The Large-Sized Telescopes of CTAO

First Science results

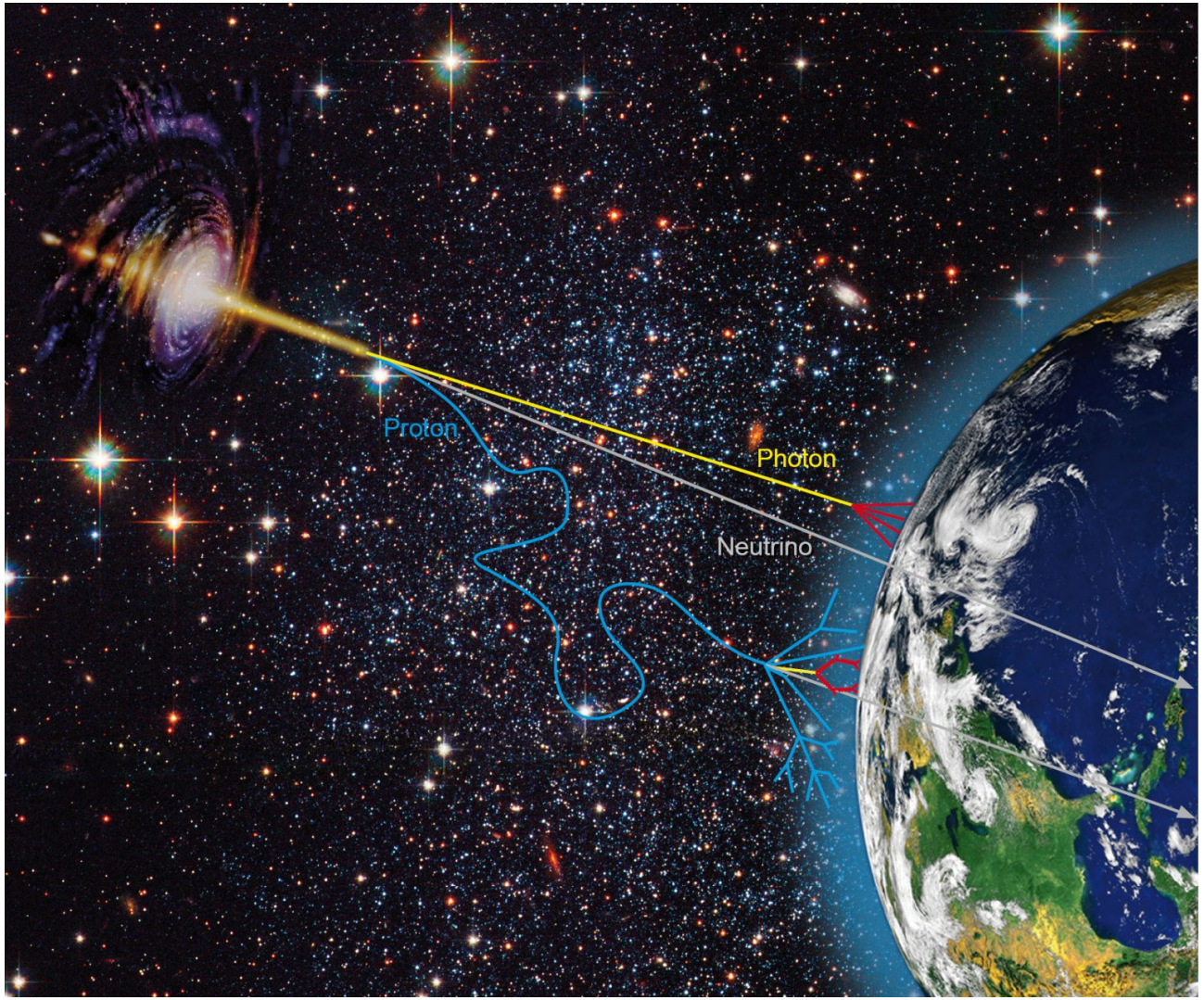
Pol Bordas
for the CTAO-LST Project

RENATA meeting 2025
Zaragoza, 22.09.2025

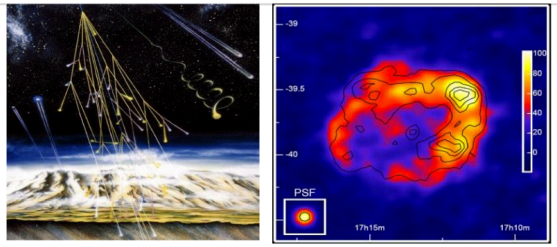
Multi-messenger Astrophysics

Understanding the High-energy Universe is most effective using independent channels

Gamma rays provide the cleanest and most direct information

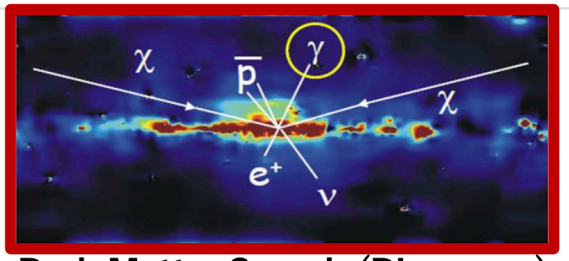


VHE gamma-ray astrophysics



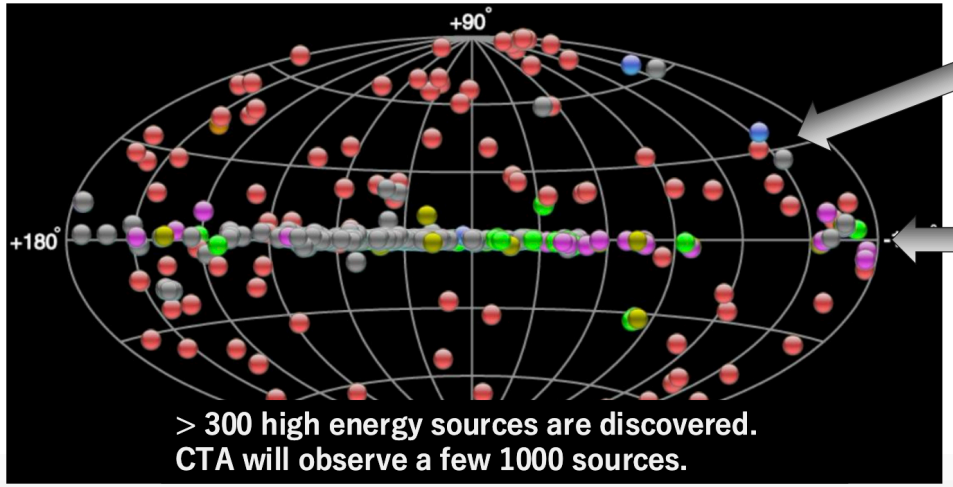
Cosmic Ray Origin

Super Massive Black Holes



Dark Matter Search (Discovery)

- Origin of Cosmic Rays (Big accelerators)
- Black Hole and S.M.B.H.
- Dark Matter Search



> 300 high energy sources are discovered.
CTA will observe a few 1000 sources.

