

A New Era of Astrophysics: CTAO at the Forefront

LST Inauguration Workshop – 16 October 2026

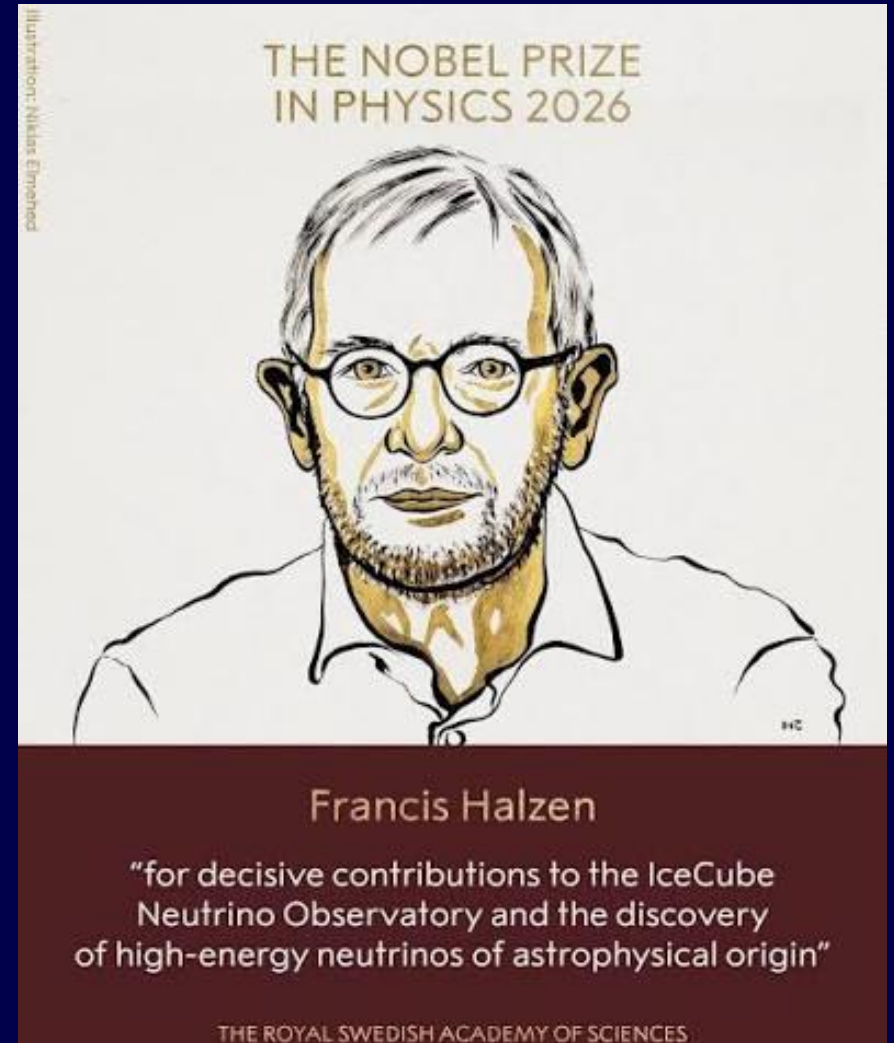
Roberta Zanin, CTAO Project Scientist
roberta.zanin@cta-observatory.org

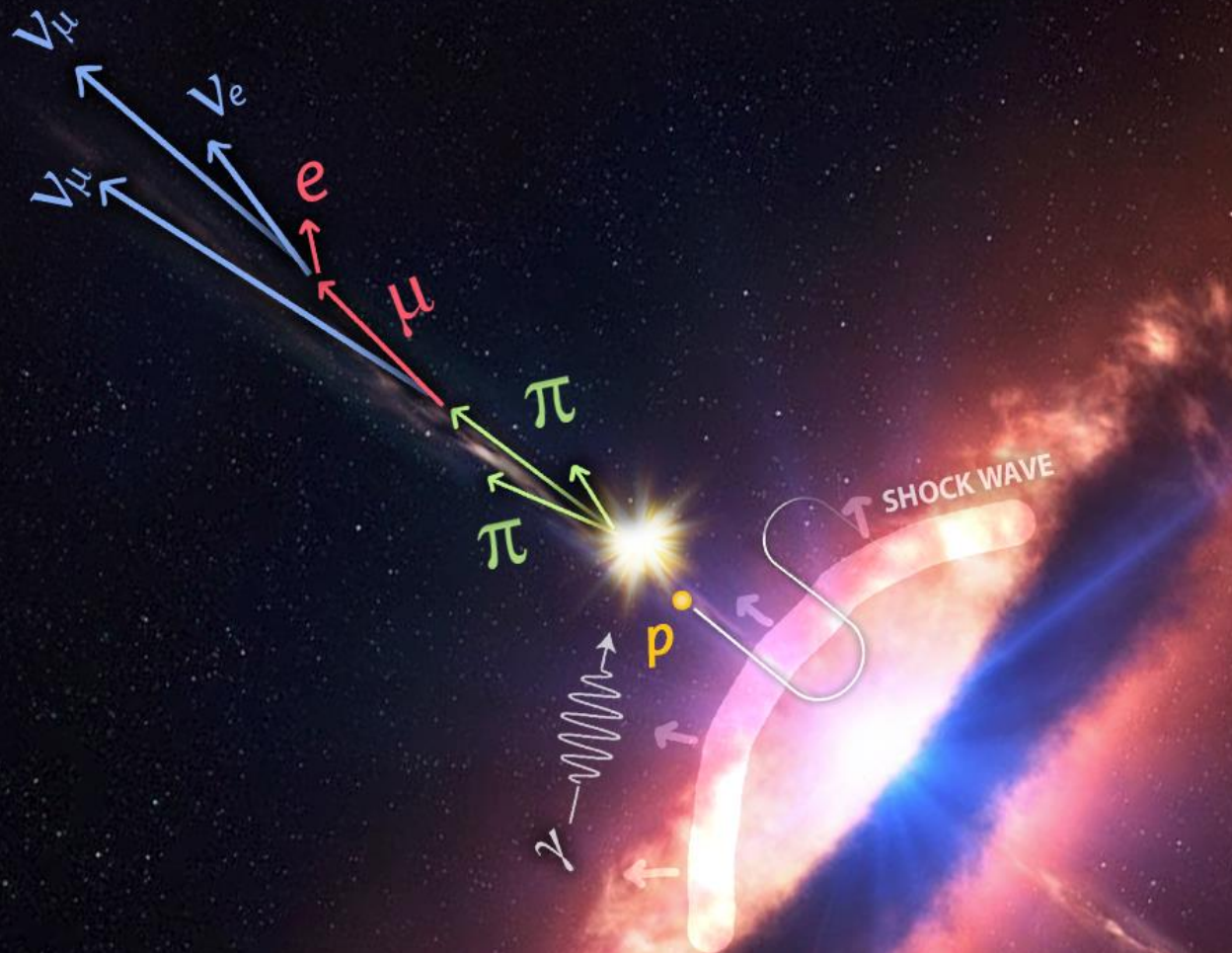
A New Era in Astrophysics

How do we understand the most extreme phenomena in the Universe?



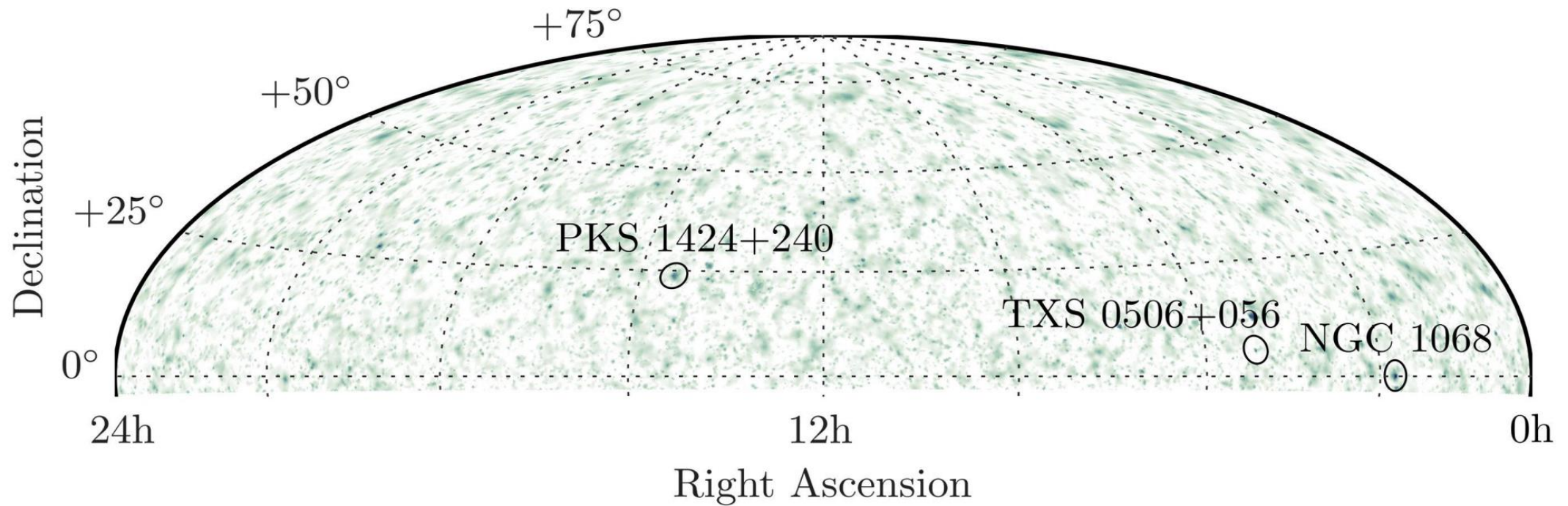
Multi-messenger Astrophysics: Nobel Prize to ν





