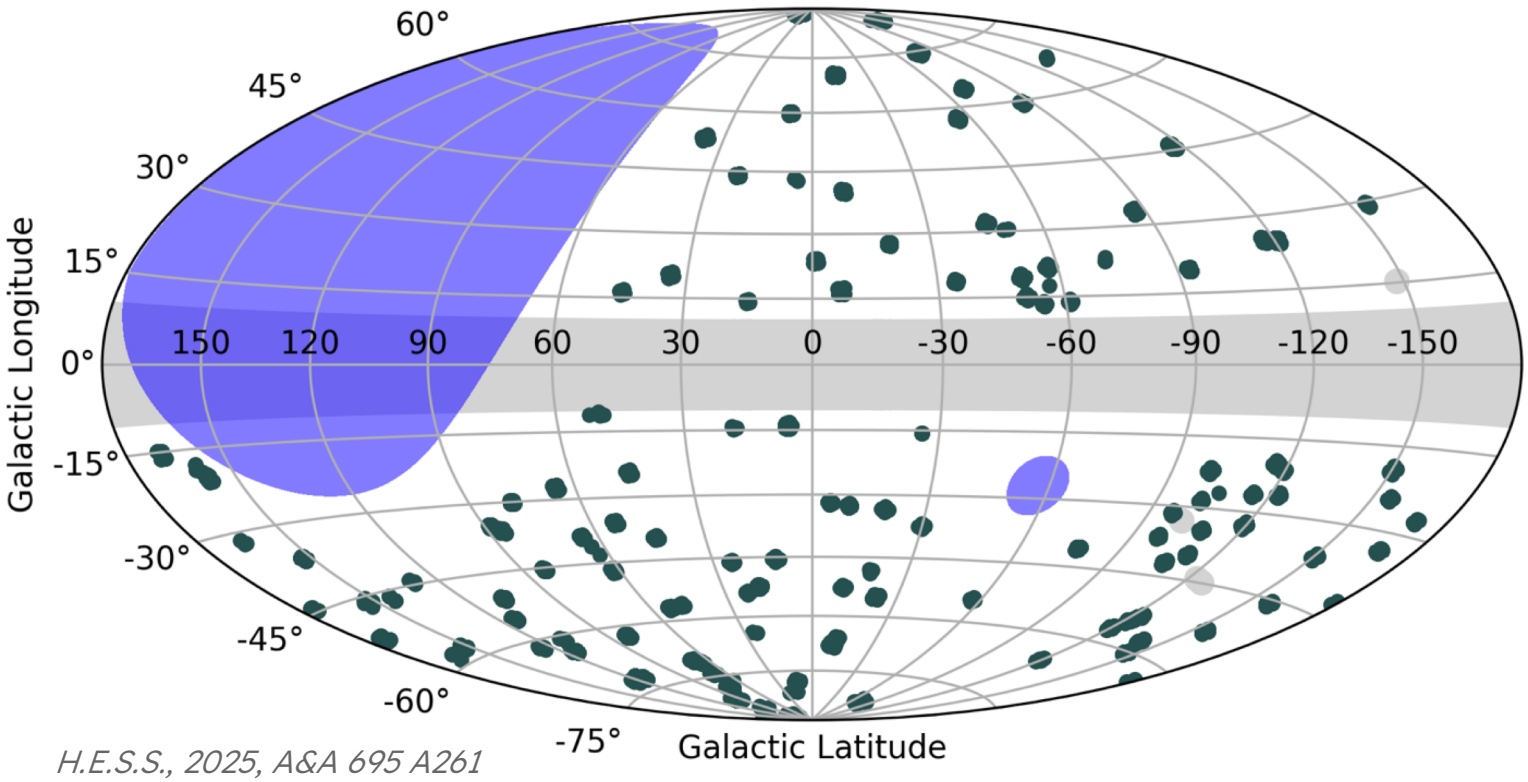
Burst on 8 August 2021 : brightest nova ever in gamma rays

First detection of VHE gamma-ray emission from a nova!