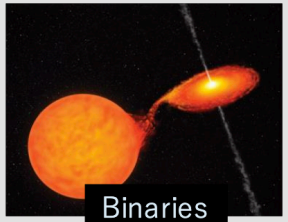
Extragalactic Sources

Active Galactic Nuclei

Gamma Ray Bursts

Galactic Sources

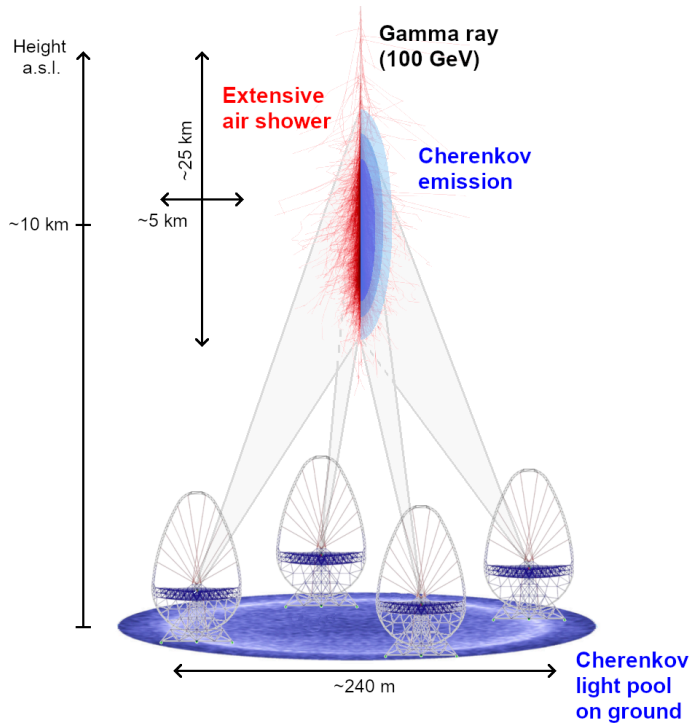
Super Nova Remnants

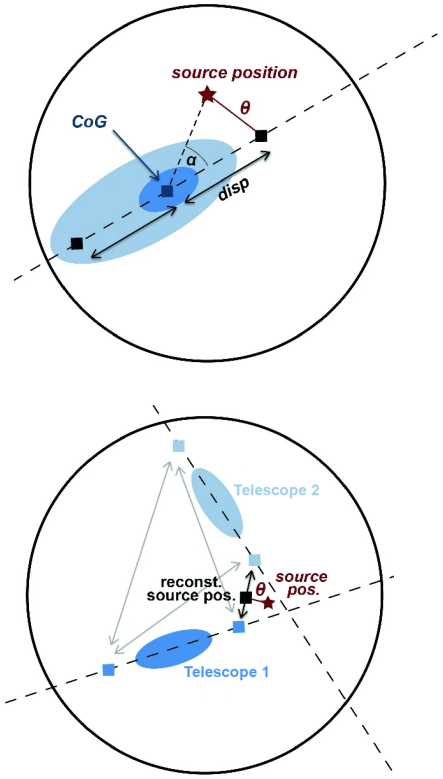


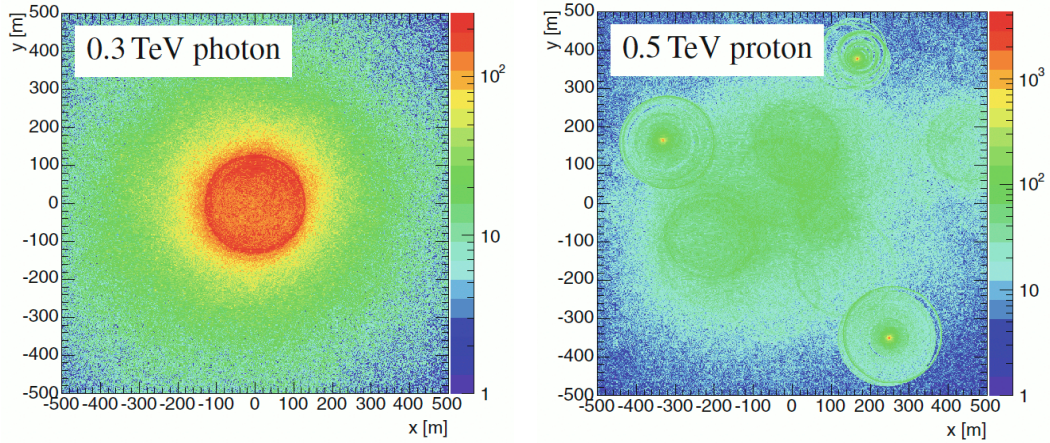
Binaries

VHE gamma-ray astronomy with IACTs

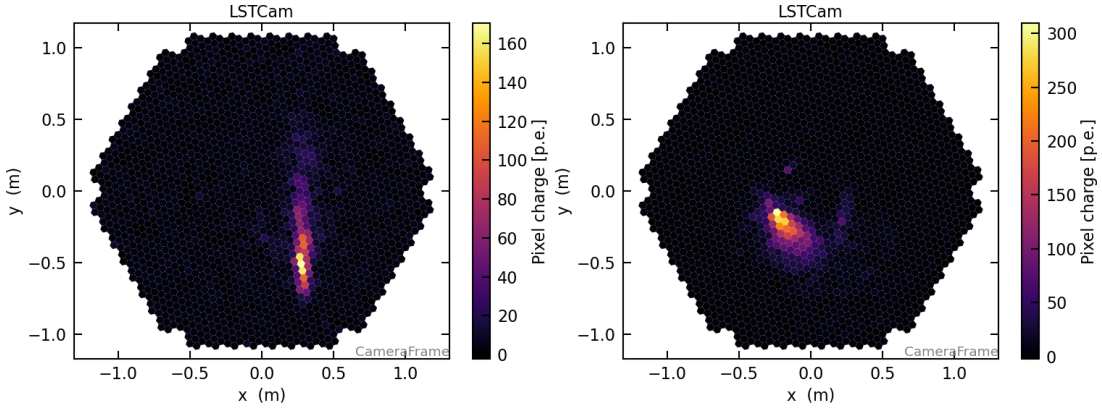
- Detection of Cherenkov radiation produced by gamma-ray induced EAS in the atmosphere







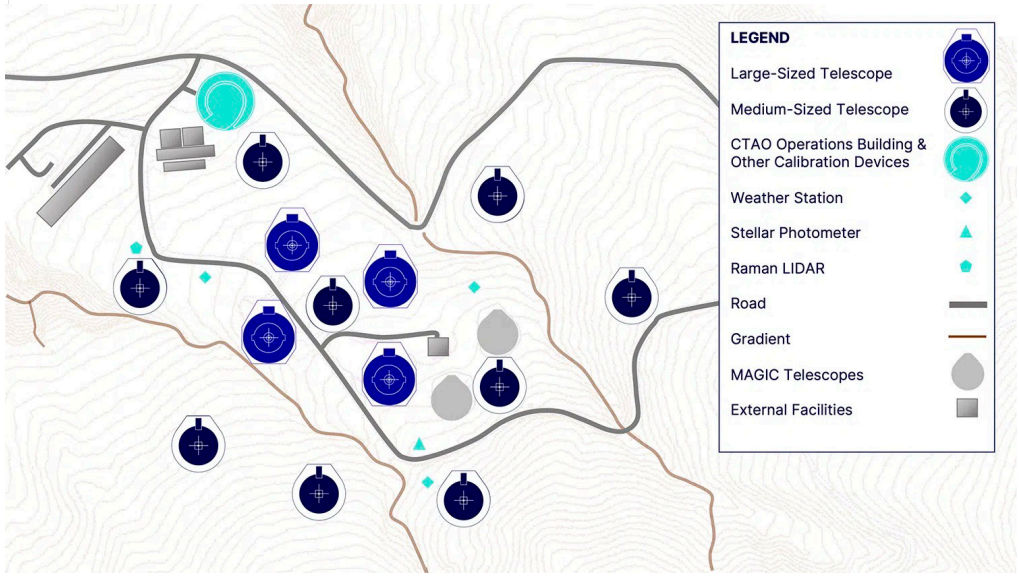
Credit: Errando & Saito (2024)



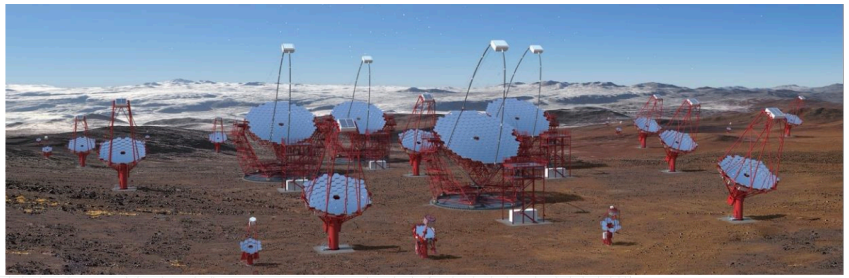
Adapted from A. Aguasca-Cabot (2025, PhD Thesis)

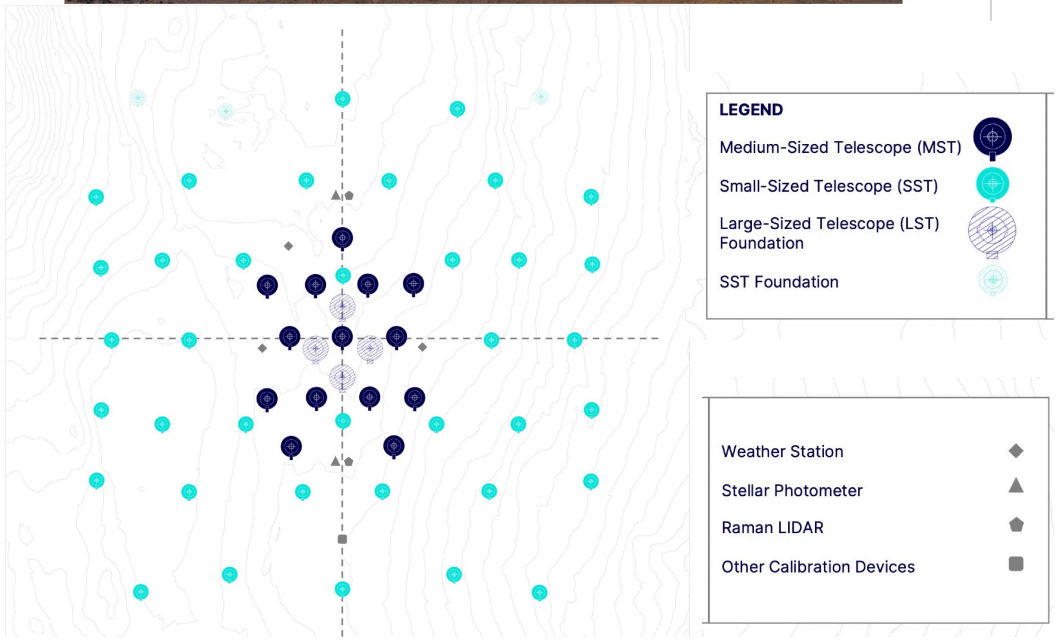
Cherenkov Telescope Array Observatory (CTAO)