ν astronomy

IceCube coll 2022

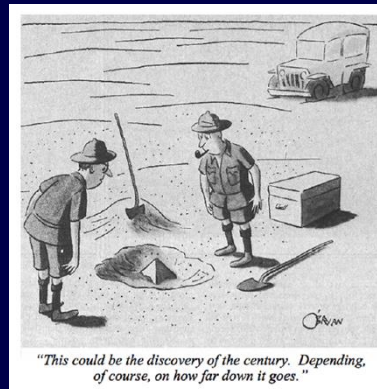
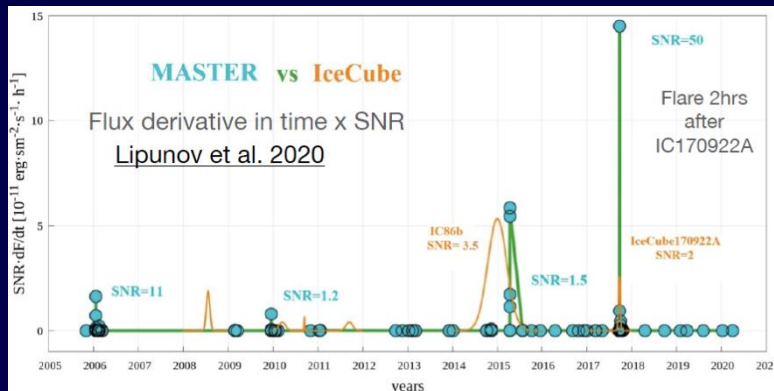


TXS 0506+056

Follow-up detections of IC170922 based on public telegrams



Inoue+2020

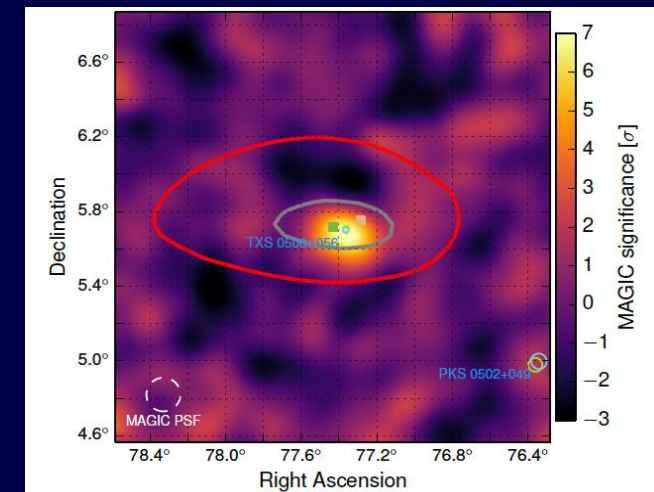
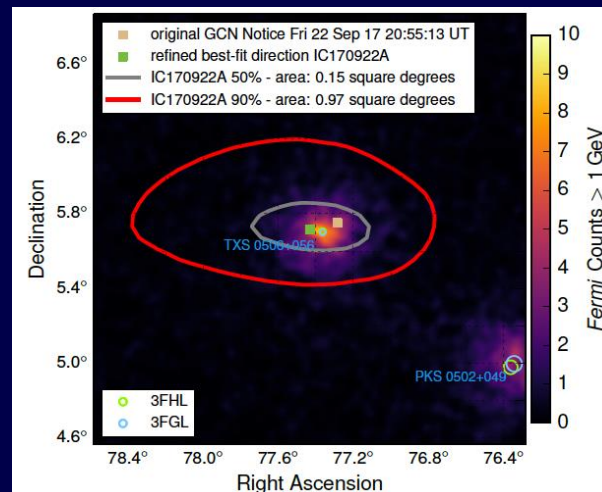
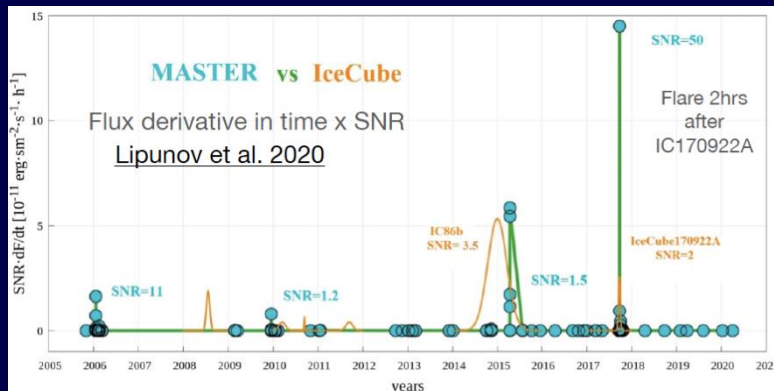


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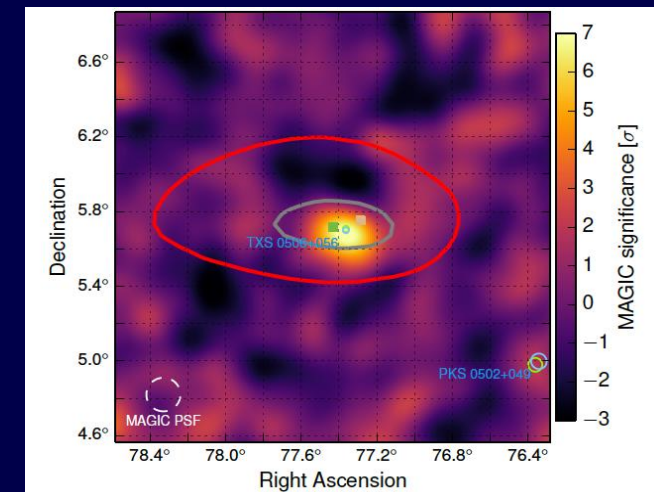
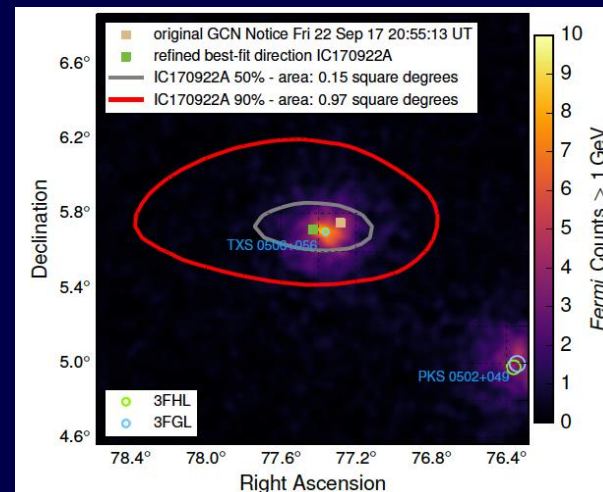
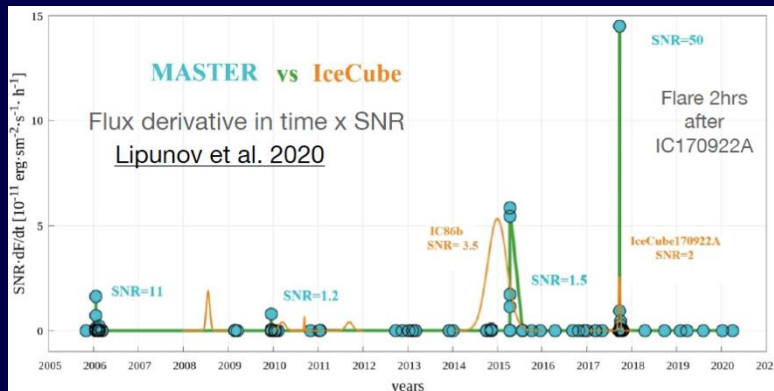
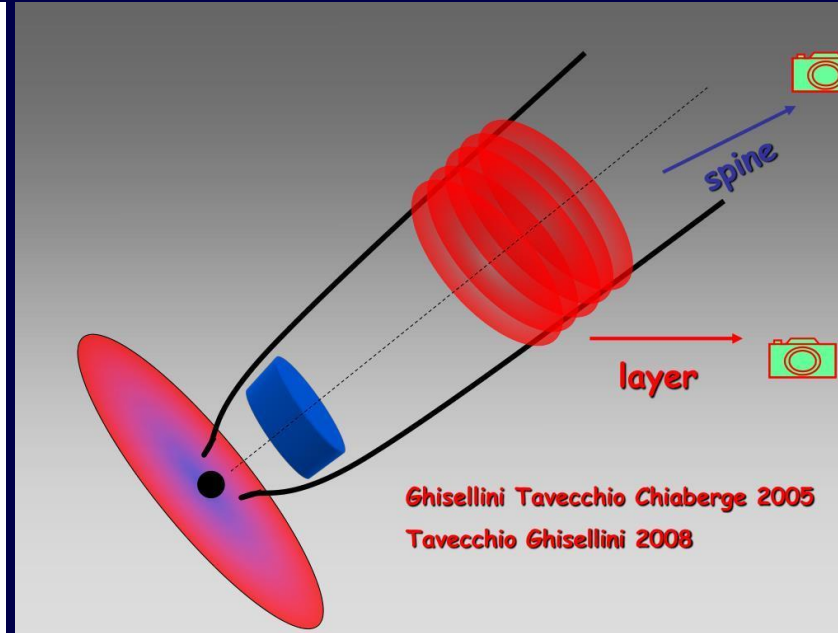
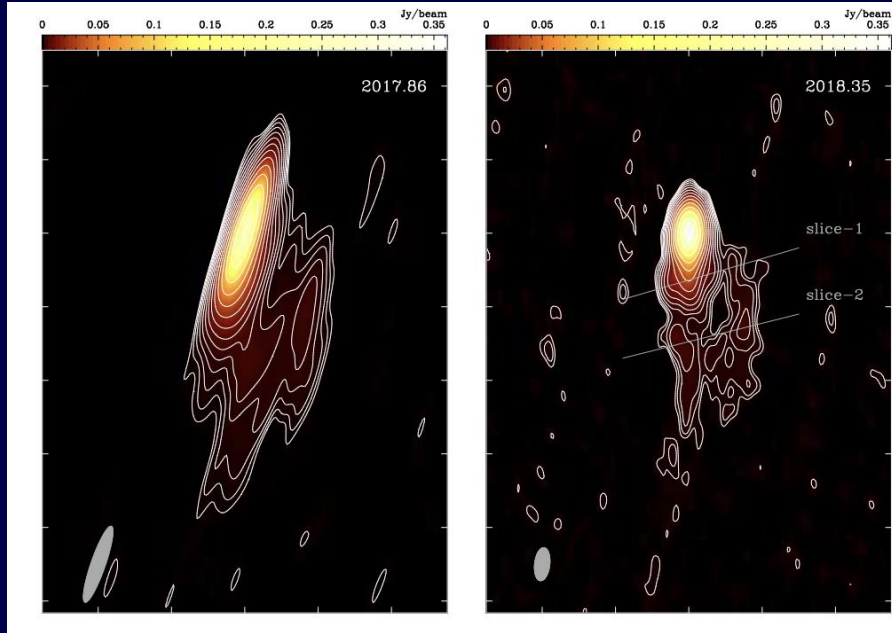
Inoue+2020



