The current view of the gamma-ray sky: status of Fermi-LAT and the MAGIC telescopes

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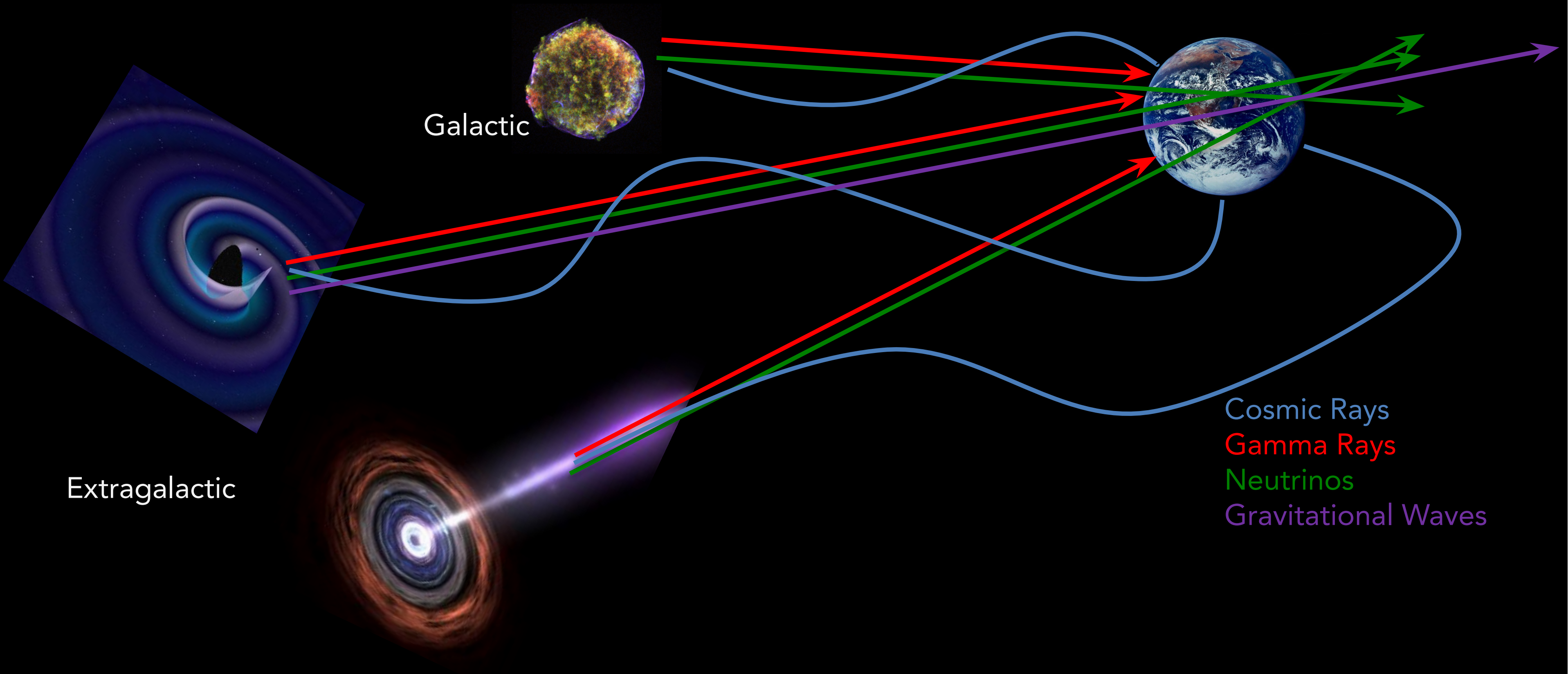
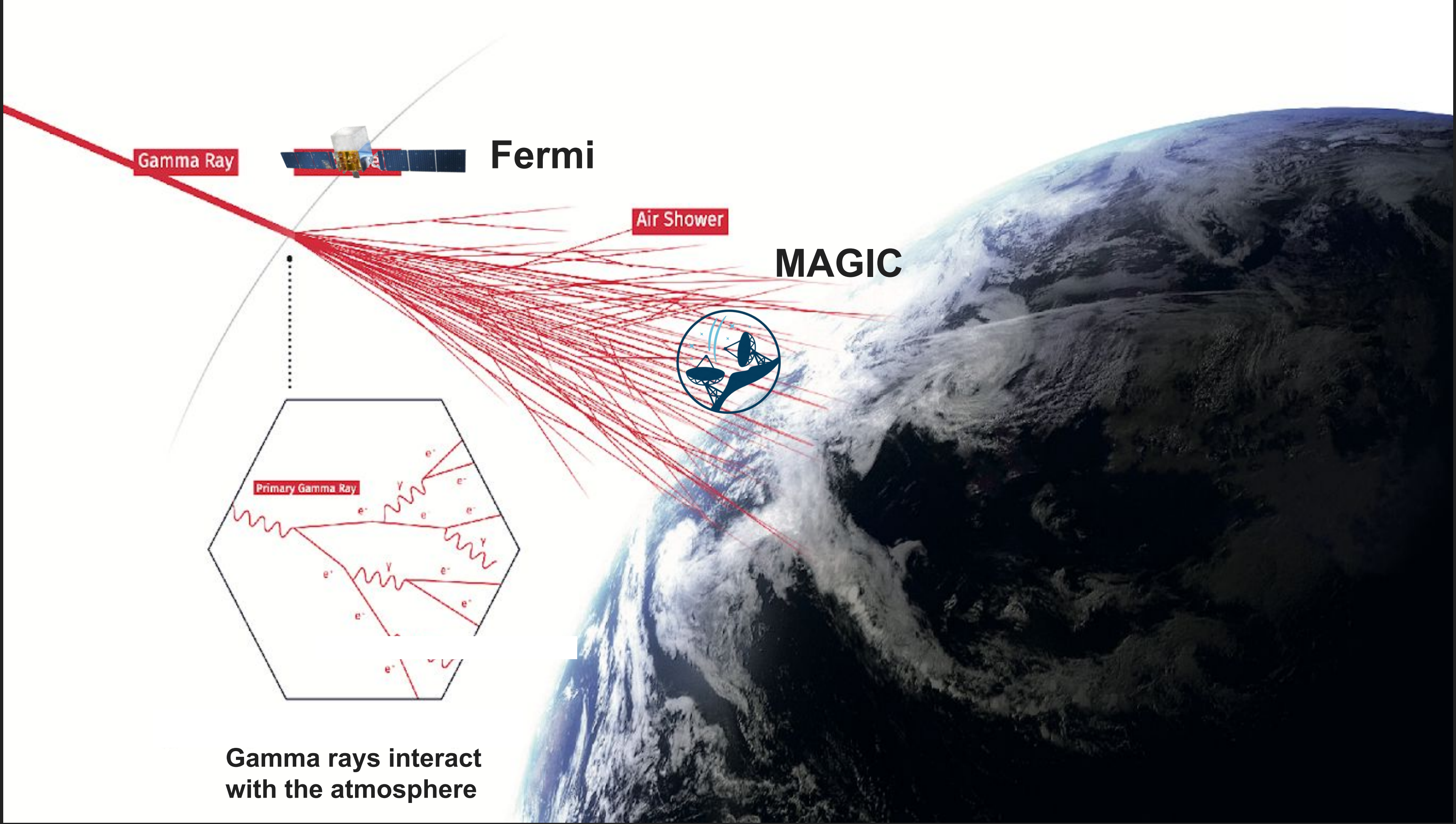
on behalf of the Fermi-LAT and MAGIC collaborations
(IPARCOS & Universidad Complutense de Madrid)