Roque de los Muchachos Observatory
La Palma, Spain



Paranal, Chile

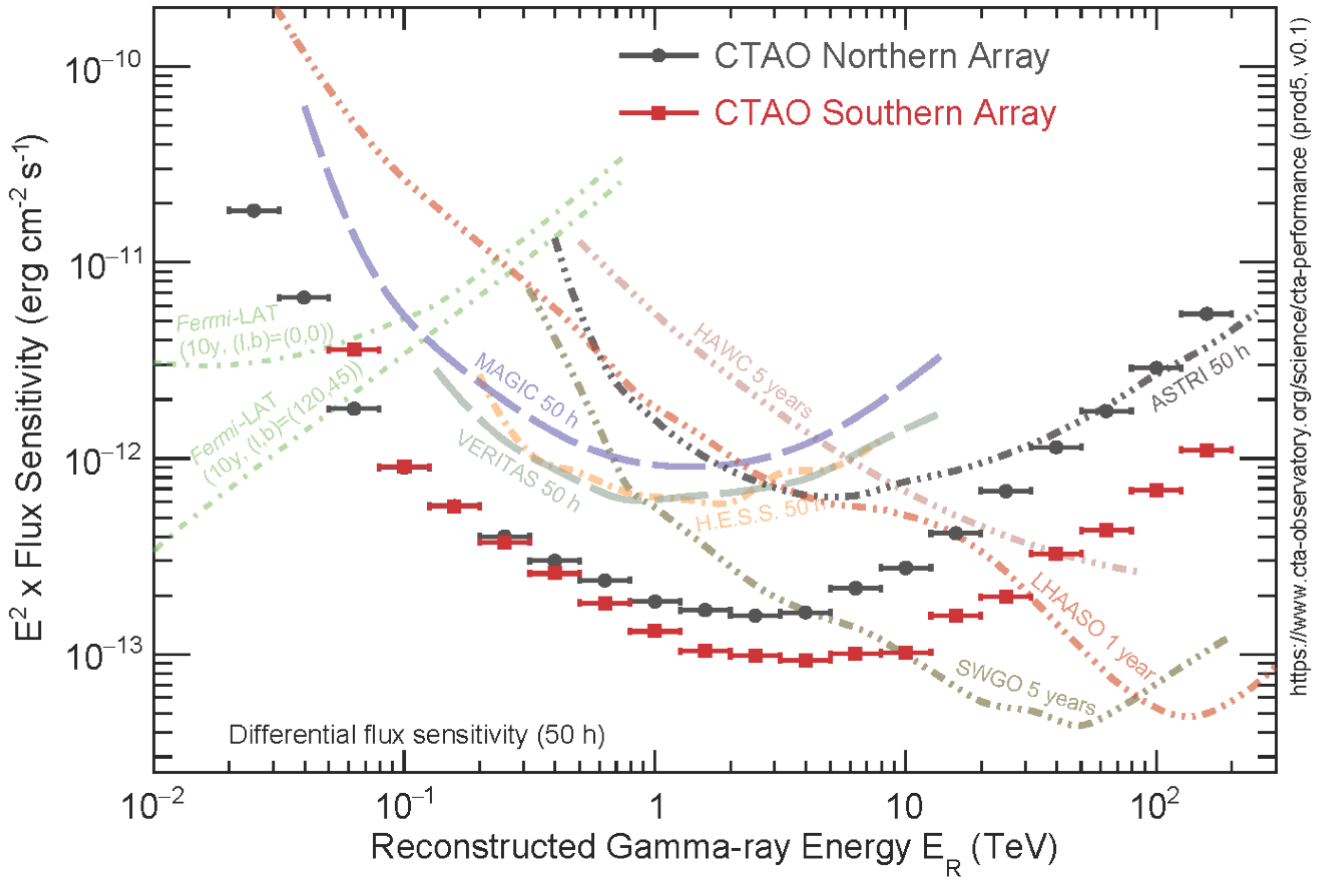




www.ctao.org

Cherenkov Telescope Array Observatory (CTAO)

- larger E-coverage: 20 GeV - 300 TeV
- x10 better flux sensitivity
  => spectral studies, source discoveries
- x5 better angular resolution
  => morphology studies, less confusion
- Large field-of-view
  => 4.3˚ LST, 7.5˚ MST, 10.5˚ for SST
- 2 sites to cover **both hemispheres**:
  => La Palma (Spain) and Paranal (Chile)



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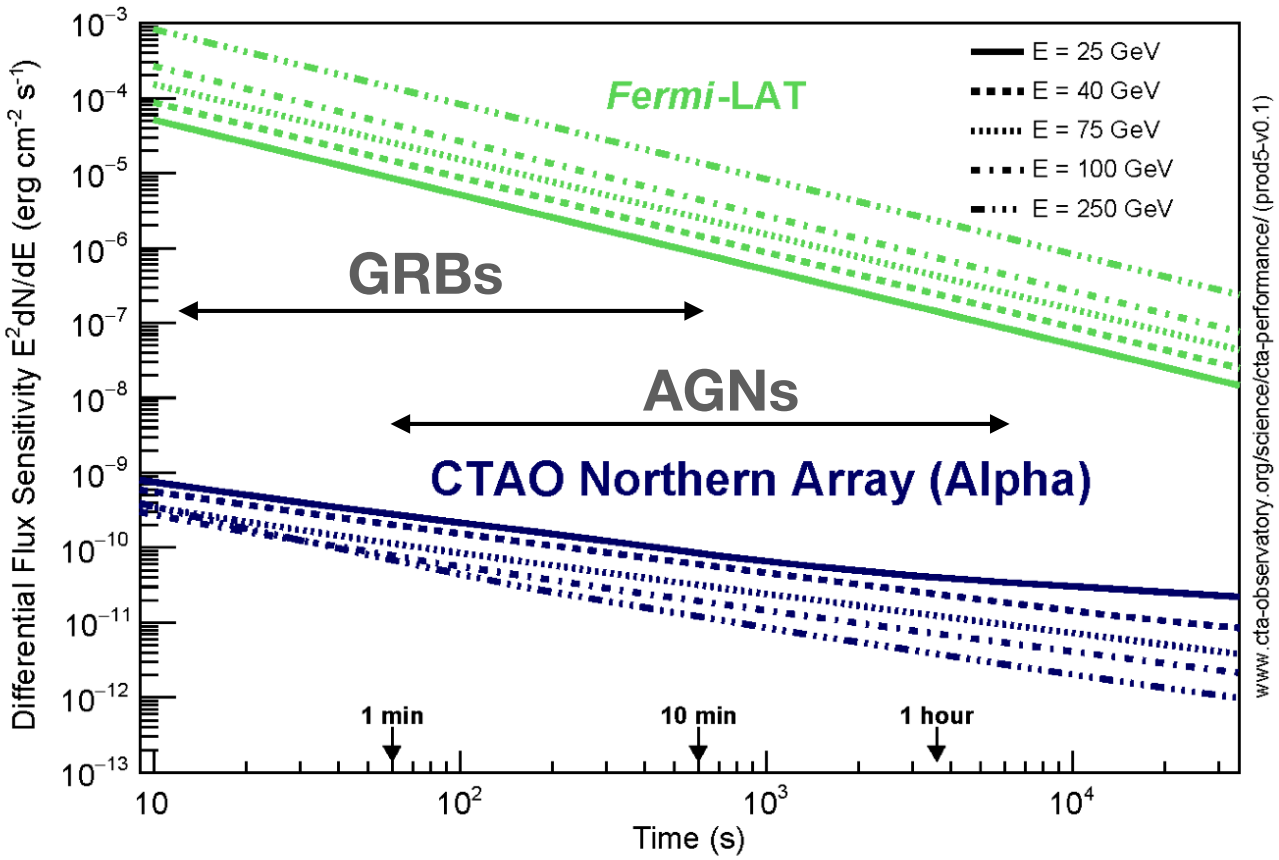
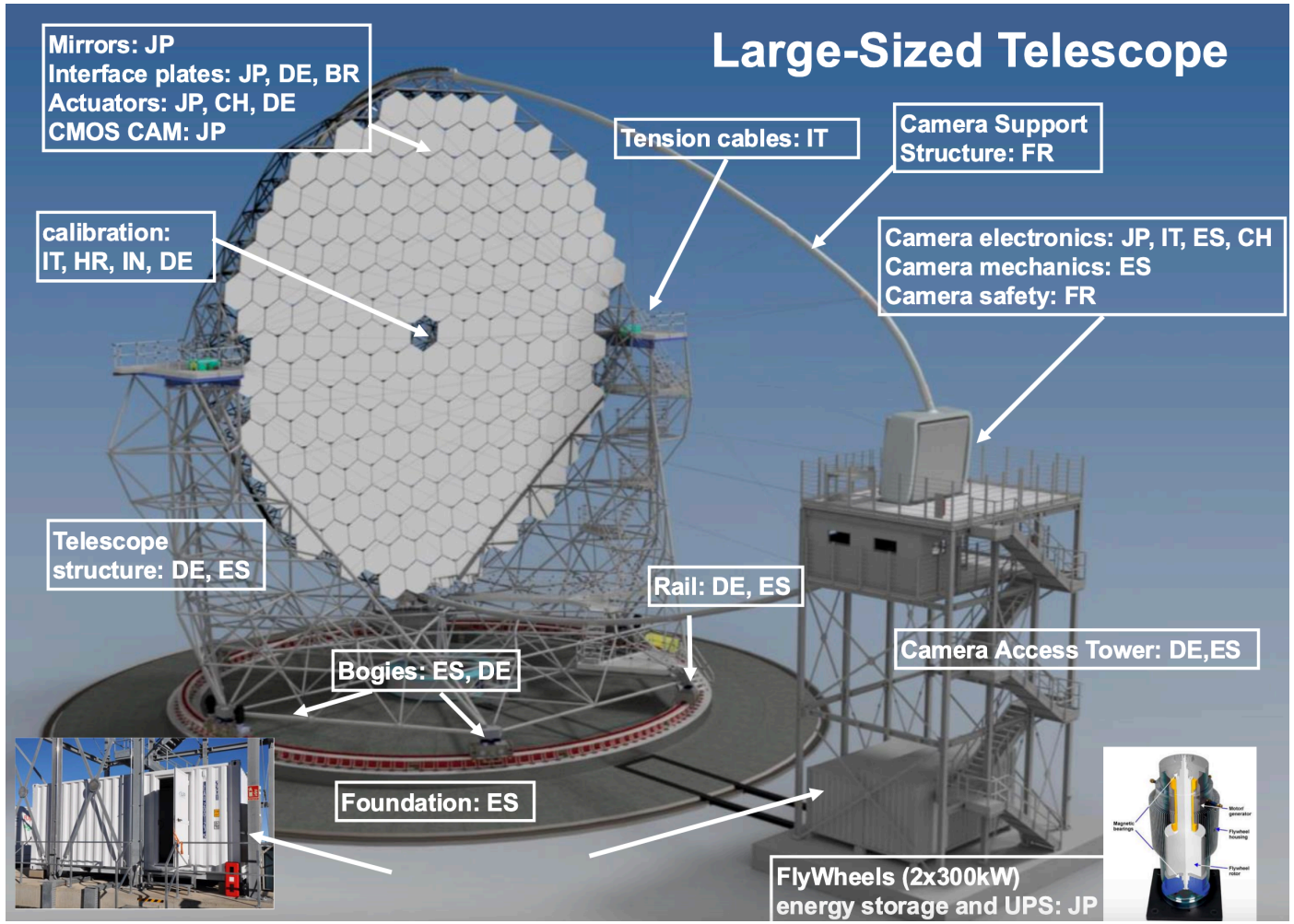


The CTAO/LST-1 prototype

- LST1 inaugurated in 2018. Regular **data taking since January 2020**
- LST2-4: being build up, **operative in ~early 2026**

LST-1 specs

- Alt-Azimuth mount, with a **parabolic 23m mirror dish**
- Camera:**1855 PMTs**, **FoV ~ 4.3°**
- Focal length: 28 m
- **Eff. Area ~370 m2**