MAGIC Coll 2017

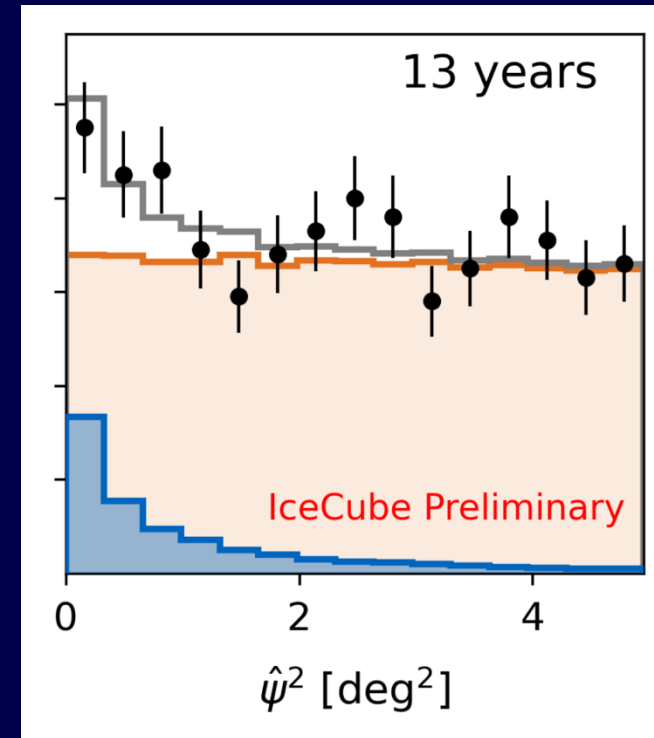
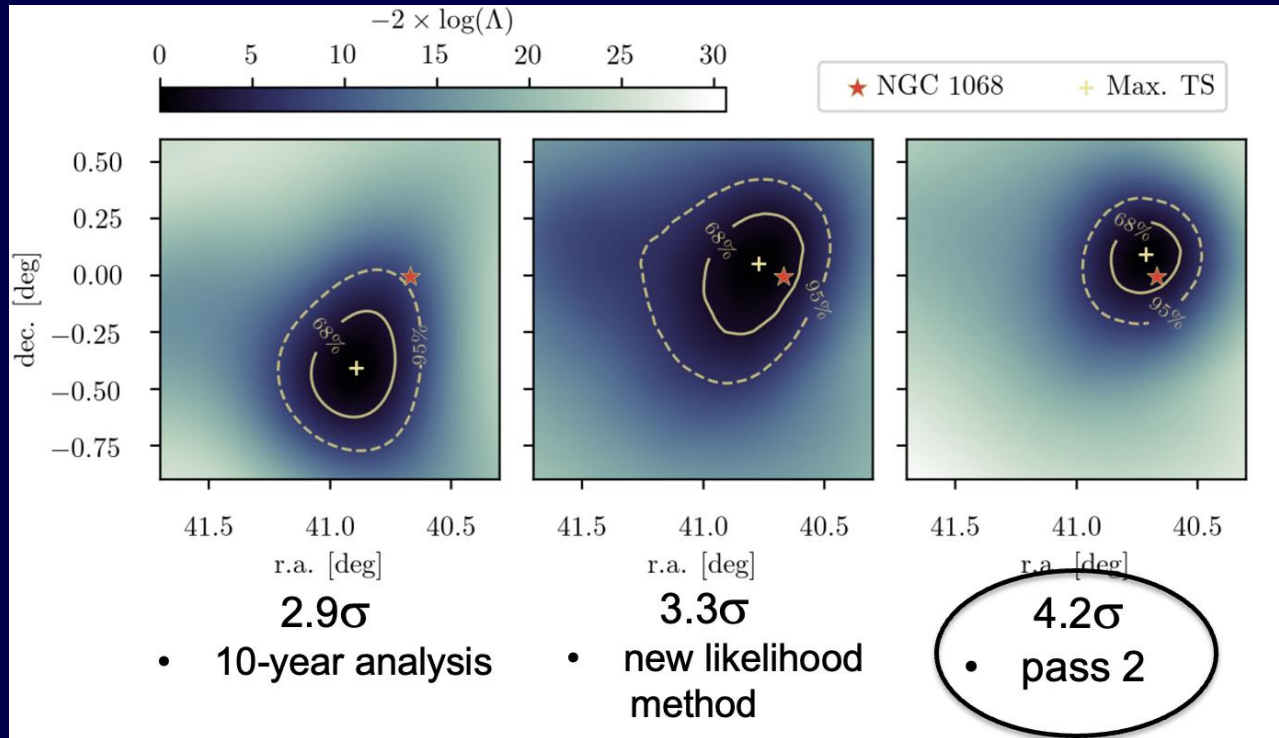
TXS 0506+056

Ros+2020

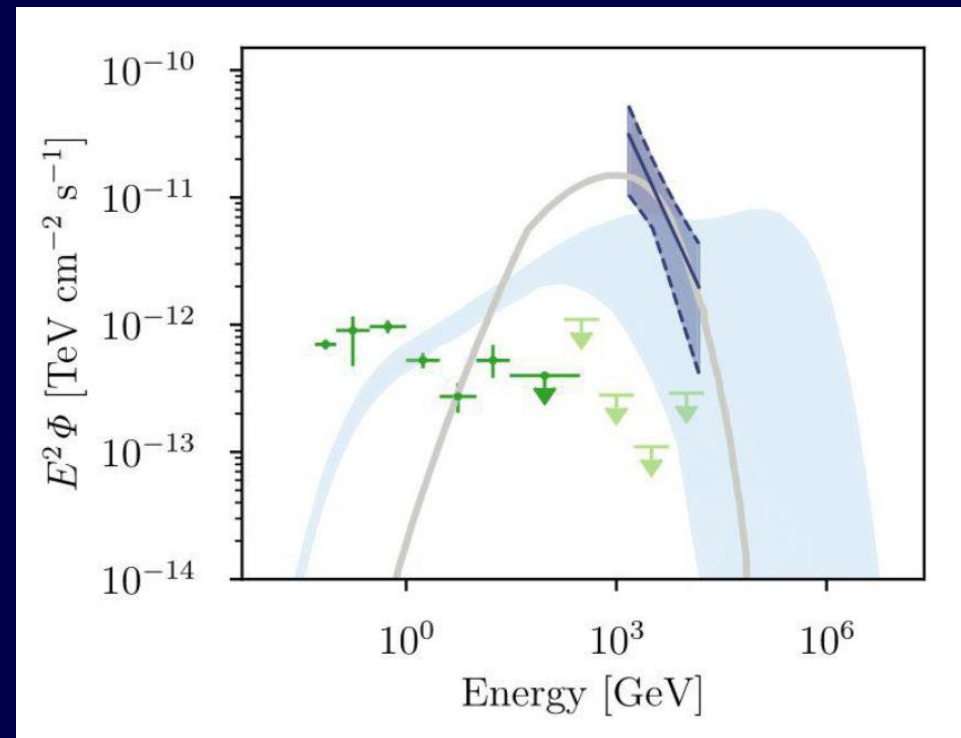
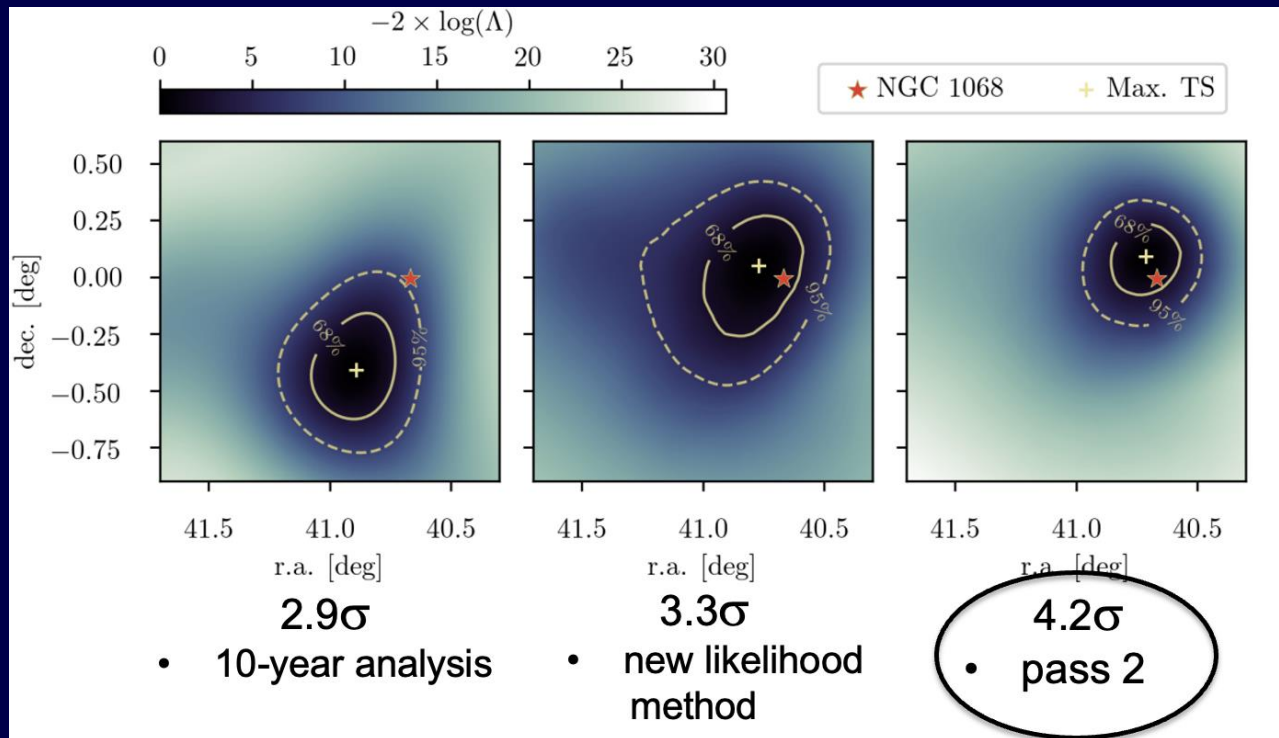
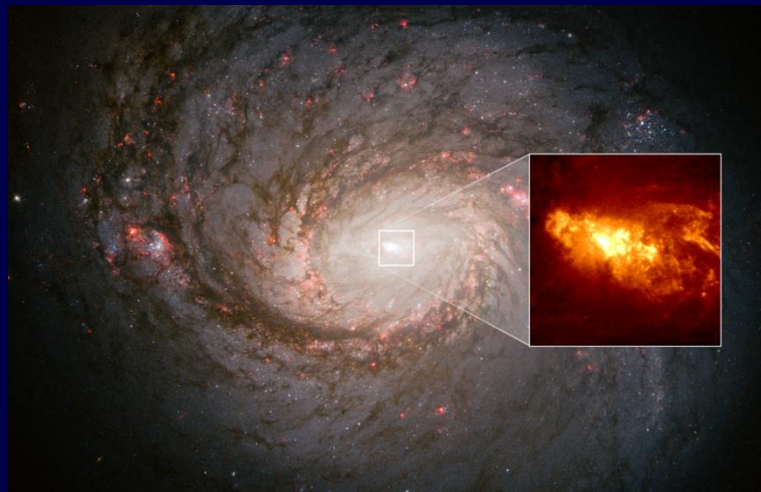