CTAO-LST, 2025, A&A 695 A152

The extragalactic sky



H.E.S.S., 2025, A&A 695 A261

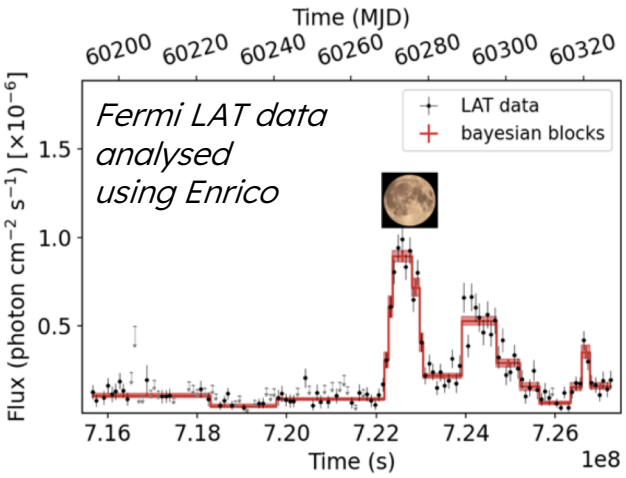
HESS extragal. sky survey:

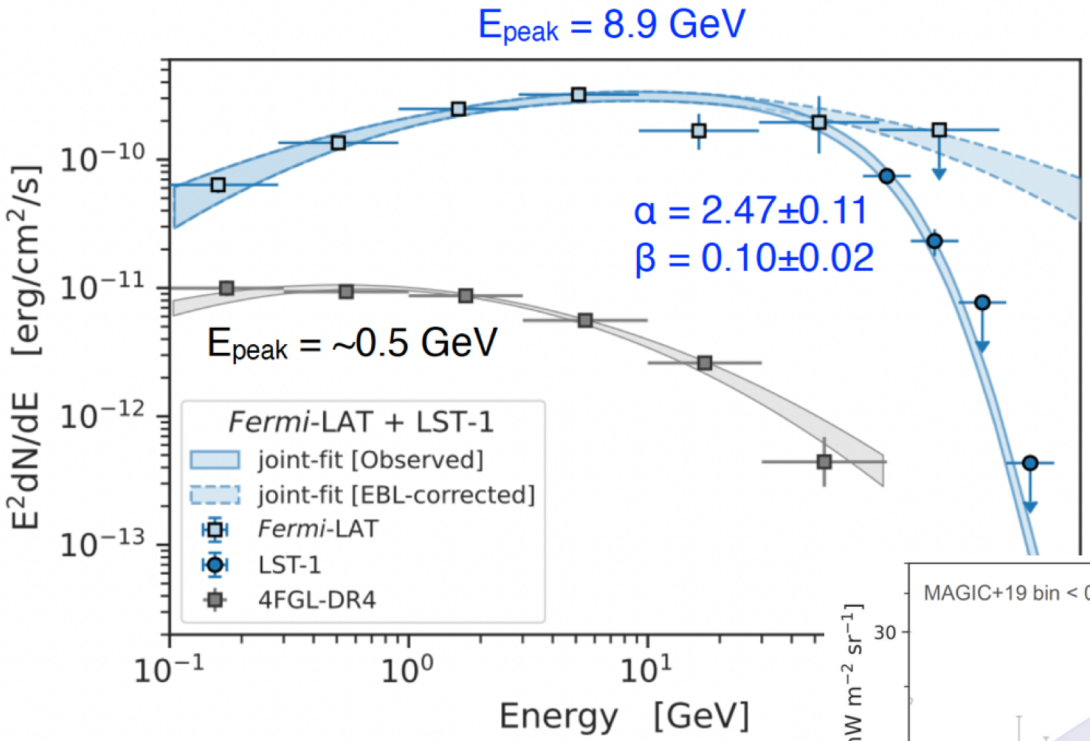
- 2720h of observation
- 98 clusters
- ~5.7% of the sky (non-uniform exposure)