Adapted from D. Mazin, Canfranc (2025)

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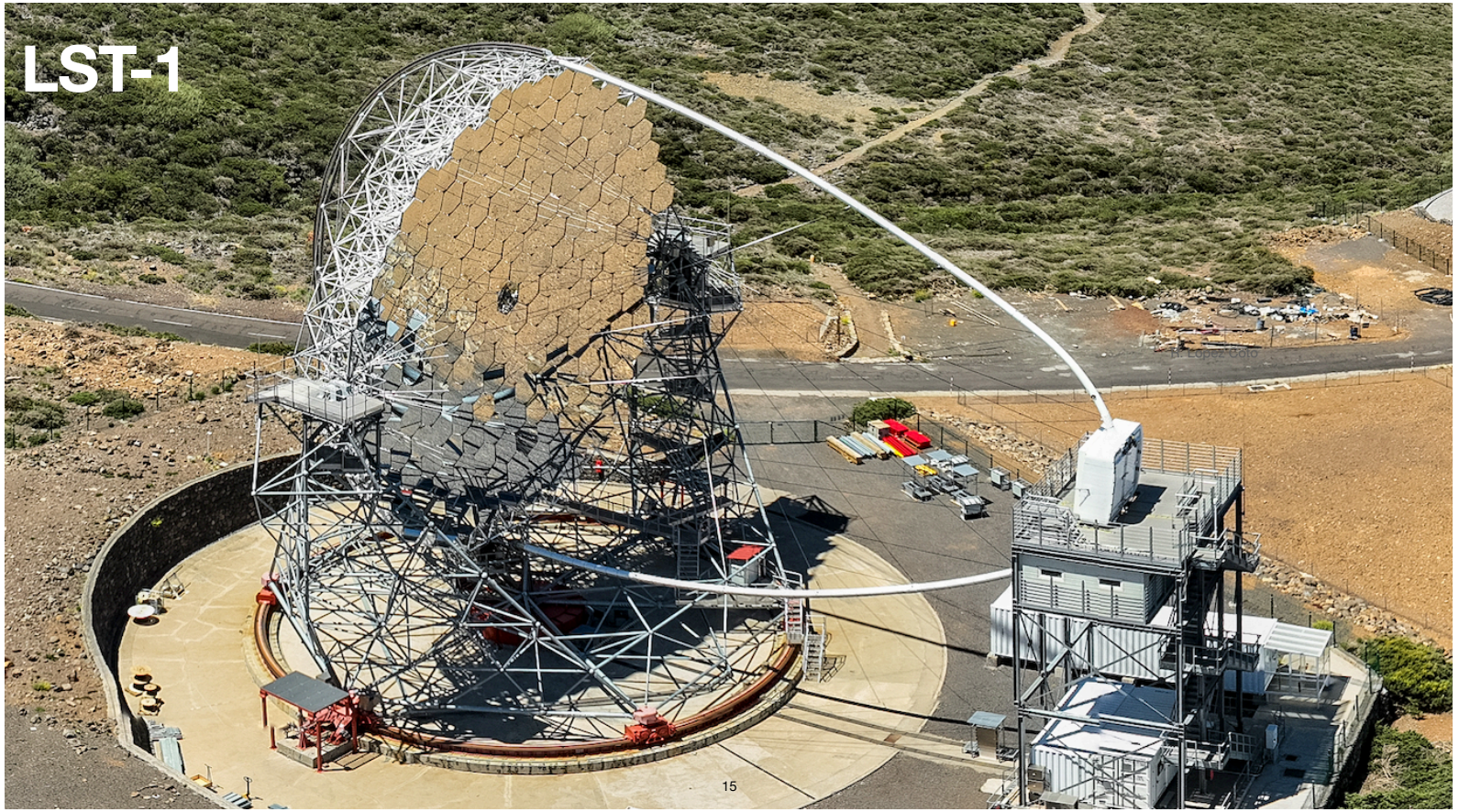
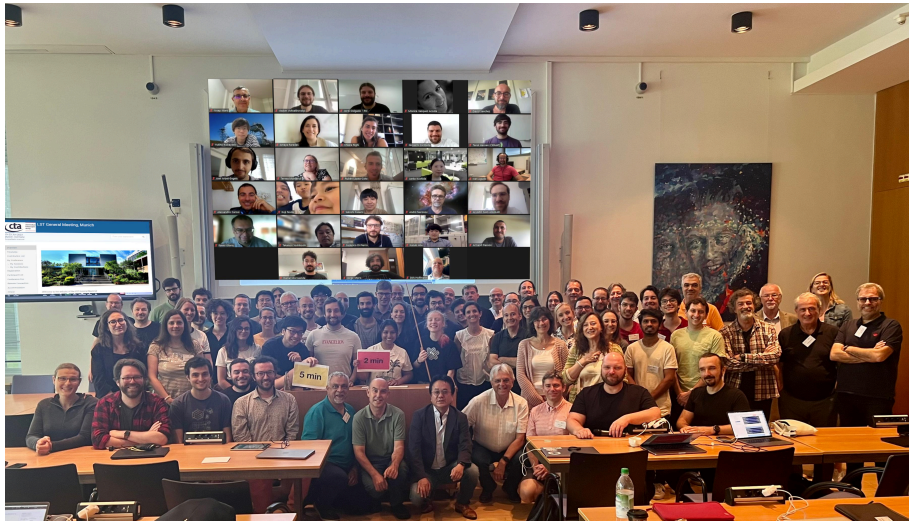
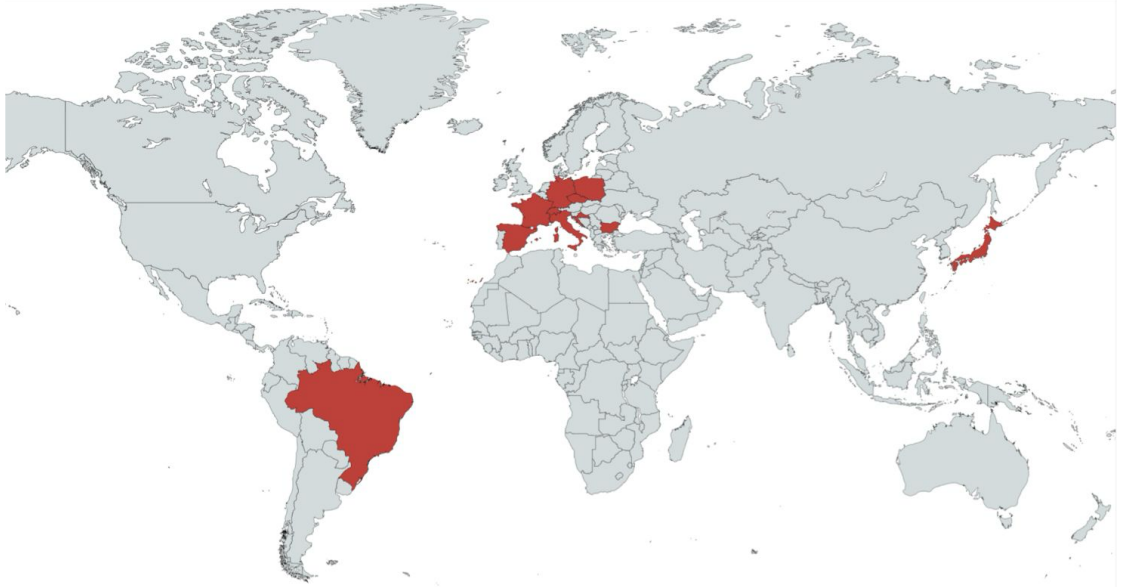


Adapted from D. Mazin, Canfranc (2025)

LST Collaboration

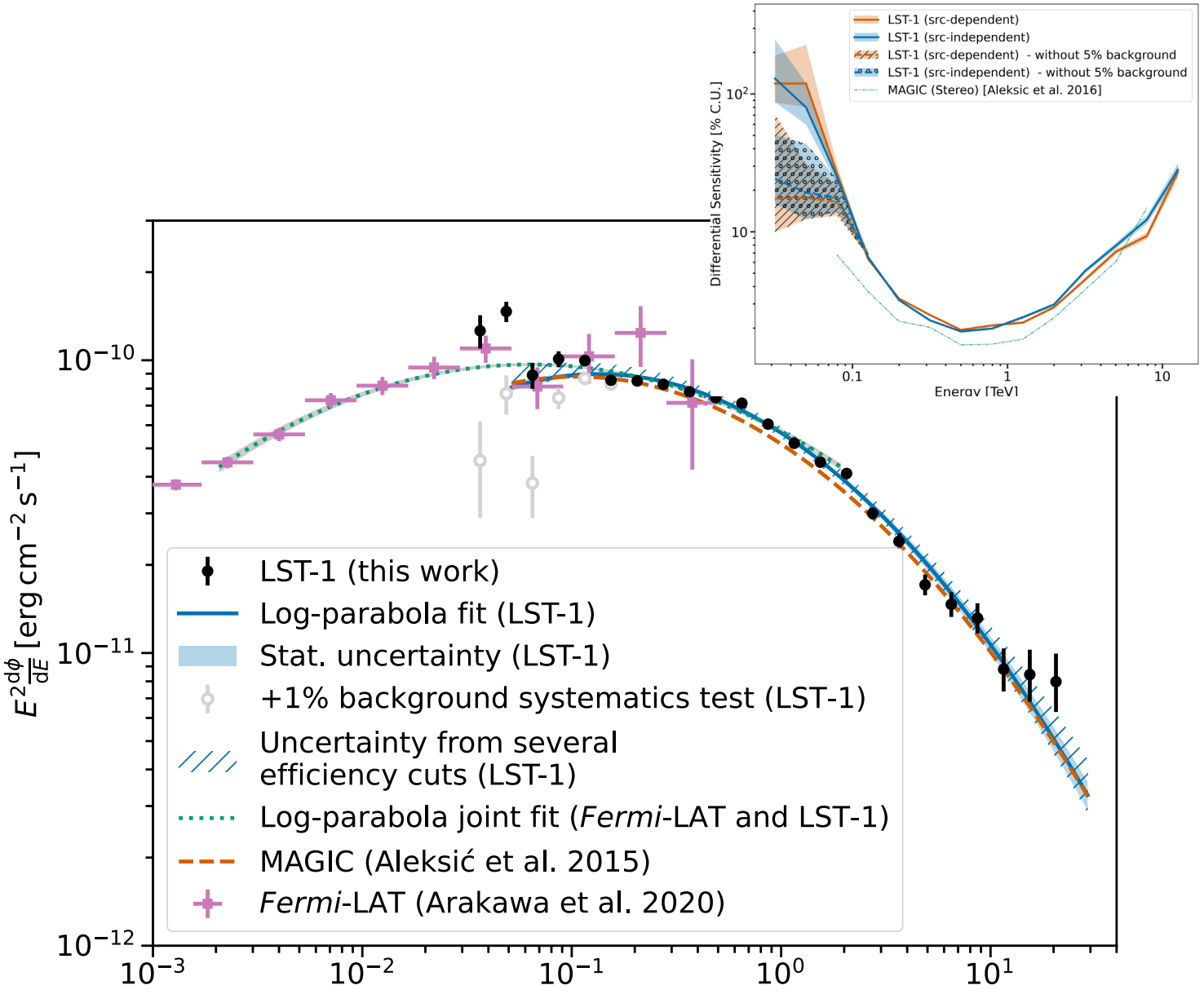




- **> 330 scientists** + **160 engineers** from 11 countries
- Building of **4 LSTs (CTA-N) + 2 LSTs (CTA-S)**
- https://www.cta-observatory.org/project/technology/lst/