MAGIC Coll 2017

NGC 1068



NGC 1068



NGC 1068

- Target densities required
 - to produce the ν flux
 - to suppress the flux of the π_0 -produced gammas

place a constraint on the emission region < 100 Schwarzschild radii

corona or jet base?

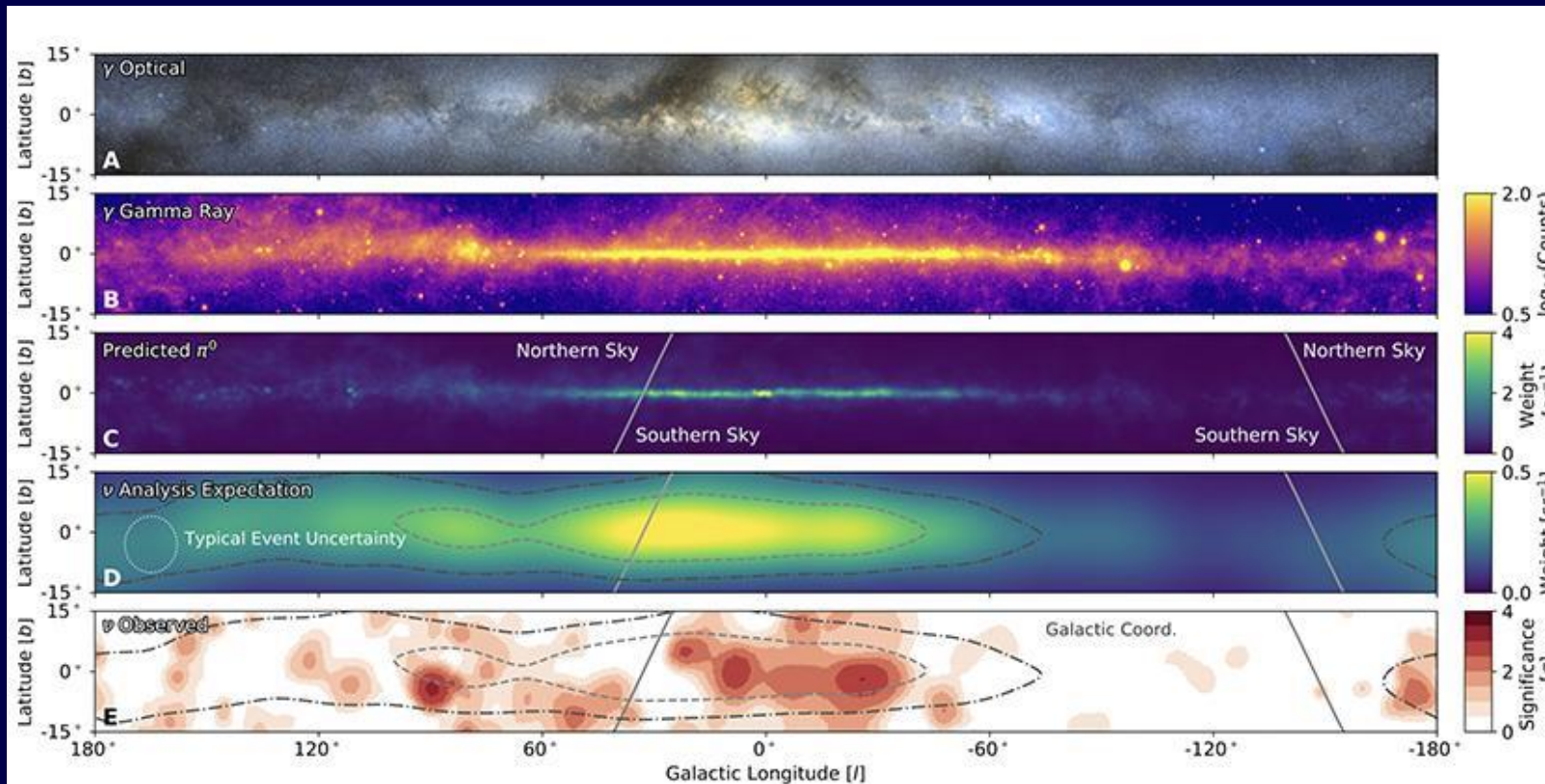
In Gamma-ray-obscured corona

What's the difference with TXS 0506?

* the same with gammas produced with the neutral pion absorbed and we see different gammas (*Zathul+ 2024*)

* Unlikely to be the same (*Damiano+2025*)

Galactic Plane: CRs- ν - γ



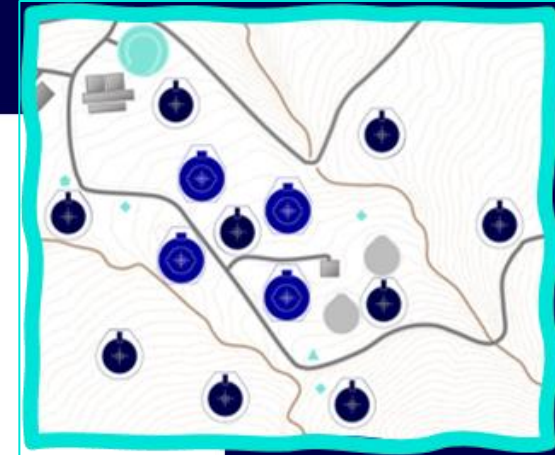
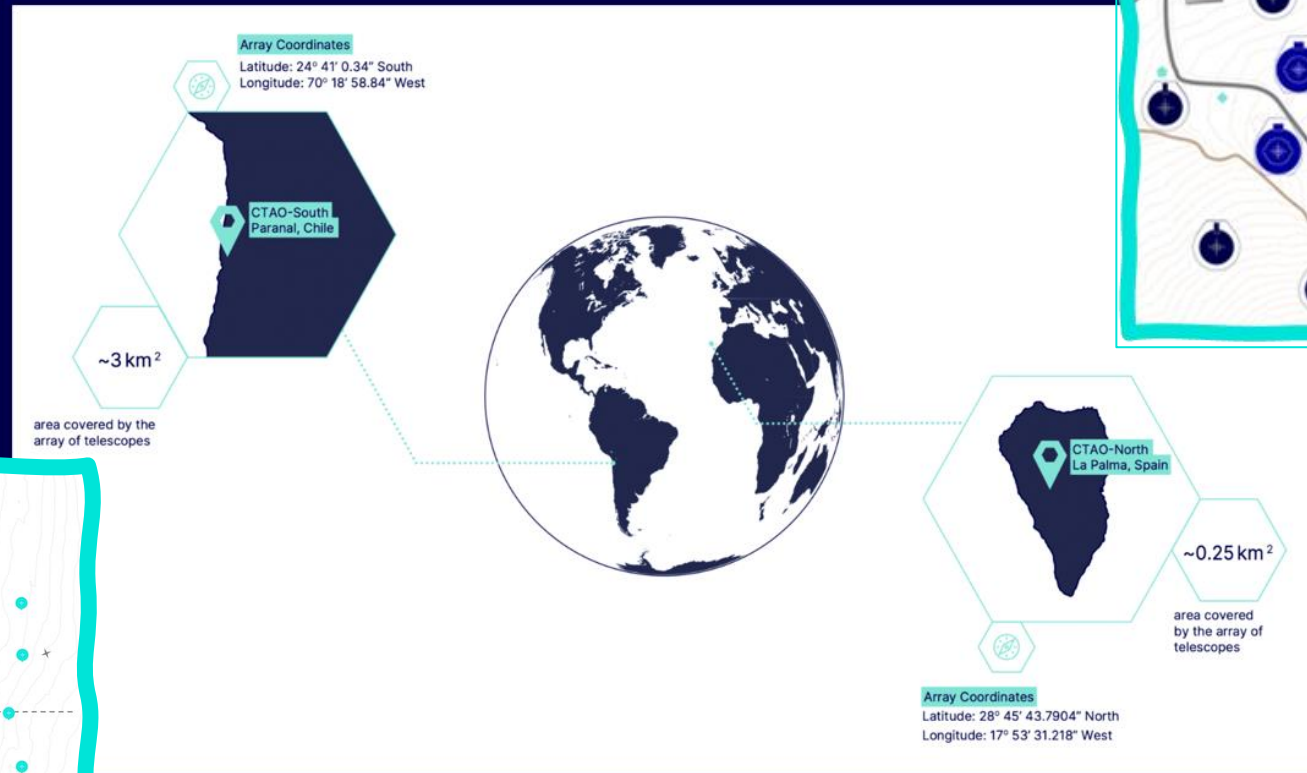
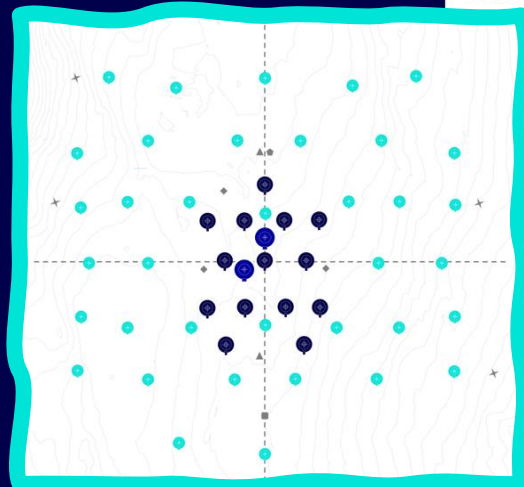
A multi-messenger view of the Milky Way galaxy, centered on the Galactic center and viewed in galactic coordinates.
(Credit: IceCube Collaboration)