Similar activities by other observatories

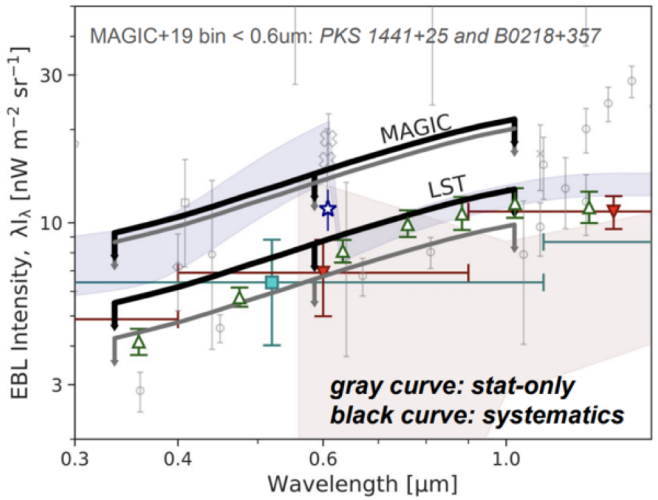
Overall more than 100 extragalactic sources listed at ~TeV energies
- Mainly blazars (Active Galaxy Nuclei with jet towards us)
+ radio galaxies, starburst galaxies

The farthest ever detected at VHE - OP 313



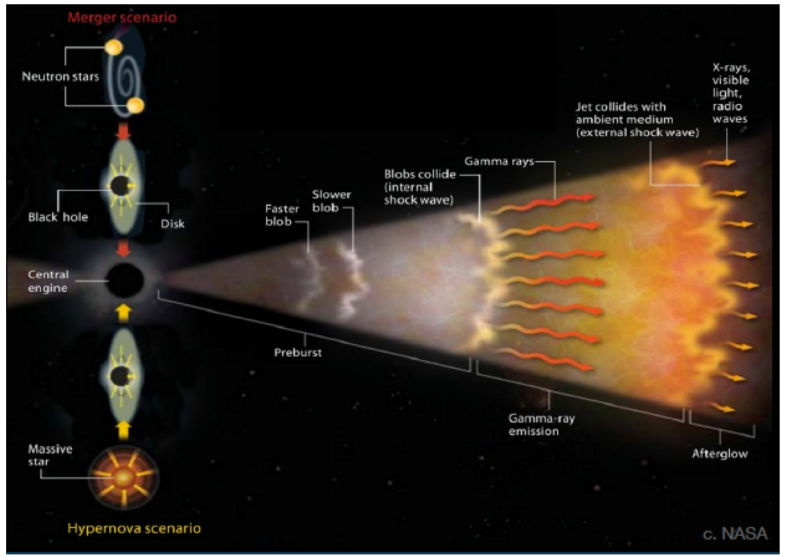


CTAO LST & MAGIC TevPa 2025



- Flat Spectrum Radio Quasar (FSRQ)
- **Very distant: z = 0.997**
- Upper constraint of EBL < 1 μm

Gamma-ray bursts



Difficult quest at VHE energies

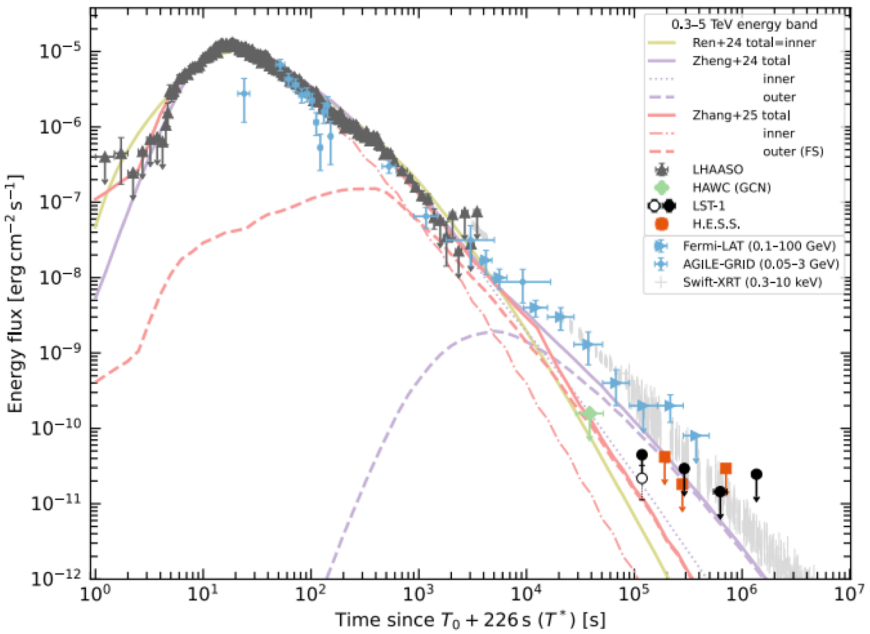
- Distant sources => photons interact with EBL
- Quickly fading emission