LST-1 performance

- "LST-1 performance paper": Abe et al. 2023
- **Low E_{th}** (down to **~20 GeV**)
- **Large eff. area** at multi-GeV range (**~ 10^4 x Fermi-LAT @ ~ minutes timescales**)
- **Angular resolution**: 0°.12–0°.40
- **E-resolution**: 15%–50%
- **Flux sensitivity**: 1.1% Crab Nebula flux at E > 250 GeV (50h obs)
-

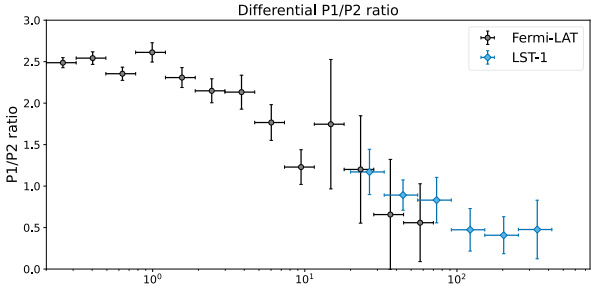


LST-1 Early Science

LST-1 observations of the Crab PSR

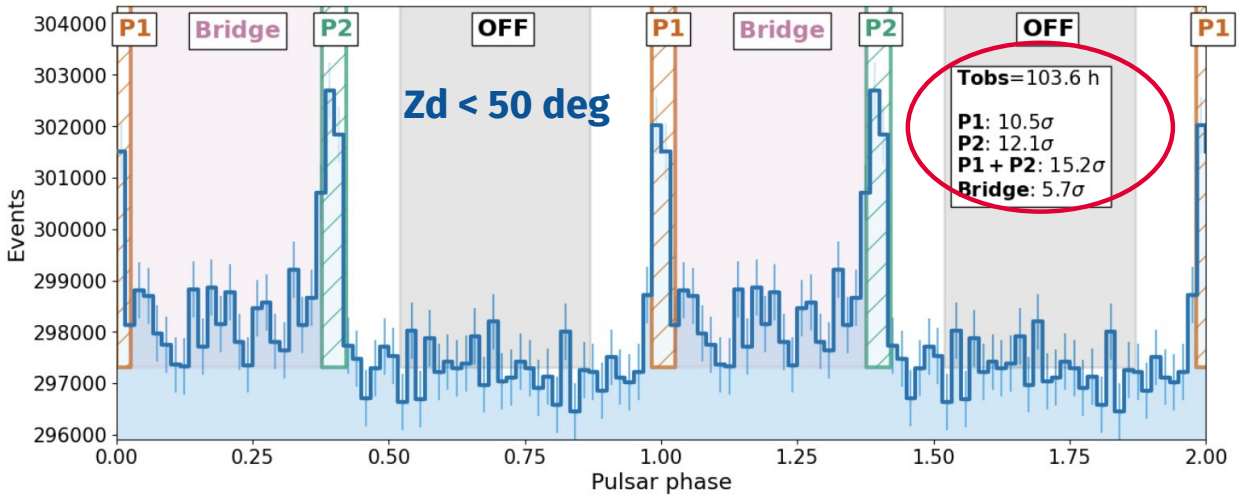
- LST-1 commissioning obs. (Sep. 2020 - Jan. 2023)
- Time after quality cuts: ~103h for Zd < 50deg

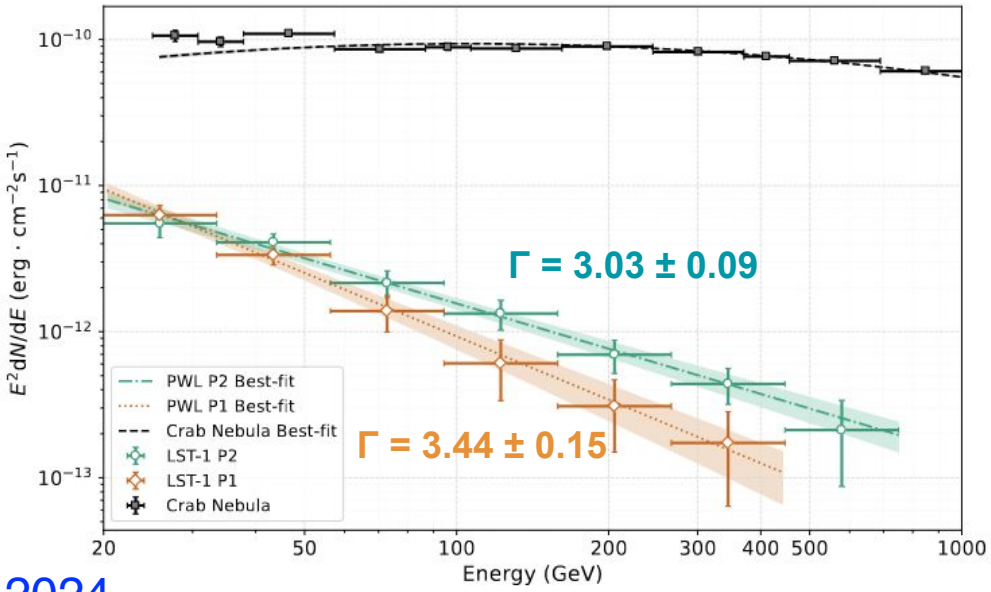
- **Peak location does not change** significantly with increasing energy (20 - 700 GeV)
- **P1 width dropping** until ~10 GeV, **P2 width decrease > 2 GeV**
- **P1/P2 ratio declines up to 100 GeV**, remains constant (P1/P2 ~0.5) at > 100 GeV



P1 + P2 detected at >15σ in 100h

Similar to MAGIC Sumtrigger-II but with only one telescope!