Inoue+2020

CTAO: a key player in MM astronomy

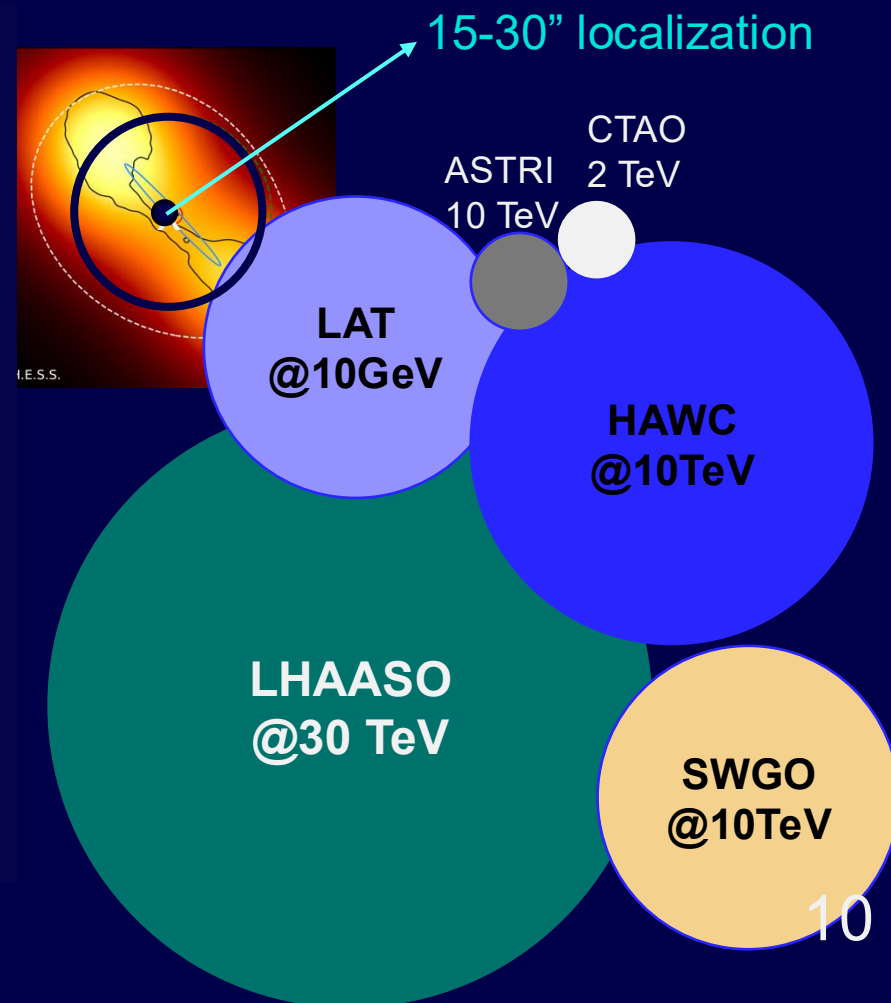
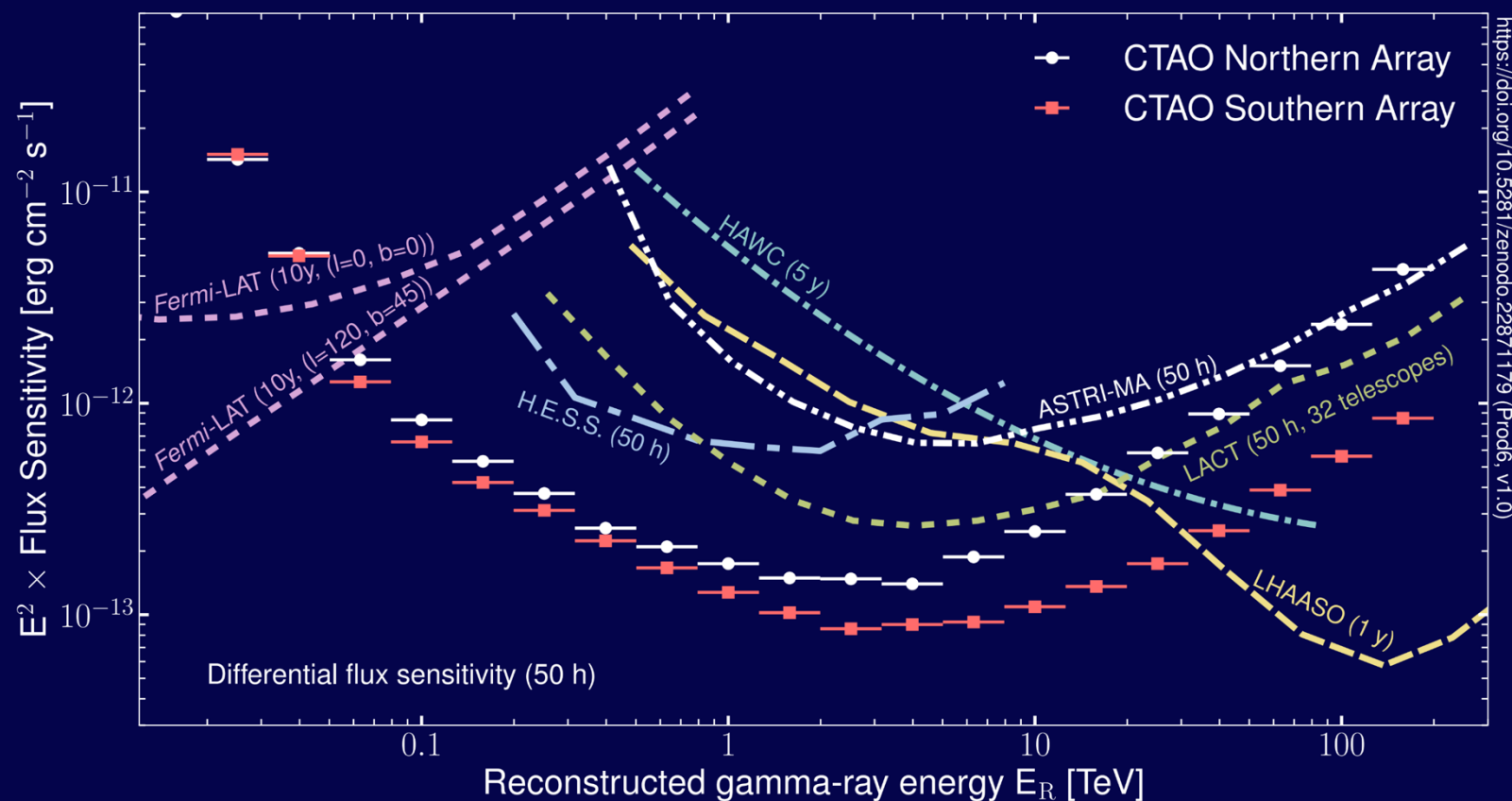
Beta Configuration