RENATA Meeting, 22 September 2025

Cosmic Accelerators and their messengers




Gamma Ray
Fermi
Air Shower
MAGIC
Primary Gamma Ray
Gamma rays interact
with the atmosphere

Fermi Gamma ray Space telescope

- ➢ Launched on June 11, 2008
- ➢ Low earth orbit, 96 minutes
- ➢ Still operating - 17+ years
- ➢ **Primary instruments**: Large Area Telescope (LAT) + Gamma-ray Burst Monitor (GBM)

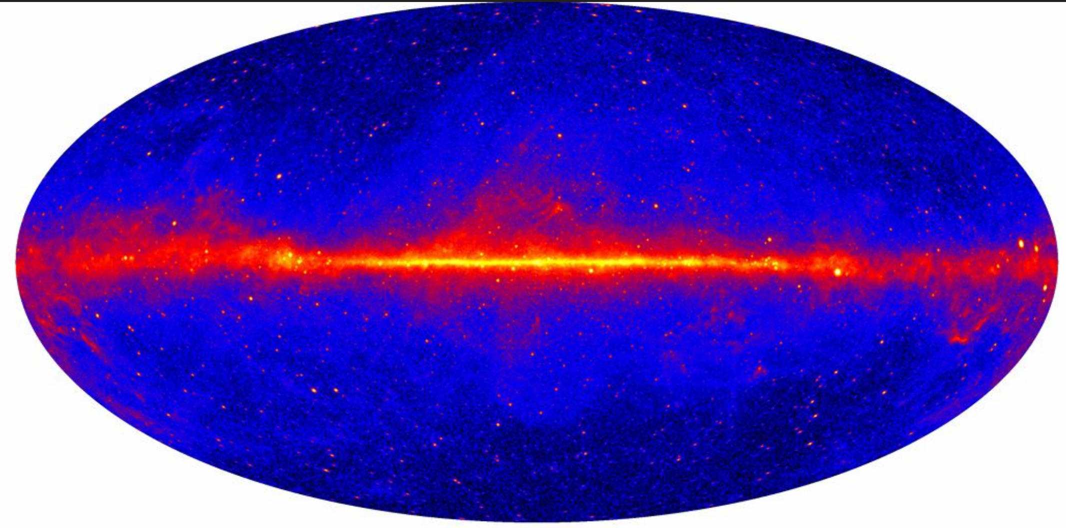
Credits: *The Fermi Gamma-ray Space Telescope*