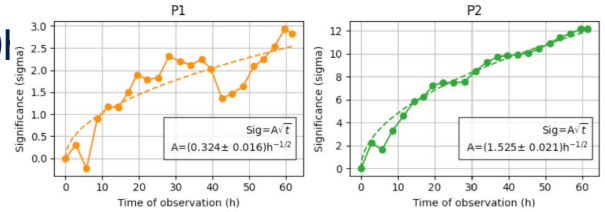
Abe et al. 2024

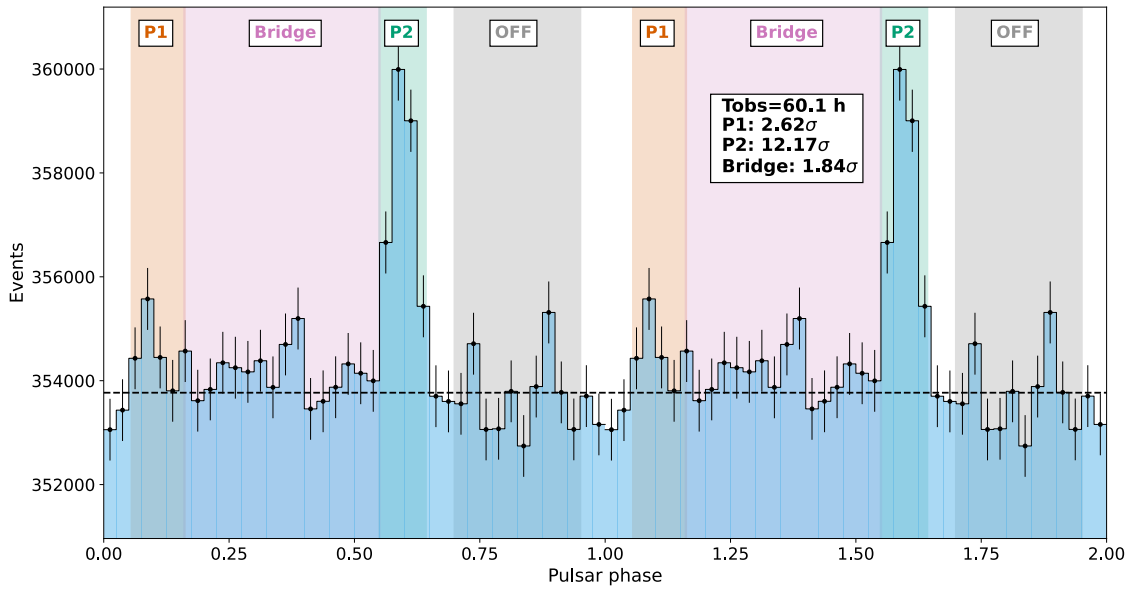
LST-1 Early Science

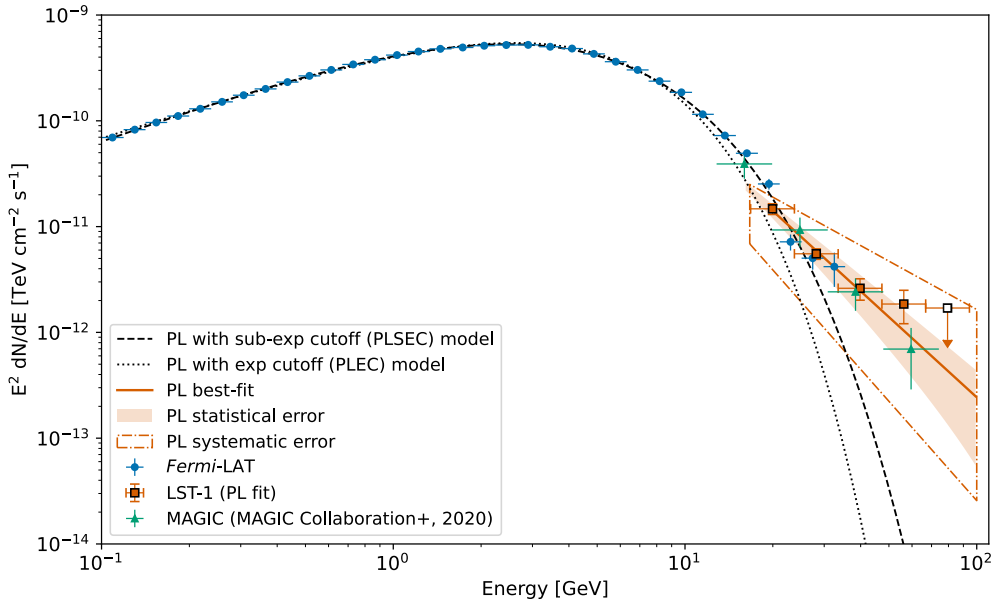
LST-1 observations of the Geminga PSR

- Observed with LST-1 on (Dec. 2022 - March 2023)
- Time after quality cuts: ~60h for Zd < 50deg

- Demonstrates **LST-1 capabilities for PSR studies**: P2 at > 12σ in 60h (vs MAGIC: 6.3σ in 80h)
- **P1 remains undetected**, (2.6σ hint => 200h for a 5σ signal, 30h with the **full LST array**)
- **No E-dependent evolution** within [15 - 31] and [31, 65] GeV bands







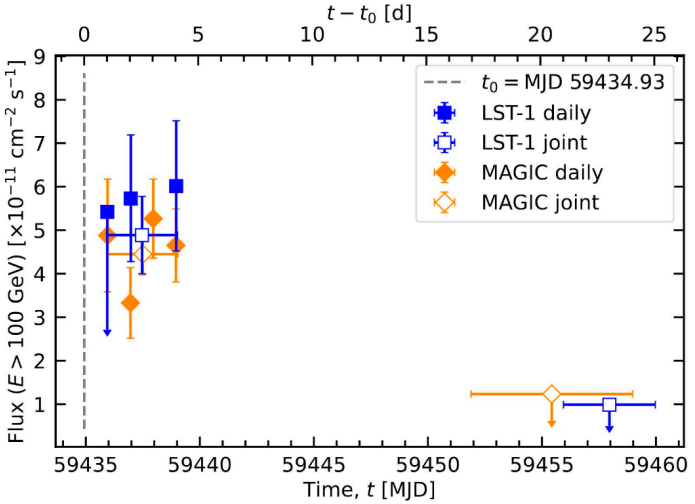
Abe et al. 2025a, accepted

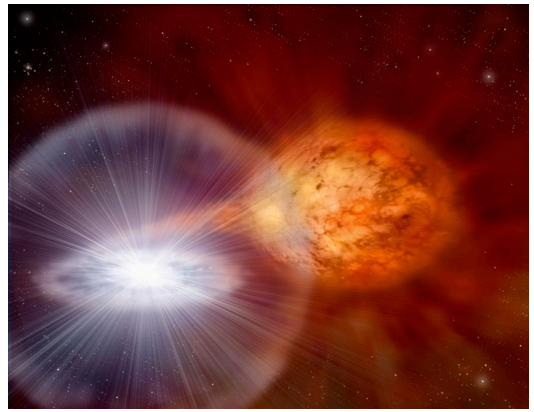
LST-1 Early Science

Nova RS Ophiuchi

Abe et al. 2025b

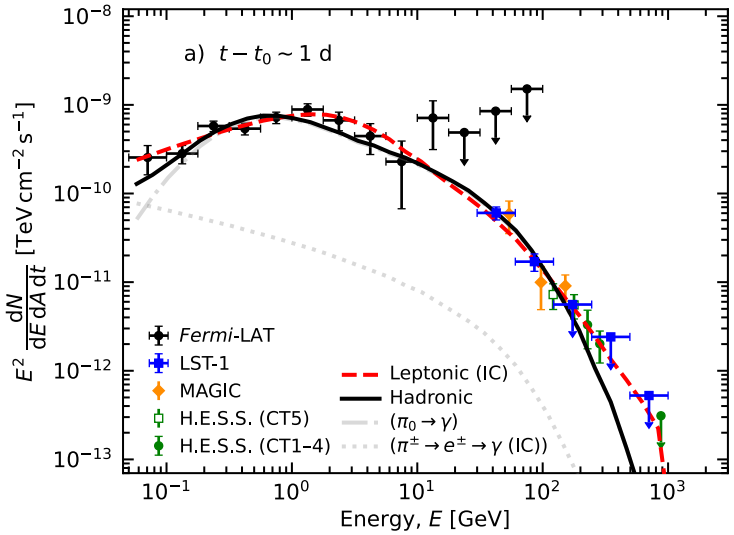
- Symbiotic binary: white dwarf + red giant star, d~2.45 kpc, with recurrent nova outbursts (~15 yr)
- **First nova ever detected at VHE gamma rays**
- Gamma-ray emission modeling: **hadronic** scenario favoured
- Retrieve **spectra of injected particles** (using LST-1, MAGIC, H.E.S.S. and LAT)
- Excellent perspectives for future novae (e.g. **T CrB**)





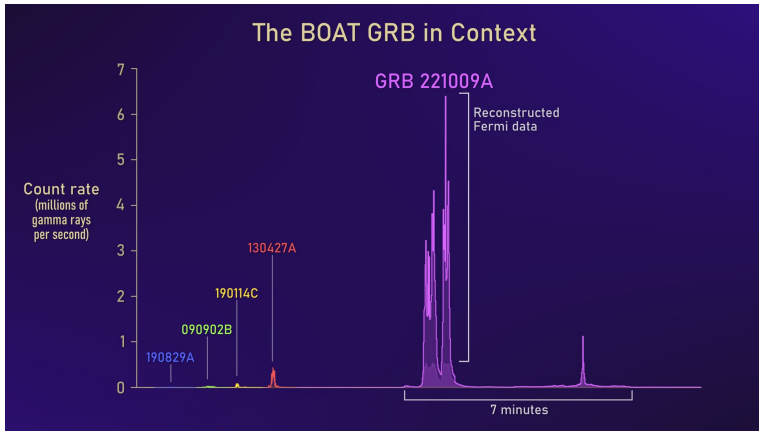
Credit: David A.Hardy/ www.astroart.org & PPARC.

Parameter	Best-fit value on observation day		
	Day 1	Day 2	Day 4
Leptonic BPL model without systematics			
Slope 1, $\Gamma_{e,1}$	$0.0^{+0.8}_{-0.6}$	$-1.3^{+1.5}_{-0.5}$	$-1.4^{+0.6}_{-0.7}$
Slope 2, $\Gamma_{e,2}$	$-3.79^{+0.17}_{-0.18}$	$-3.57^{+0.11}_{-0.15}$	$-3.52^{+0.05}_{-0.06}$
$E_{b,e}$ [GeV]	14^{+3}_{-3}	17^{+8}_{-4}	22^{+9}_{-6}
$\chi^2/N_{d.o.f}$	12.9/15	24.9/21	24.9/15
χ^2_{red}	0.86	1.19	1.66
AIC_c	23.7	34.9	35.8
Hadronic ECPL model without systematics			
Slope, Γ_p	$-2.25^{+0.13}_{-0.13}$	$-2.49^{+0.07}_{-0.07}$	$-2.48^{+0.08}_{-0.08}$
$E_{c,p}$ [TeV]	$0.26^{+0.08}_{-0.08}$	$1.0^{+0.3}_{-0.3}$	$1.6^{+0.6}_{-0.6}$
$\chi^2/N_{d.o.f}$	21.5/16	24.9/22	26.5/16
χ^2_{red}	1.34	1.13	1.66
AIC_c	29.1	32.0	34.1



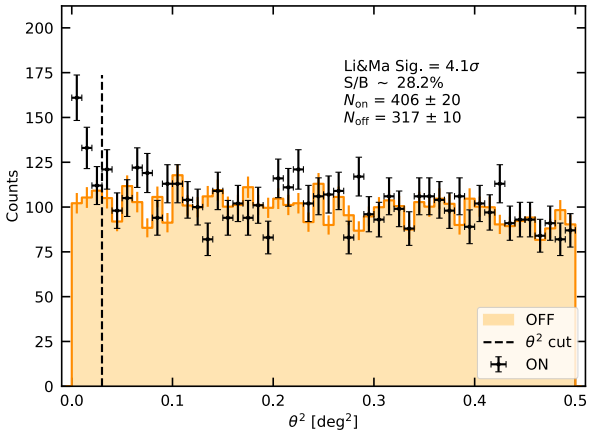
LST-1 Early Science

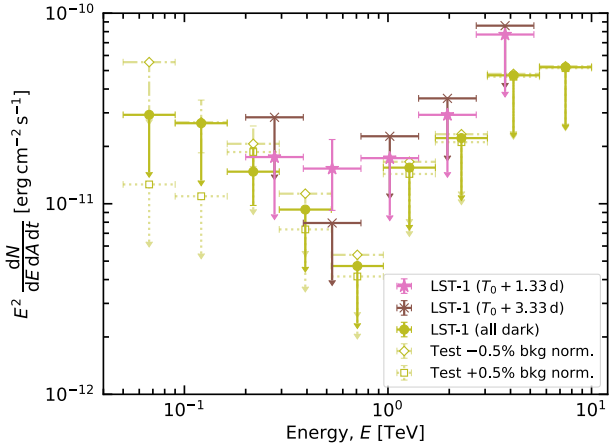
GRB221009A: “The Boat"