CTAO-South
2 LSTs
14 MSTs
37 SSTs

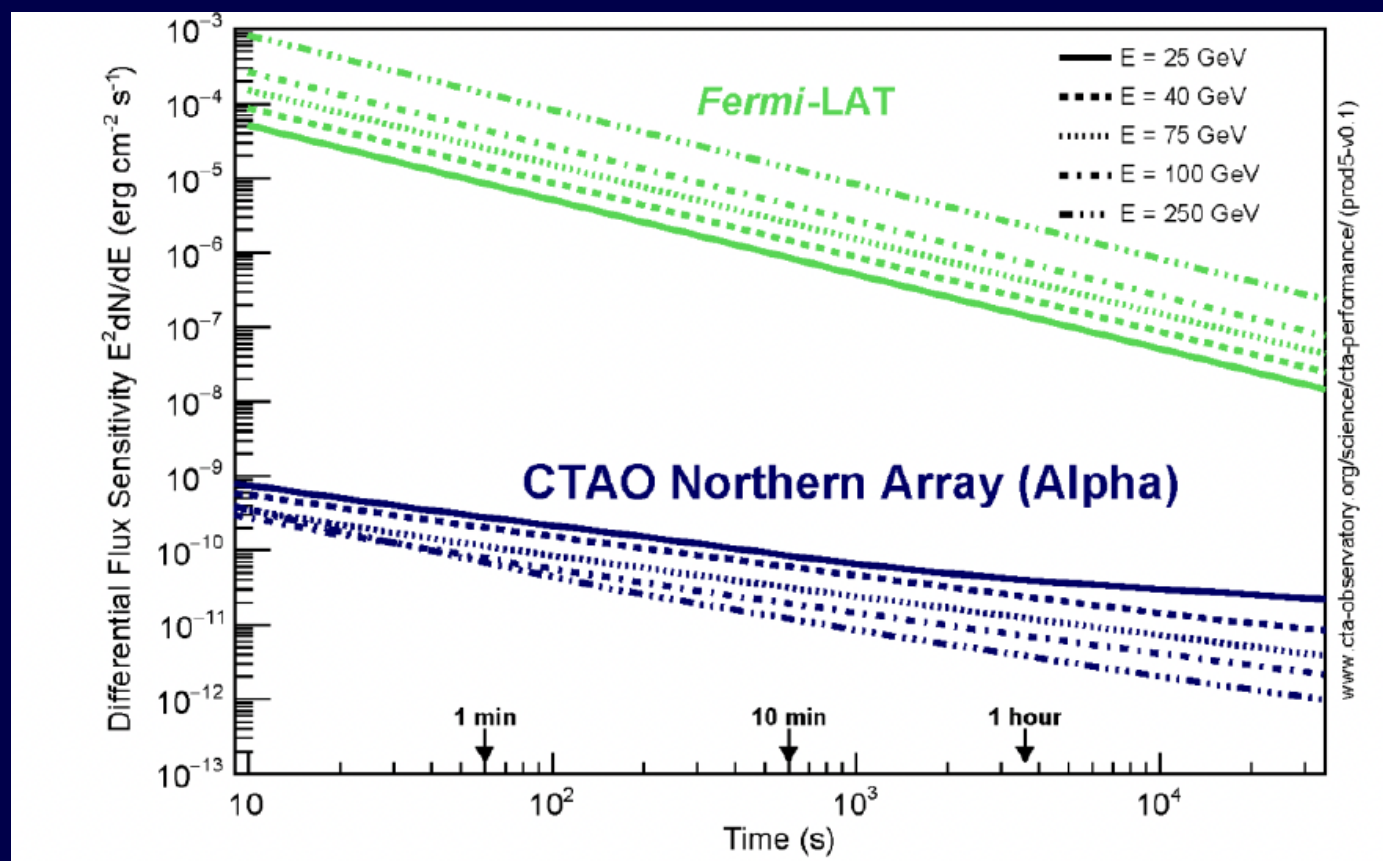


CTAO-North
4 LSTs
9 MSTs

CTAO Steady-Source Performance

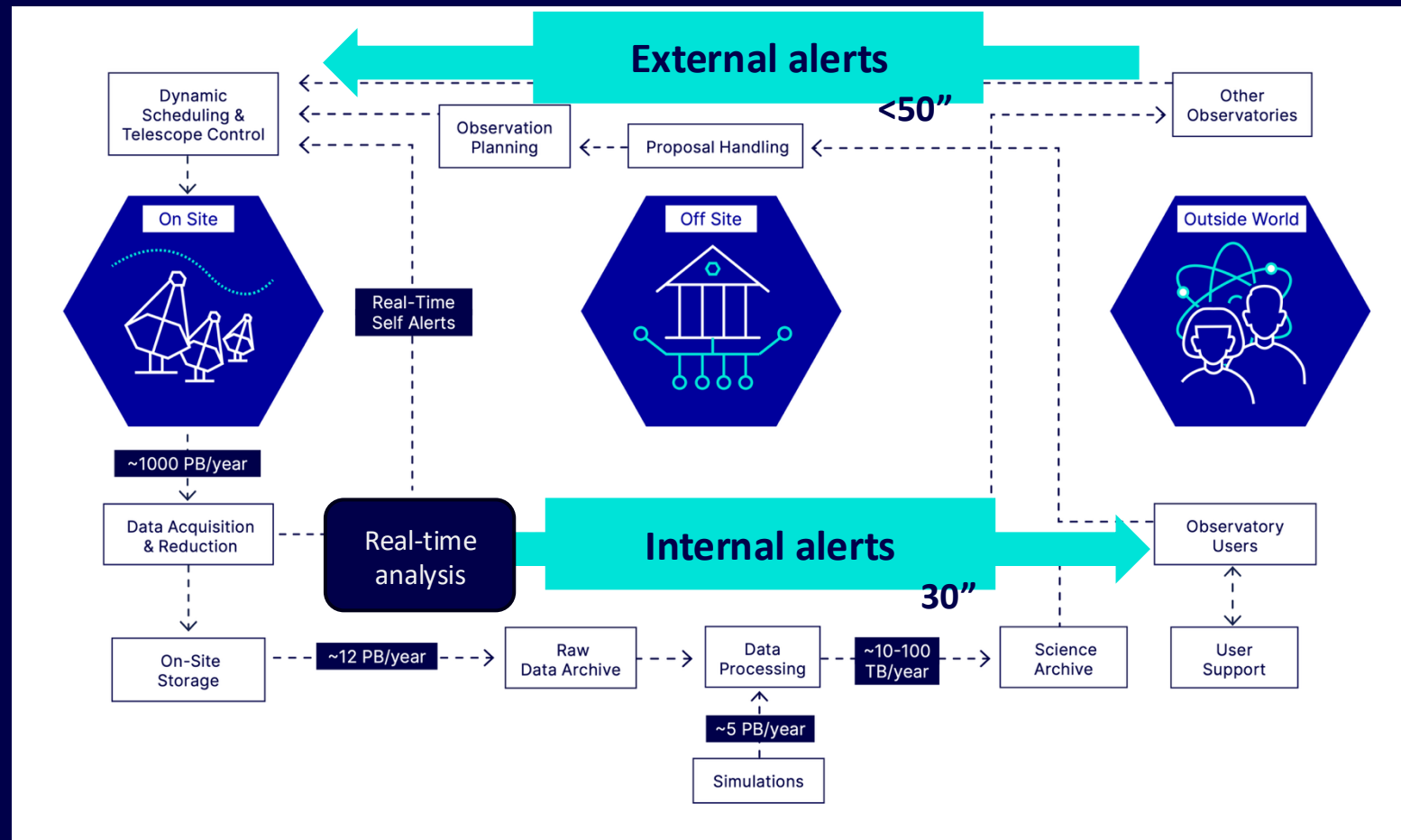


A Cornerstone in the MM/MWL Era



- Unbeaten transient sensitivity!
- Orders of magnitudes more sensitive for duration below 1h

A Cornerstone in the MM/MWL Era



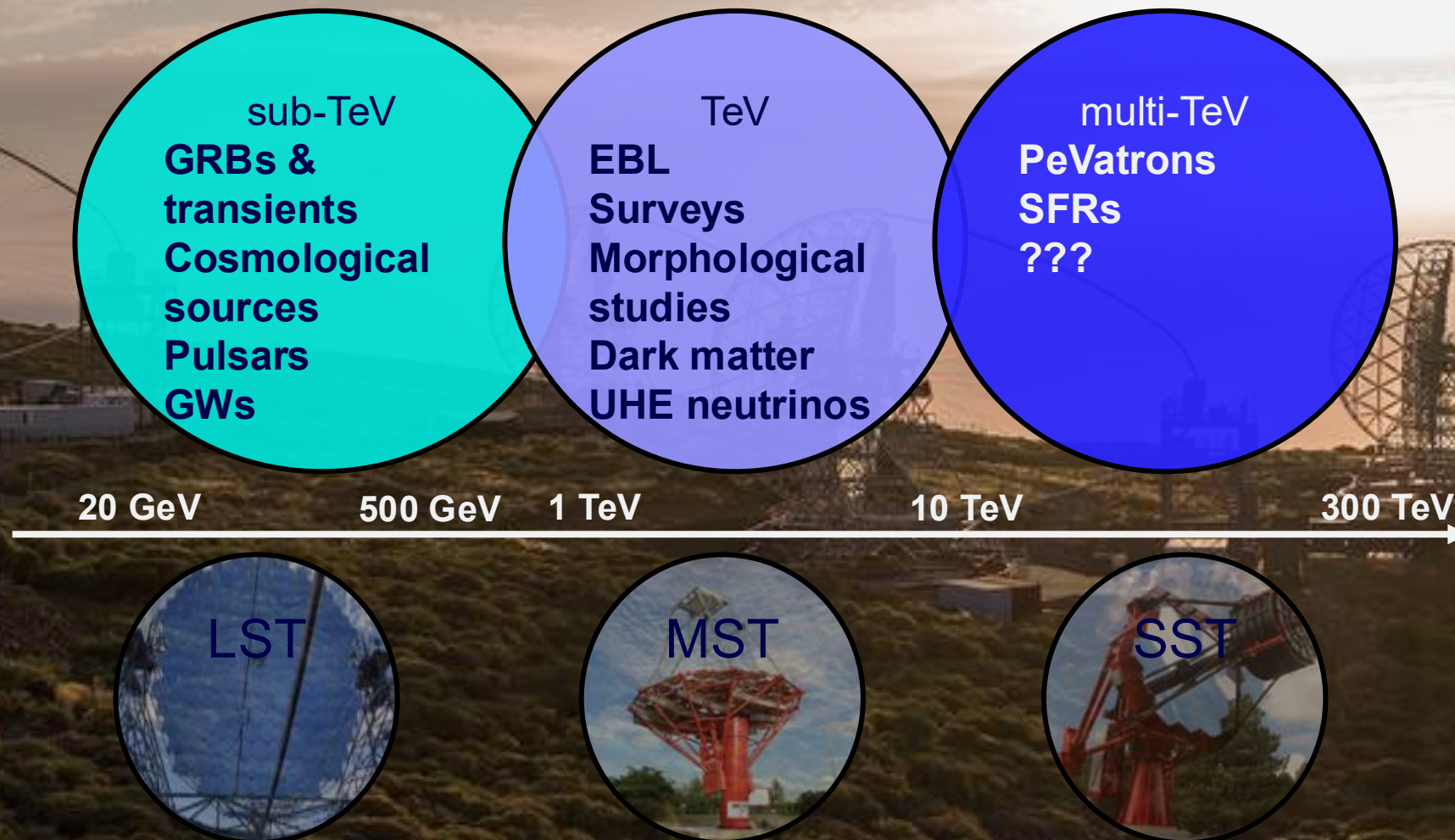
points any point
in the sky in 20"