Fermi Large Area Telescope

- ➢ Large field of view (1/5 of the sky)
- ➢ Broad energy range covering ~20 MeV-300 GeV (optimised for 100 MeV-800 GeV)
- ➢ Pair conversion telescope

Provides **GeV bridge** between GBM (7 keV–40 MeV) and ground Cherenkov arrays (≥50 GeV)-vital for broadband SEDs

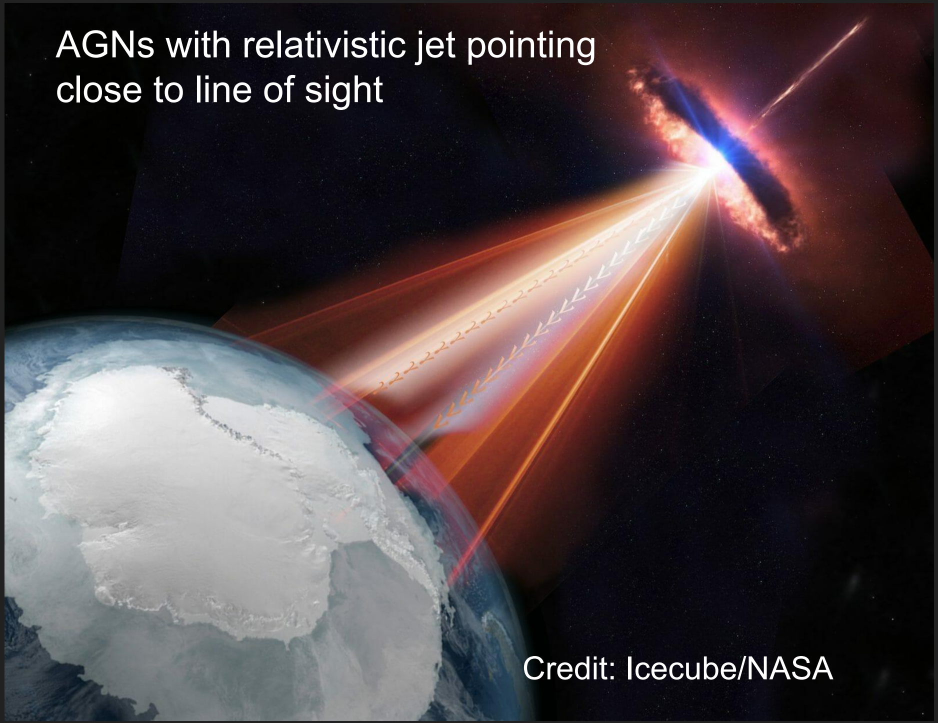
Mapping the γ-ray Universe



Fermi LAT, Energy > 1 GeV, 15 years of data (9,211,207 photons)

- **17-yr all-sky survey** - LAT sweeps the entire sky every regularly - monitoring high-energy activity across solar cycles and AGN flares
- **4FGL-DR4 catalog (2023): 14 yr catalog, 7000+ sources** spanning 50 MeV-1 TeV; approx 40% still unassociated, encouraging follow-up campaigns (4FGL DR3;Ballet et al., 2024 arXiv:2307.12546, 4FGL;Abdollahi *et al* 2020 *ApJS* 247 33)
- Important for multi-wavelength planning, stacking studies (e.g., Paliya et al., 2019)
- **Public interactive tools**: Light Curve Repository, FAVA, GW Table

Blazar Physics at GeV Energies

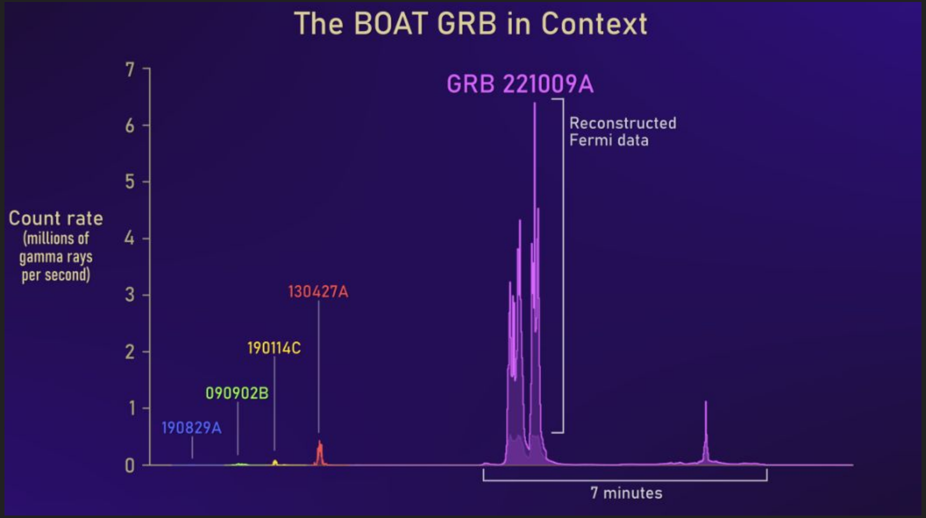


4LAC-DR3 catalog: 3407 AGN (|b| > 10°) - the largest uniform sample of relativistic jets; (Ajello et al., 2022)