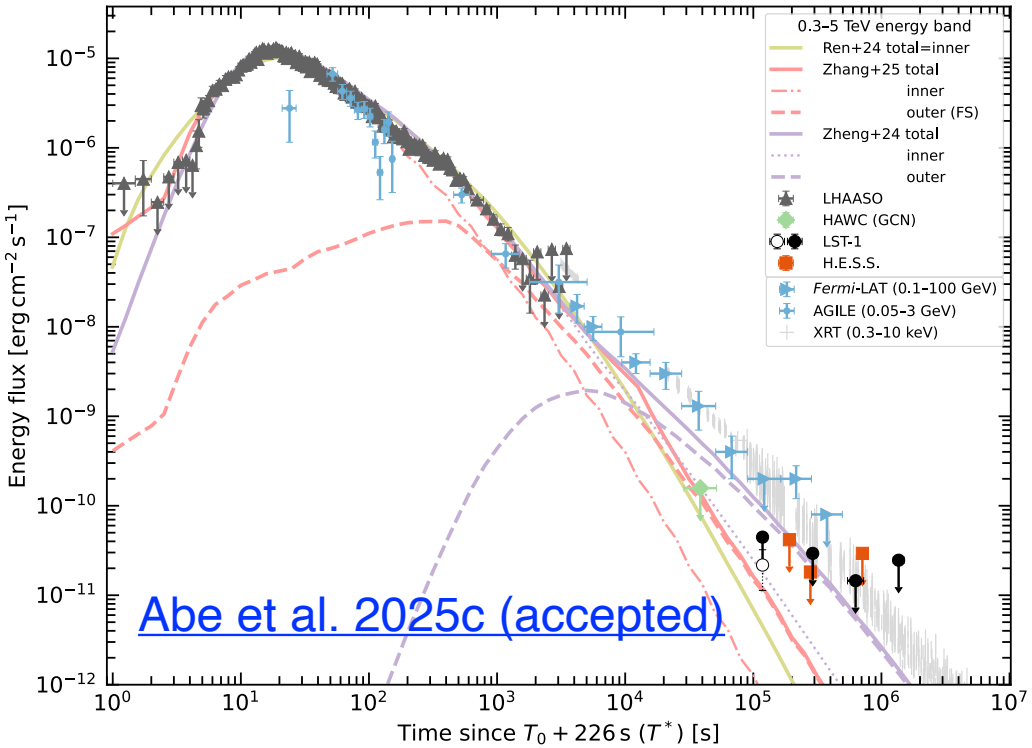


- The brightest of all time (“The BOAT") GRB, **1 event every ~10^3 yrs**
- **Peak energy flux* = 10^5 Crab Units** (LHAASO 2023)
- GRB prompt phase during strong moonlight conditions

- **Hint of detection with LST-1** on Oct. 10 (T0 + 1.33 d): **4.1σ**
- Bridges the HAWC and H.E.S.S. ULs, and provides constraints structured jet models (Ren+ 2024, Zheng+ 2024)



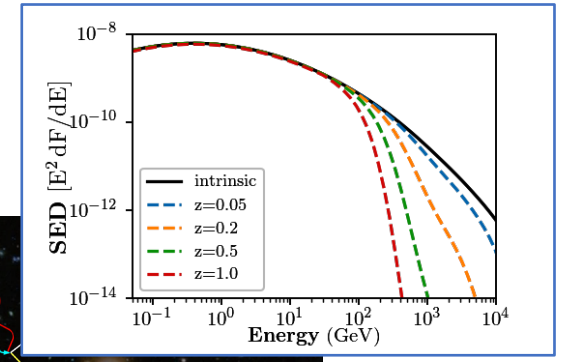


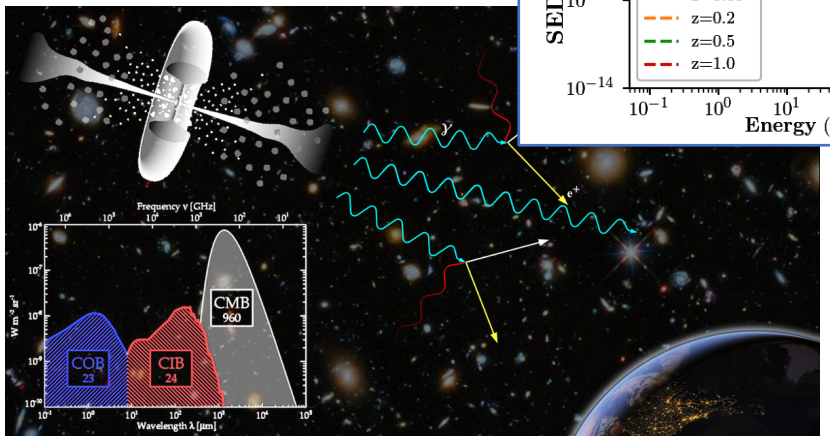


LST-1 Early Science

OP 313: the farthest AGN @ VHEs

- **Most distant quasar ever detected in VHE** (z=0.9973) and second most distant VHE source after GRB 201216C
- Not detected in VHE before. Attempted by MAGIC (2014, 2019)
- Strong attenuation by EBL in the VHE regime + intrinsic γ-γ absorption
- **Extensive MWL campaign** (radio, IR, optical, UV, γ-ray)

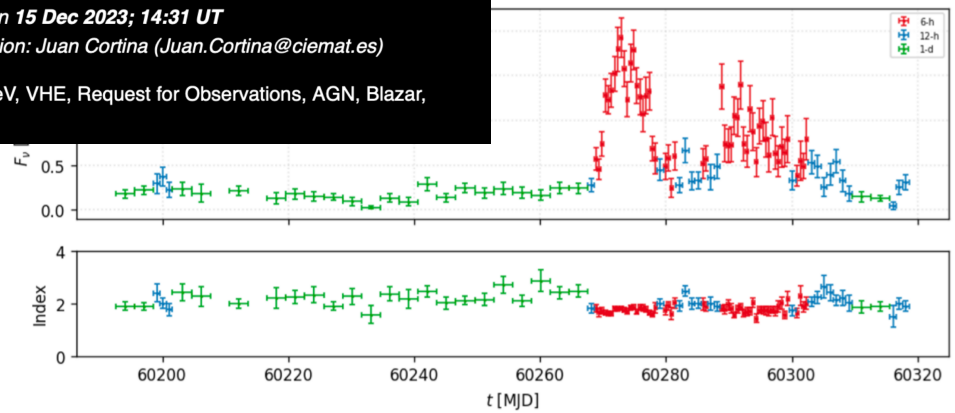


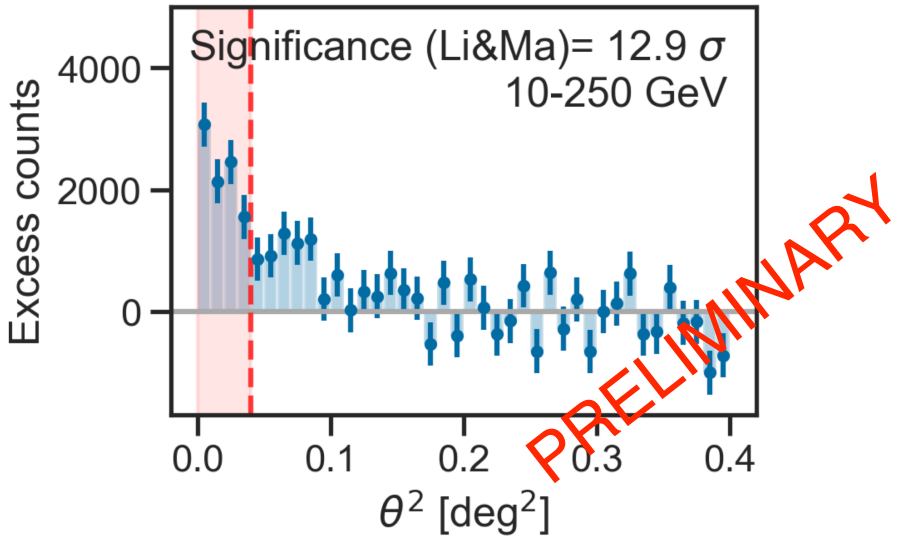


First detection of VHE gamma-ray emission from FSRQ OP 313 with LST-1

ATel #16381; *Juan Cortina (CIEMAT) for the CTAO LST collaboration*
on ***15 Dec 2023; 14:31 UT***
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, AGN, Blazar, Quasar