LST designed for the low-energy frontier



LST designed for the low-energy frontier



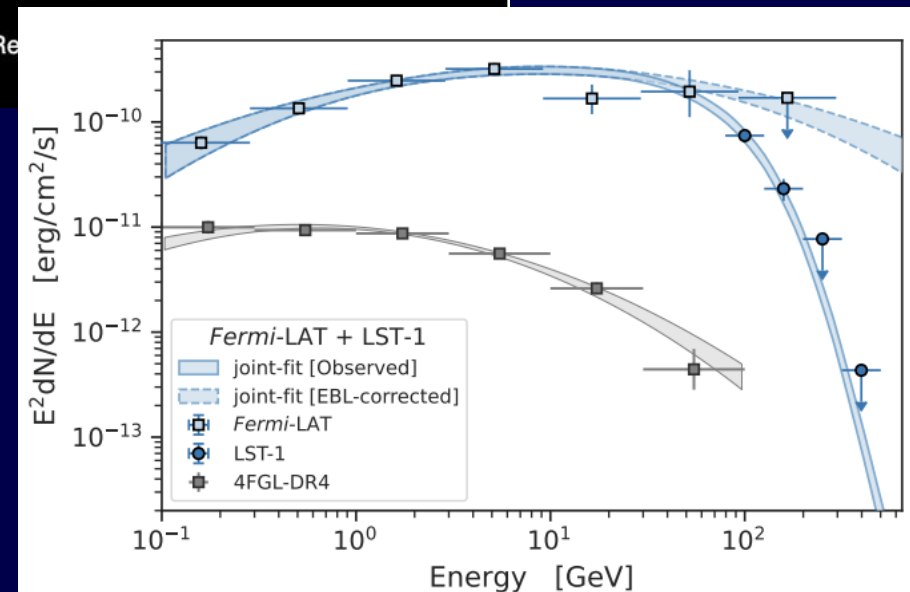
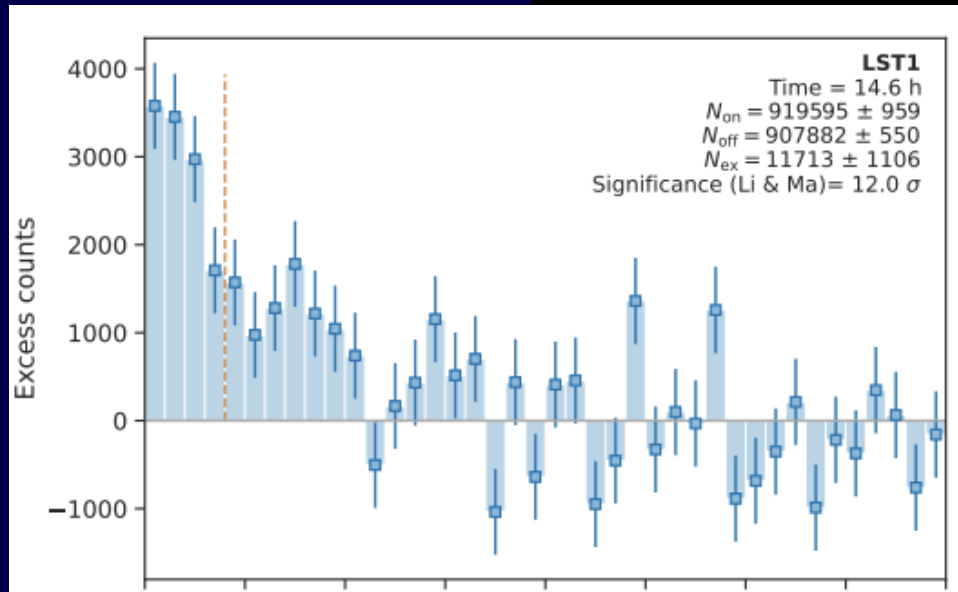
OP 313 — Reaching the Most Distant AGN at Very High Energies

**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)

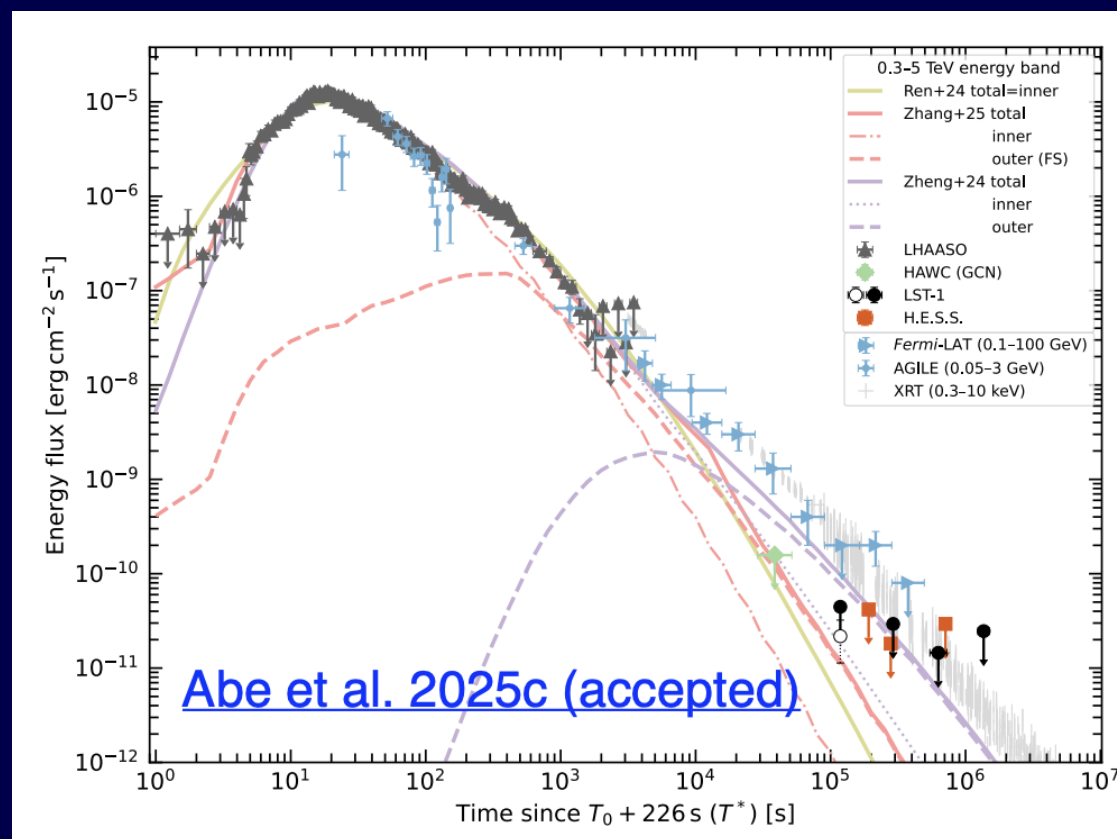
LST Coll. 2026



Credits to the LST collaboration

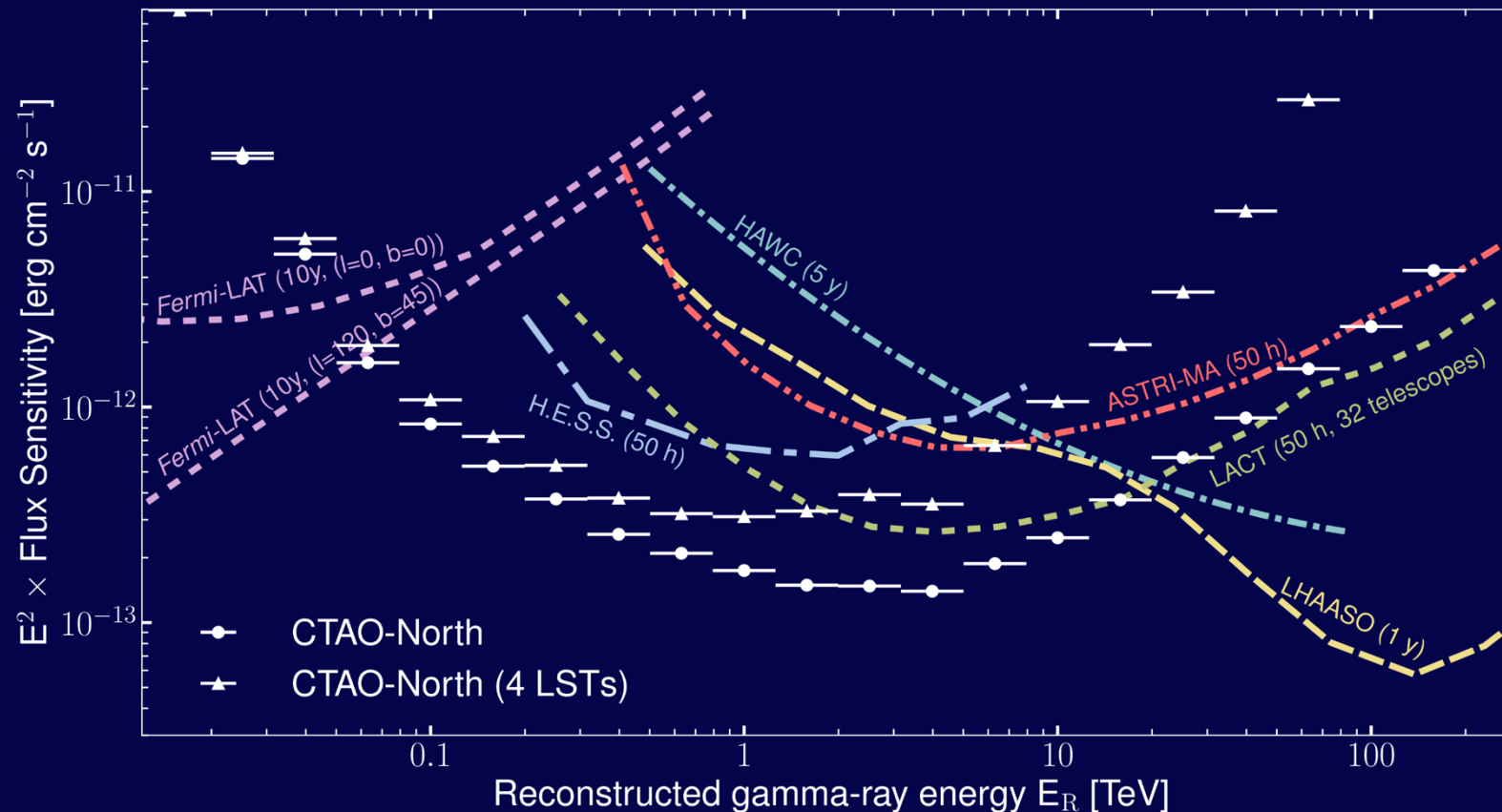
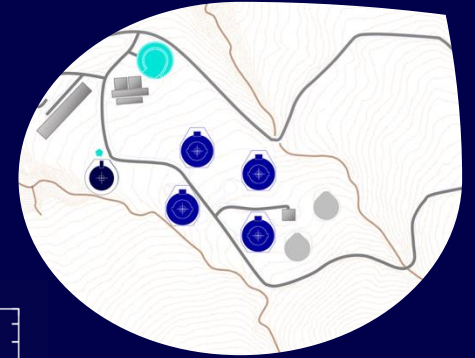
GRB 221009A — Following the BOAT