Population studies - anisotropic cosmological evolution, EBL attenuation (e.g., Abdollahi et al., 2018)

Hard-source catalogs (LAT >10-50 GeV):
the GeV→TeV **bridge** and prime target lists for ground based Cherenkov telescopes like MAGIC (1FHL (>10 GeV), 2FHL (>50 GeV), 3FHL (>10 GeV), **4FHL** (>50 GeV;16 yr, forthcoming), 5FHL (>1 GeV, in preparation)

Transient & Explosive Universe



NASA's Fermi Finds New Feature in Brightest Gamma-Ray Burst Yet Seen Summary - July 2024

Credit: NASA's Goddard Space Flight Center and Adam Goldstein (USRA)

GRB 221009A ("B.O.A.T.")

Triggered 9 Oct 2022– brightest burst seen by *Fermi*.

LAT captured photons up to **99 GeV** (prompt, 240 s) and a **400 GeV candidate** in the afterglow – highest-energy GRB photons ever detected from space (Axelsson et al., 2025)

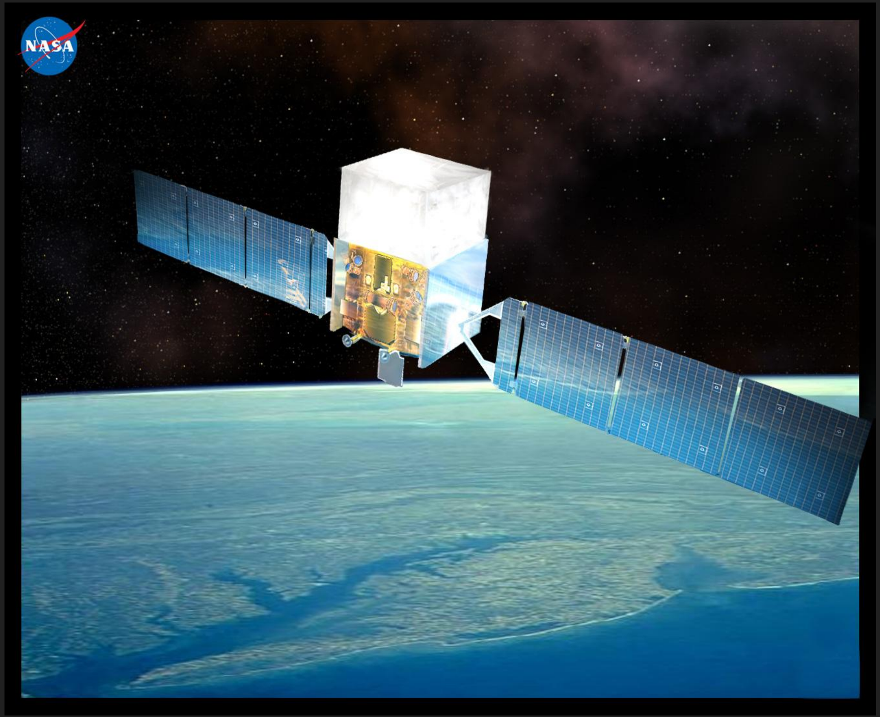
GeV light-curve constraints jet magnetisation, particle acceleration and tests of Lorentz-invariance

LAT Flare Advocate Program: daily human monitoring + automated pipelines issue alerts (ATels/GCNs) and trigger ToOs within hours, enabling rapid GRB and transient follow-ups

Fermi observatory status and future perspective

- *Fermi* continues to operate extremely smoothly and to perform at full capability
- On orbit for 17+ years
- >800 Fermi publications
- No degradation of science performance
- Improved due to software and configuration changes, restored ToO capability recently
- Recently ranked as high-priority in the 2025 NASA senior review

Orbit outlook - Lifetime of orbit extends into the mid-2030s.



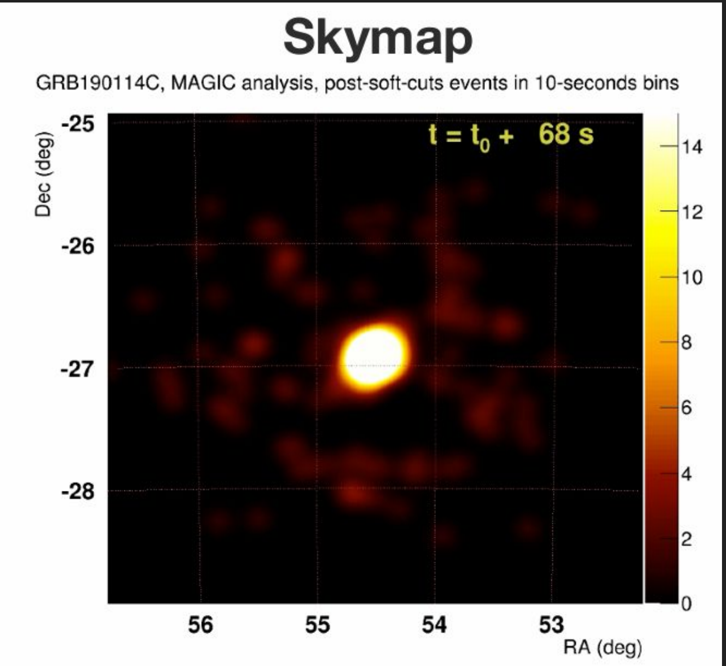
Credits: Judy Racusin talk at Fermi Summer School 2025