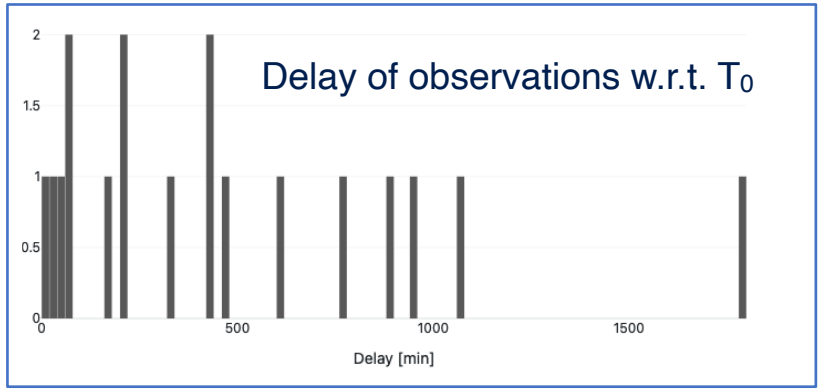




LST-1 Early Science

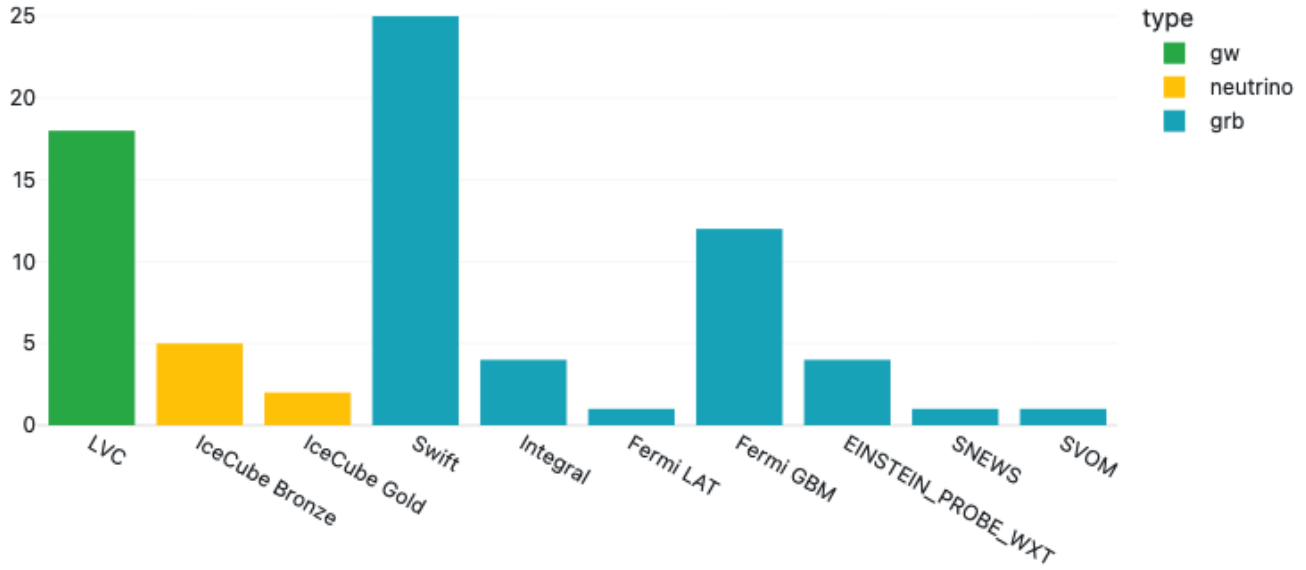
Transients follow-up

- **LST-1 low E_{th}** of few 10's GeV is crucial for transient sources (typically soft: $\Gamma \gtrsim 2$)
- **Fast repositioning** (required for very fast transient events, e.g. GRBs, GWs…)
- **Automatic follow-up** (procedure already implemented ("Transients Handler")



Total	GRBs	GWs	Neutrinos
73 # total alerts	48 # total alerts	18 # total alerts	7 # total alerts
18 # observed alerts	16 # observed alerts	2 # observed alerts	0 # observed alerts
41.2h observed	37.9h observed	3.3h observed	0.0h observed

VOE origin of alerts

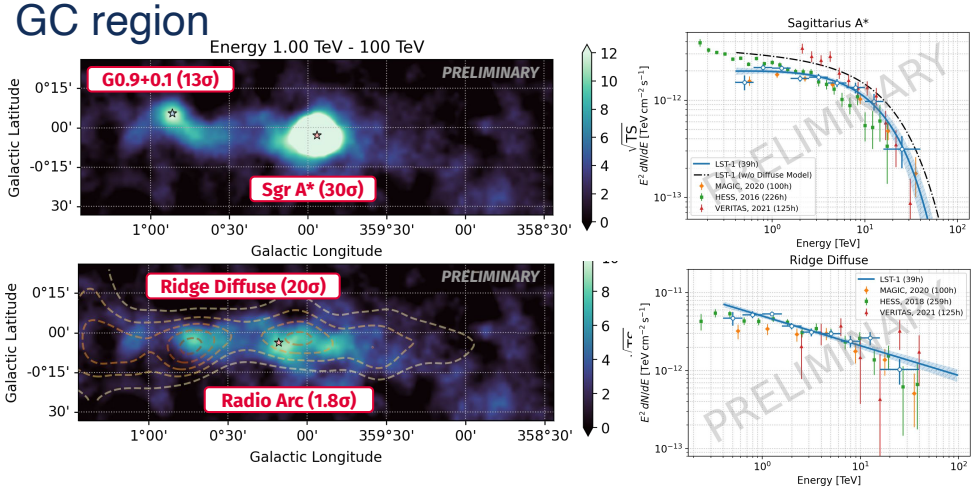


Adapted from D. Mazin, Canfranc (2025)

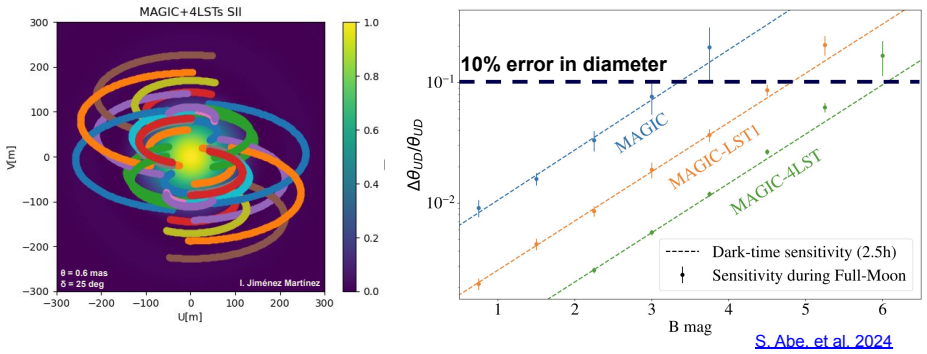
LST-1 Early Science

Steady VHE γ-ray sources

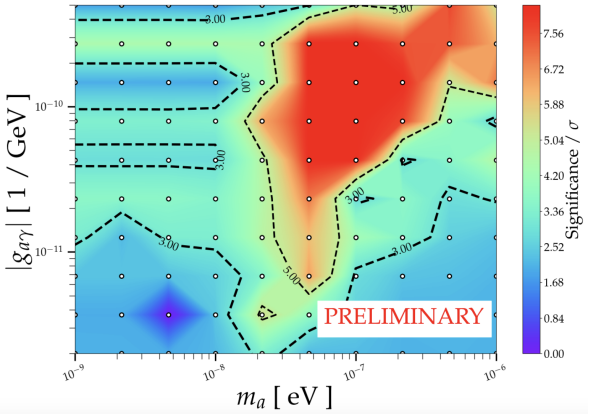
GC region

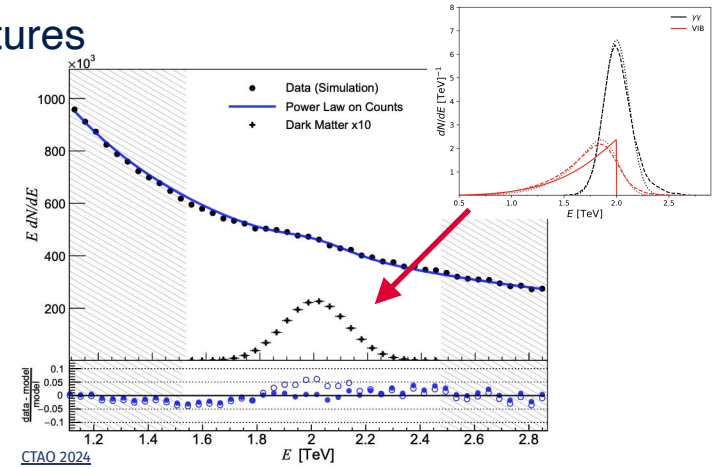


Stellar intensity interferometry

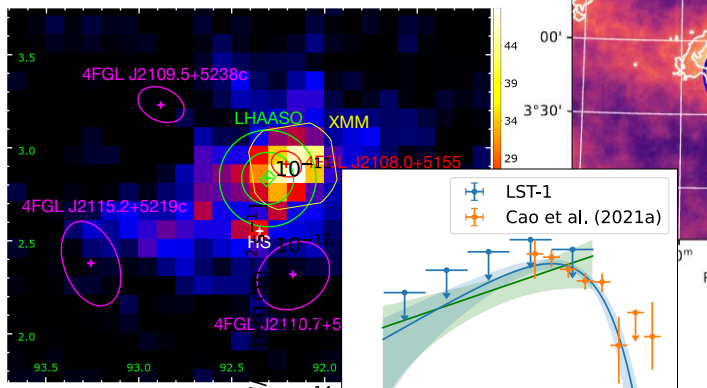


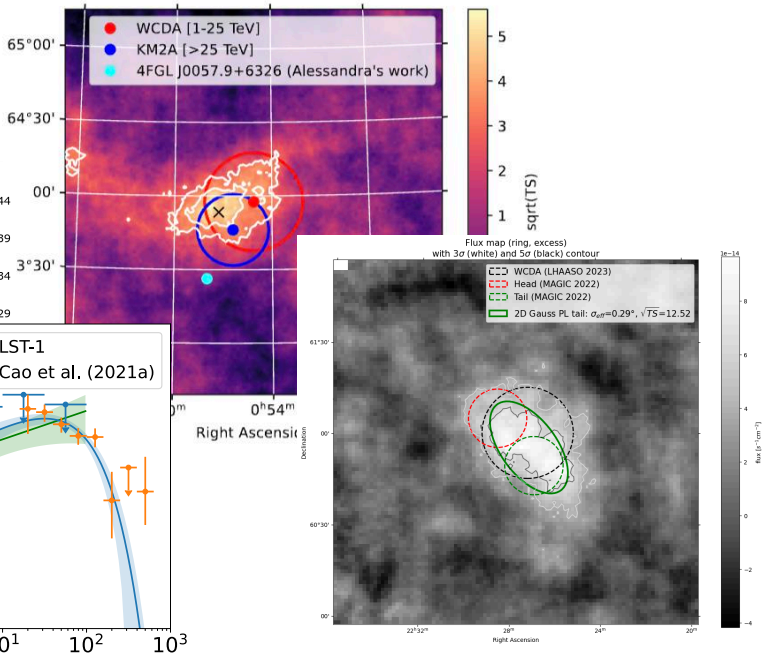
Search for Dark Matter signatures





The quest for PeVatrons





LST array coming soon…

Adapted from D. Mazin, Canfranc (2025)

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