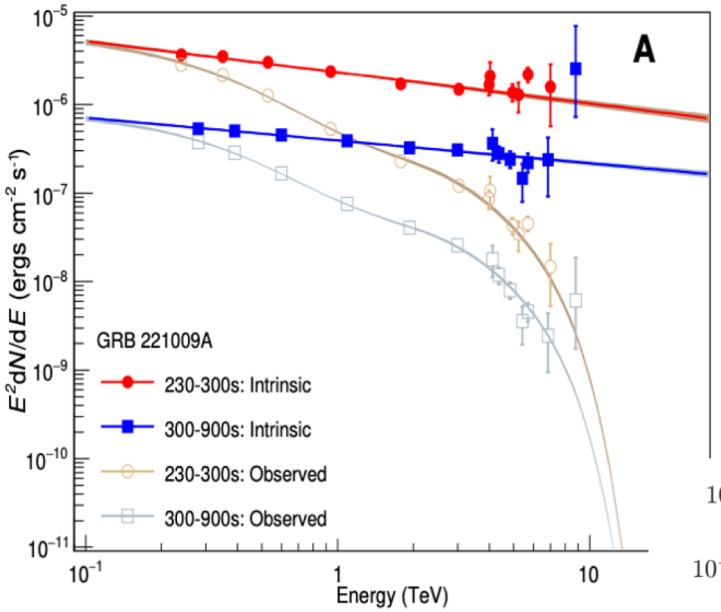
⇒ Only 5 GRB detected at VHE so far

	T_{90}	TeV detection timescale	Redshift
GRB 180720B – H.E.S.S.	50s (long GRB)	T0 + [10h-12h]	0.654
GRB 190114C – MAGIC	116s (long GRB)	T0 + [57s-2454s]	0.425
GRB 190829A – H.E.S.S.	58s (long GRB)	T0 + [4.6h-53h]	0.079
GRB 201216C – MAGIC	48s (long GRB)	T0 + [56s-2.2h]	1.1
GRB 221009A – LHAASO	~1068s (long GRB)	T0 + [226s-2000s]	0.151

The BOAT - Brightest of all time

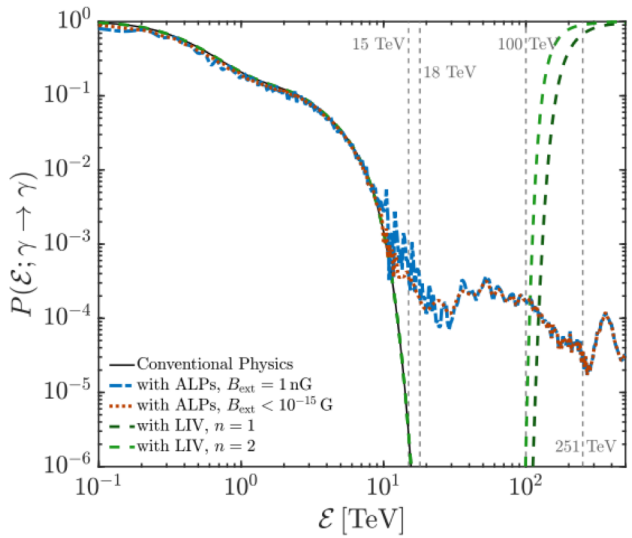
CTAO LST, 2025, ApJL 988 L42





LHAASO, 2023, Science 9 46

Galanti et al. 2023, PRL 131 251001



z=0.15 & E_{iso} = 1.5 x 10^{55} erg

⇒ Saturated various detectors (Fermi-LAT, Fermi-GBM)