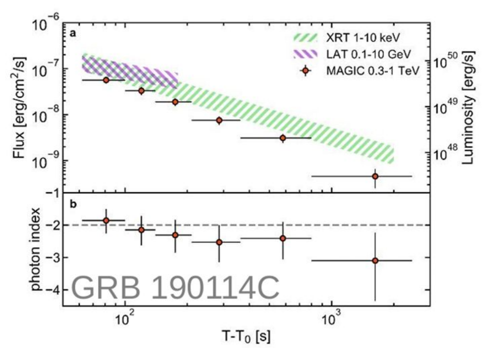
MAGIC - Major Atmospheric Gamma Imaging Cherenkov Telescopes

The MAGIC telescopes at Roque de los Muchachos, La Palma (Image: IAC)

- Imaging Air Cherenkov Telescopes
- Canary Islands, La Palma, Observatorio del Roque de los Muchachos, 2200 meter a.s.l.
- 2003 first telescope
- 2009 stereoscopic
- Two 17-meter telescopes
- Energy range ~ 50 GeV to ~ 100 TeV
- Lightweight for fast repositioning

Energetic Cosmic Explosions





Gamma ray burst (GRB)

➢ GRB 190114C (14 Jan 2019): first TeV photons from a GRB; MAGIC saw 0.2-1 TeV afterglow starting ~1 min post-trigger

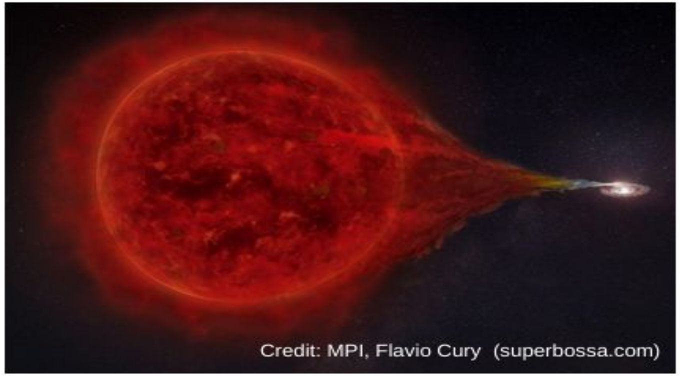
➢ First detection of TeV photons from a γ-ray burst

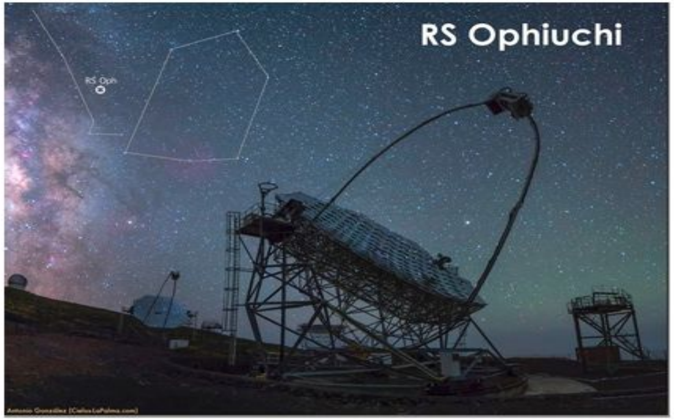
➢ MAGIC measured an inverse-Compton afterglow peaking at > 1 TeV, opening a new window on prompt/afterglow physics

MAGIC Coll. et al. Nature, 2019, 575, 455

Outburst of recurrent nova RS Ophiuchi

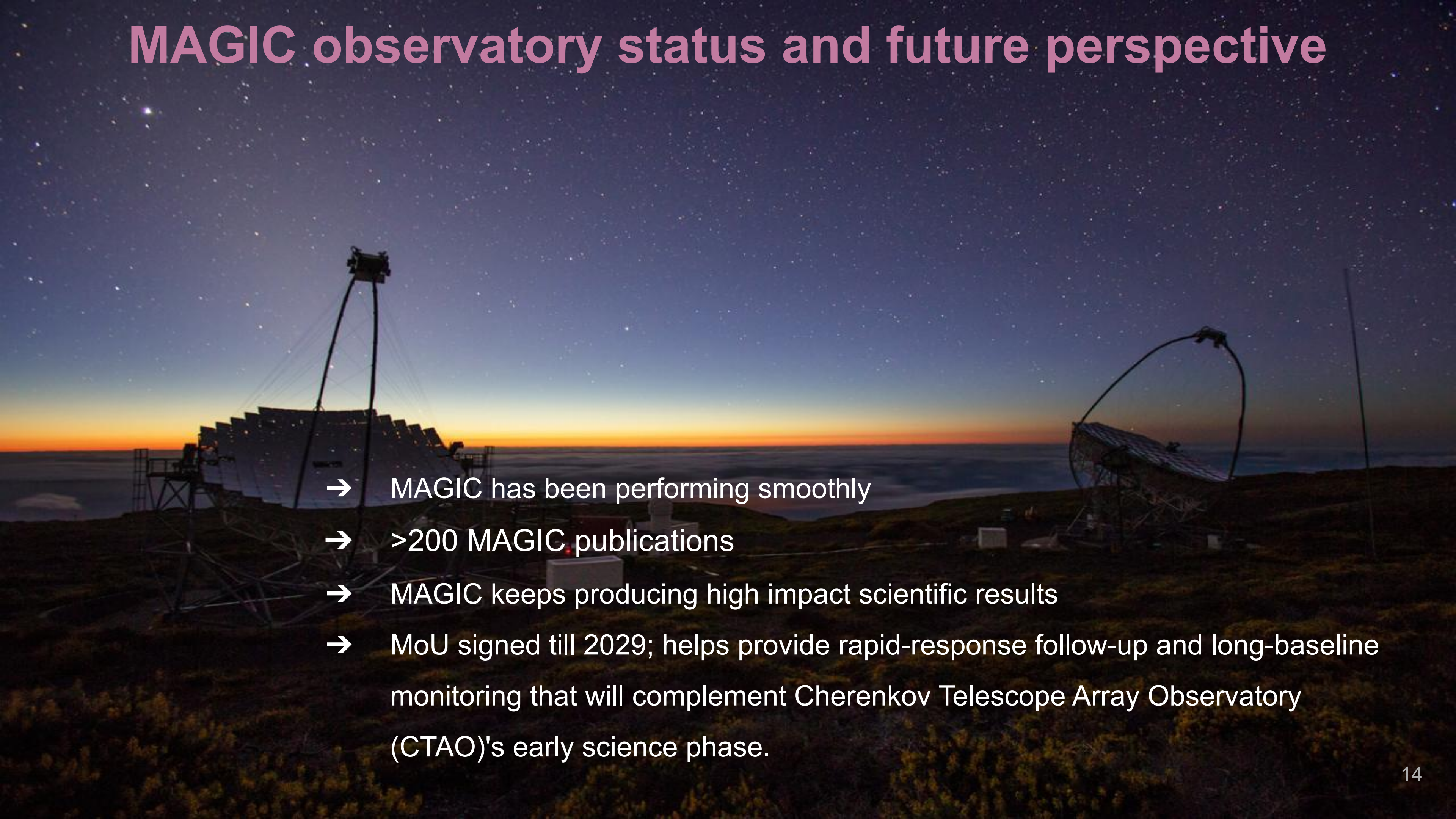
- ➔ The first nova detected in VHE gamma rays
- ➔ Recurrent symbiotic novae with outbursts every ~15 years
- ➔ Latest outburst on 2021.08.8 UT ~22:20
- ➔ Independently followed and detected by H.E.S.S. (Aharonian et al. 2022) and MAGIC (Acciari et al. 2022)
- ➔ Indicates rapid (day scale), efficient cosmic ray acceleration in a dense magnetised environment





Optical Intensity Interferometry

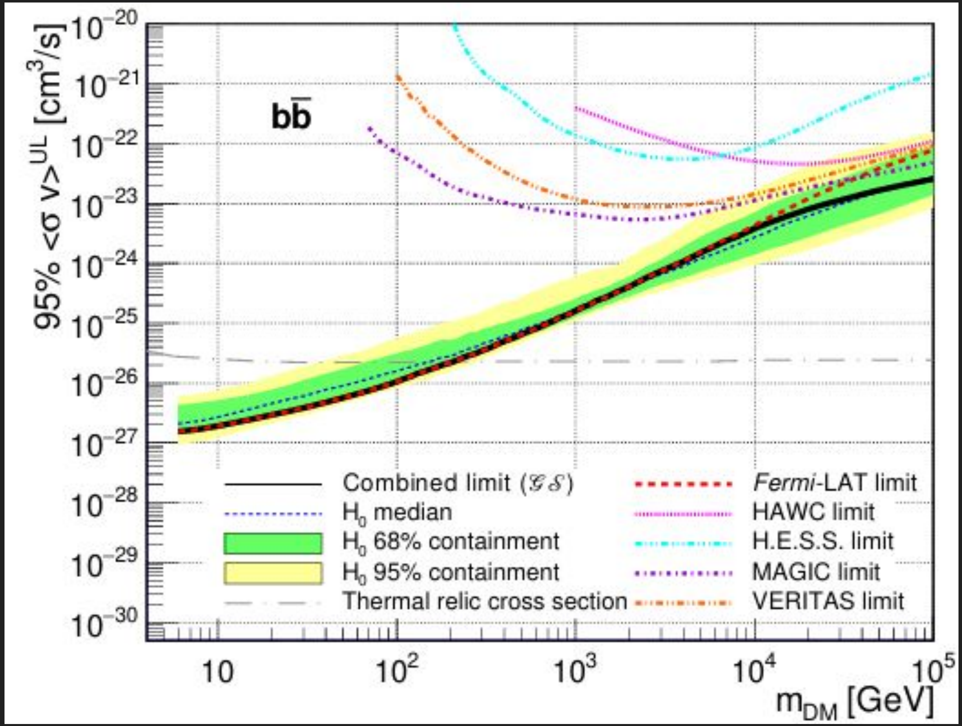
- ➔ Measure size of stars in optical
- ➔ Started in 2019
- ➔ Minimal changes to hardware
- ➔ Data taking during Moon time, where regular observations not possible
- ➔ First **MAGIC-Stellar Intensity Interferometry** measurements (22 stellar diameters) show the telescopes doubling as a precision optical interferometer (Abe et al, 2024, MNRAS)