⇒ 1 such event every 10000 years

TeV detection in the early afterglow by LHAASO up to 13 TeV

Summary

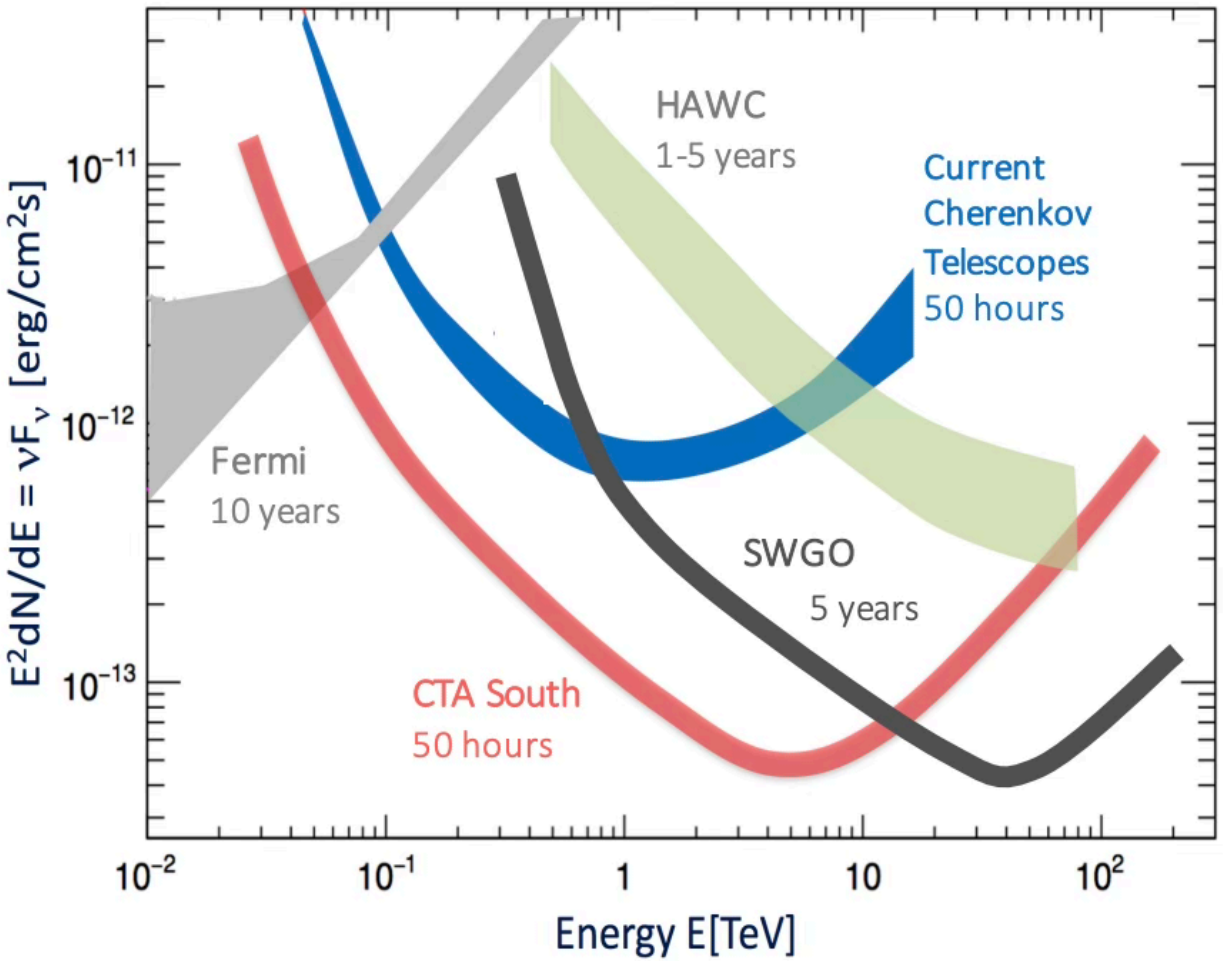
- As of today more than 300 sources detected above 100 GeV
  - Rich range of galactic and extragalactic objects type
  - Without mentioning studies of exotic or fundamental physics question (Dark Matter, LIV, ALPs…)

⇢ D. Kersberg's talk on wednesday

- **Future instruments** will bring in a couple of year a boost in sensitivity and transient response.

⇢ M. Seglar-Arroyo's talk tomorrow

Current ground -based instruments



Hinton & Ruiz-Velasco 2020