MAGIC observatory status and future perspective

- ➔ MAGIC has been performing smoothly
- ➔ >200 MAGIC publications
- ➔ MAGIC keeps producing high impact scientific results
- ➔ MoU signed till 2029; helps provide rapid-response follow-up and long-baseline monitoring that will complement Cherenkov Telescope Array Observatory (CTAO)'s early science phase.

Joint Dark-Matter Limits with Fermi-LAT and IACTs



[Fermi-LAT, HAWC, H.E.S.S., MAGIC & VERITAS - Combined dSph DM search, arXiv:2508.20229]

- ➢ Unified joint-likelihood analysis across 20 dwarf spheroidal galaxies, spanning 5 GeV-100 TeV
- ➢ Combined search by Fermi-LAT; the imaging atmospheric Cherenkov arrays MAGIC, H.E.S.S., and VERITAS; and the HAWC water Cherenkov detector
- ➢ **Common analysis, stronger limits**: A global joint likelihood across 20 dwarfs yields up to 2-3× tighter cross-section limits than any single instrument

Joint Observations MAGIC - LST 1

- LST-1 is the first large-sized telescope out of four that will be a part of CTAO North
- MAGIC and LST-1 are on the same site, joint observations improve sensitivity
- CTAO - see the next talk by Rubén López Coto

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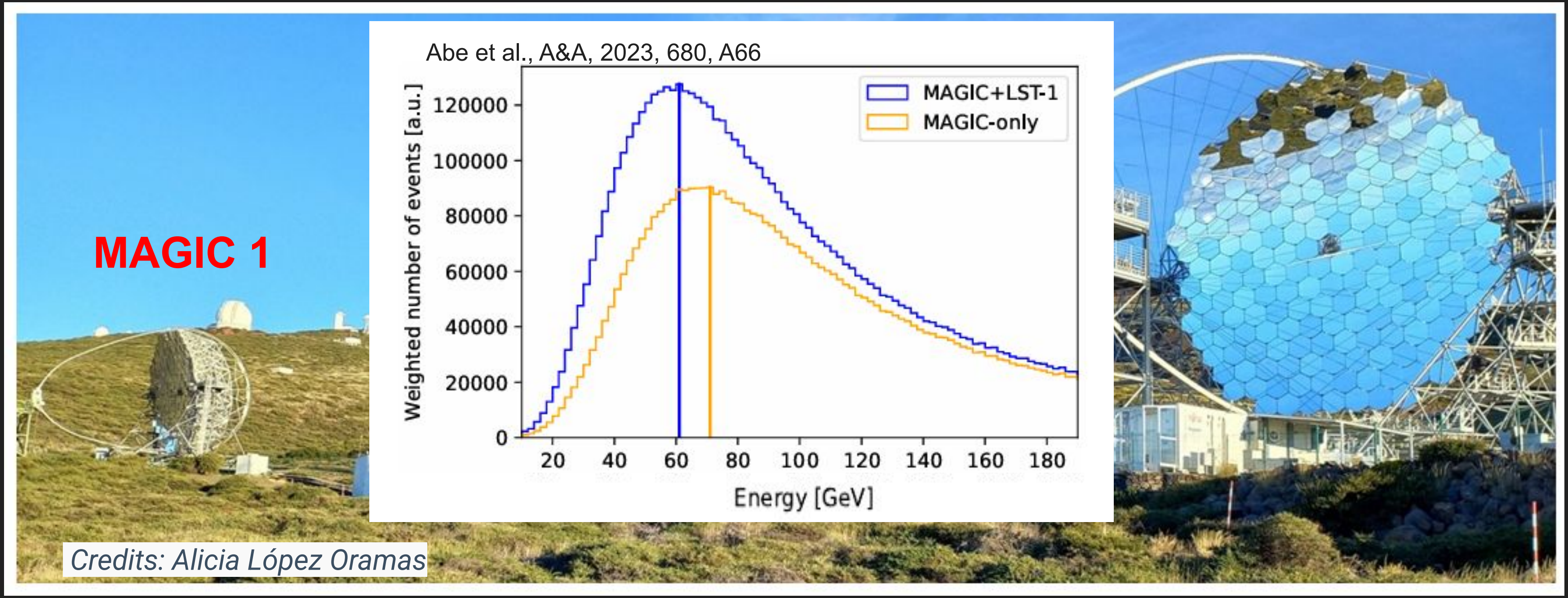

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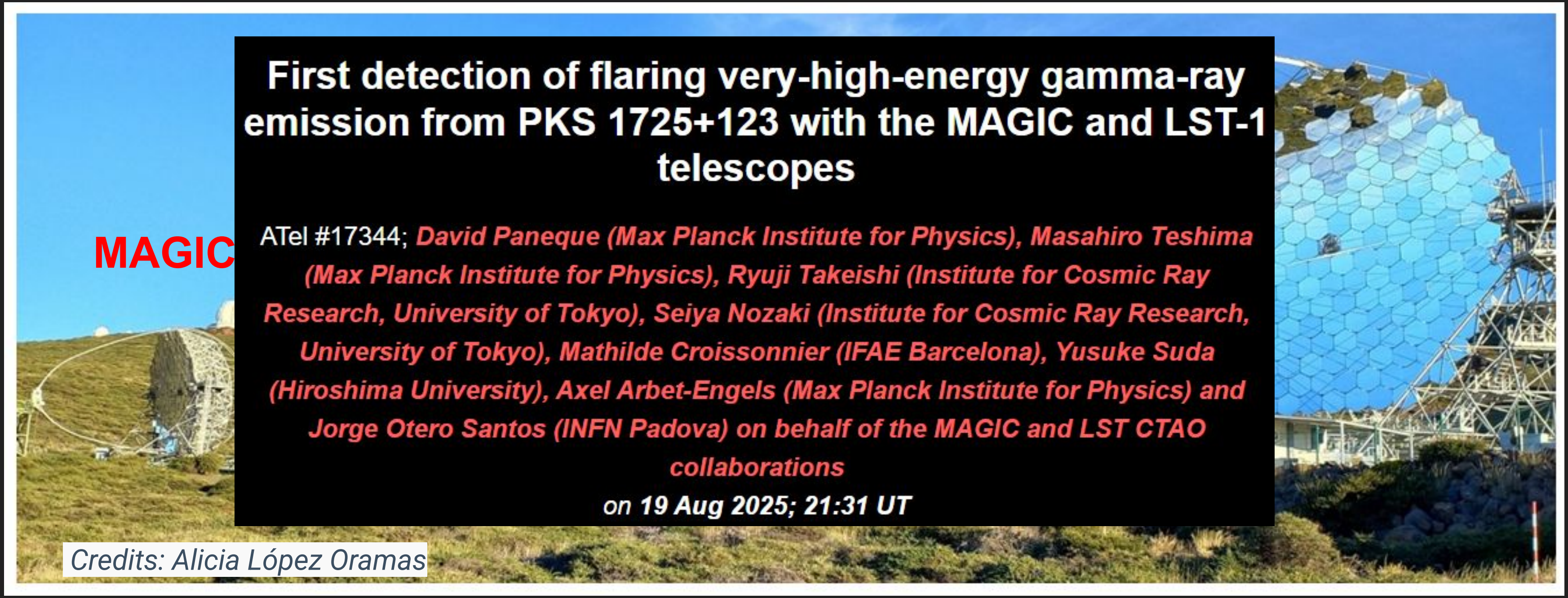
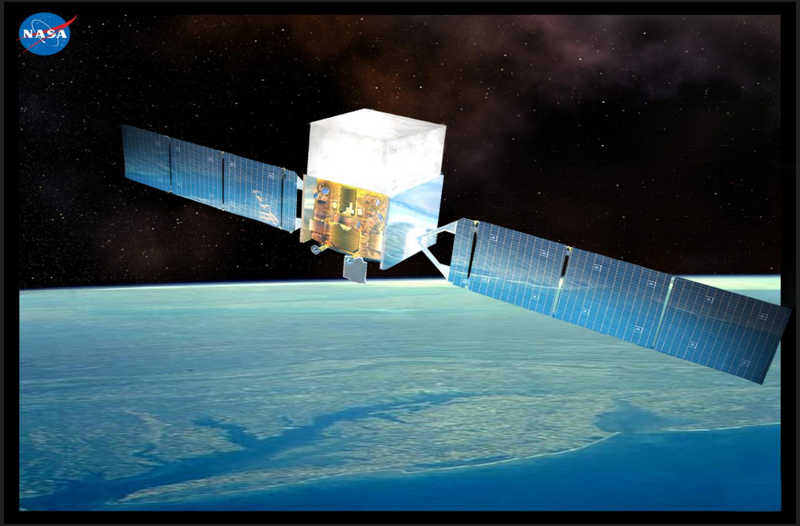


Summary

- *Fermi*-LAT scans the entire sky optimized for the 100 MeV-800 GeV band pass from space, while MAGIC images 50 GeV-100 TeV air-showers on La Palma, covering the gamma-ray sky



- Ongoing software and hardware upgrades plus MoUs through ~2030 keep both facilities running smoothly and ready for CTAO.

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This work was supported by the Spanish ministry of Science and Innovation and State Research Agency through project PID2022-138172NB-C42 (MCIN/AEI/10.13039/501100011033)