on Oct 10 [$T_0 + 1.33$ day] - 4.1σ during strong moonlight conditions



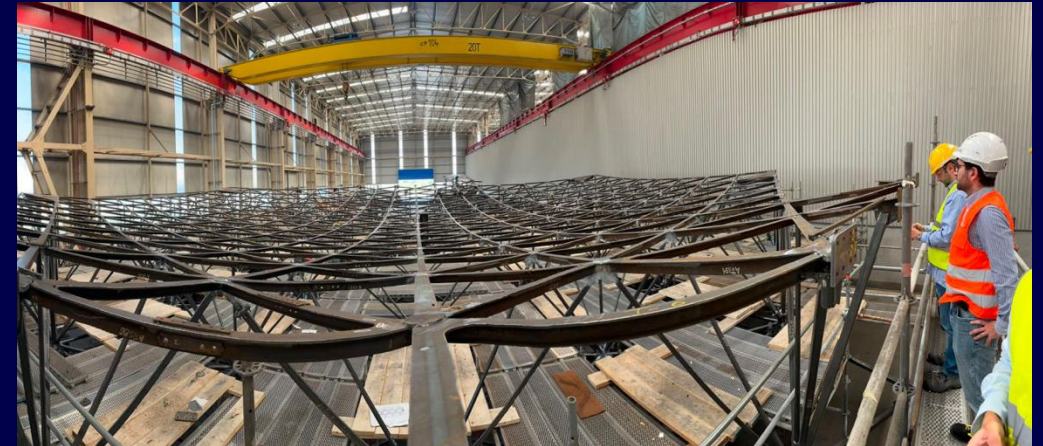
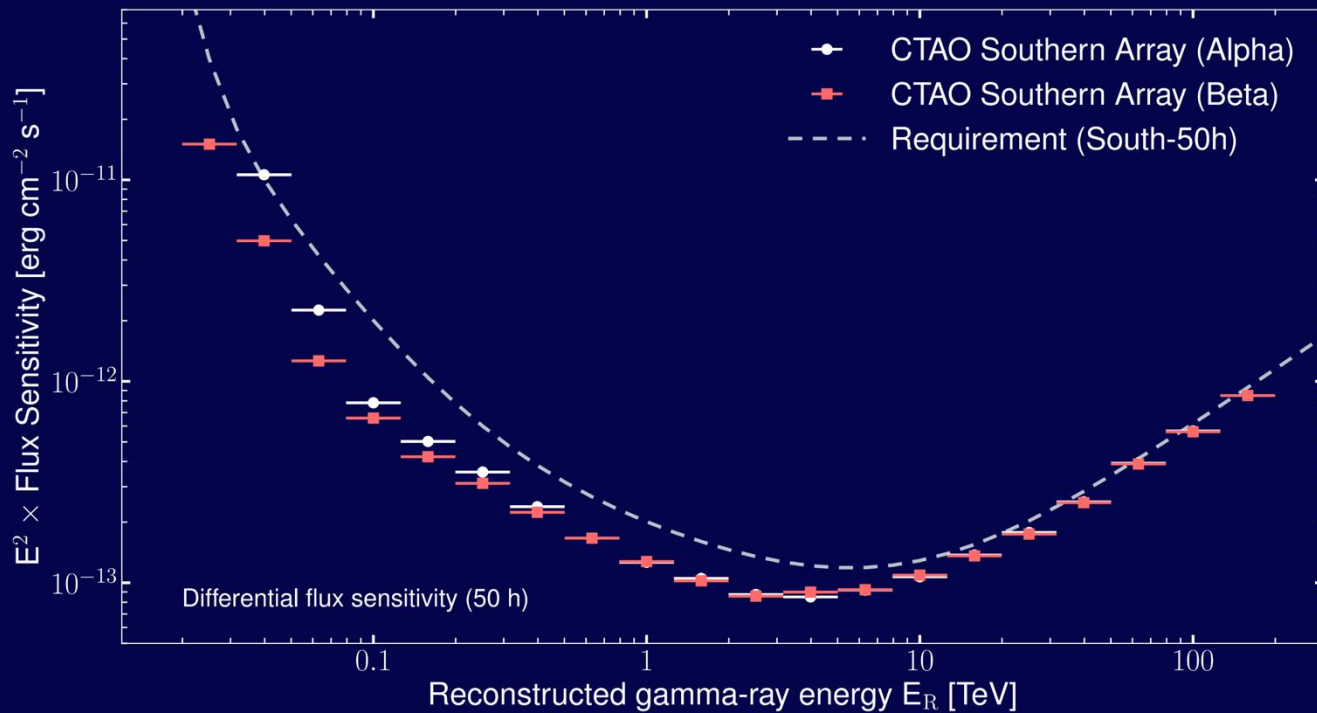
1st Intermediate Array

CTAO-North: expected late 2028



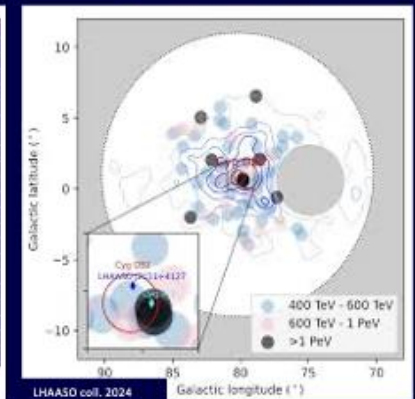
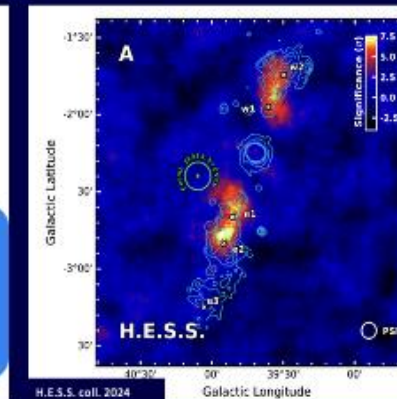
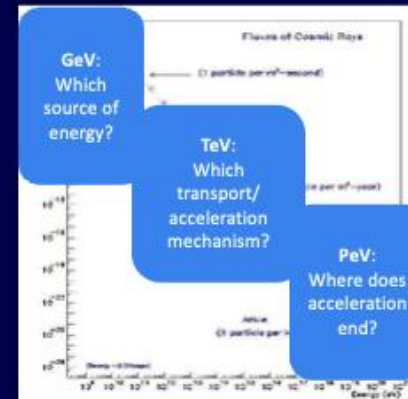
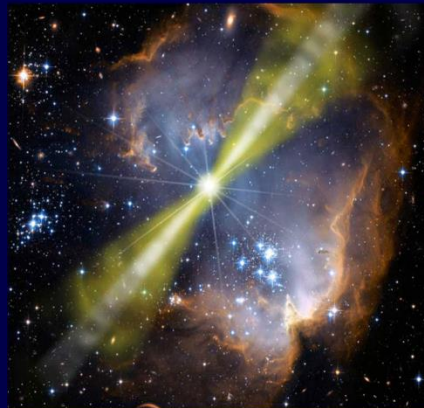
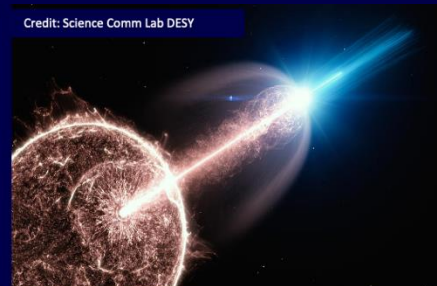
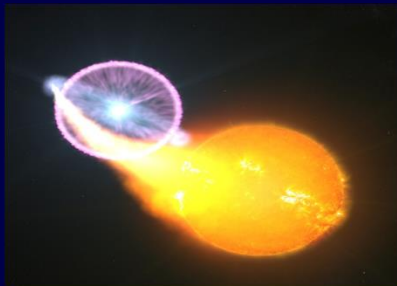
LSTs @ CTAO-South

By 2029

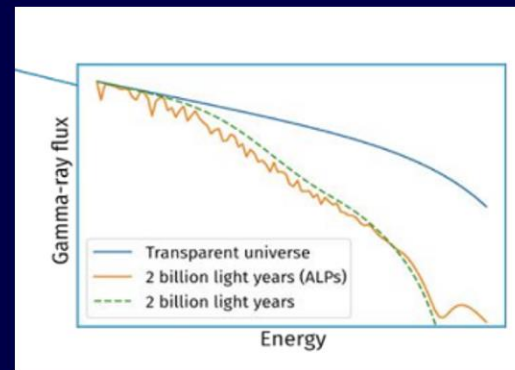
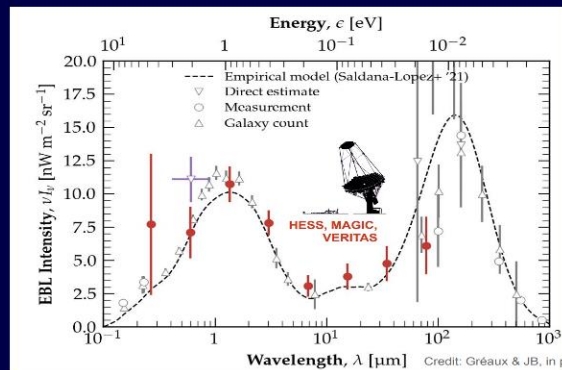
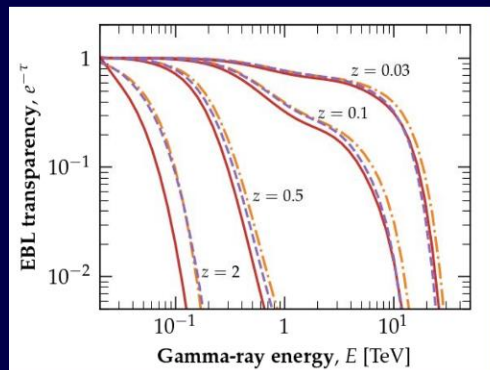
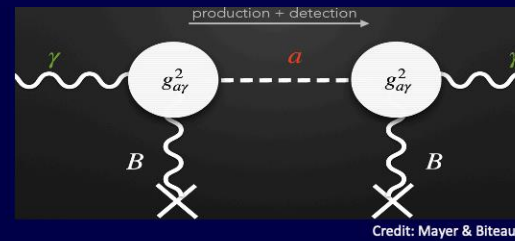
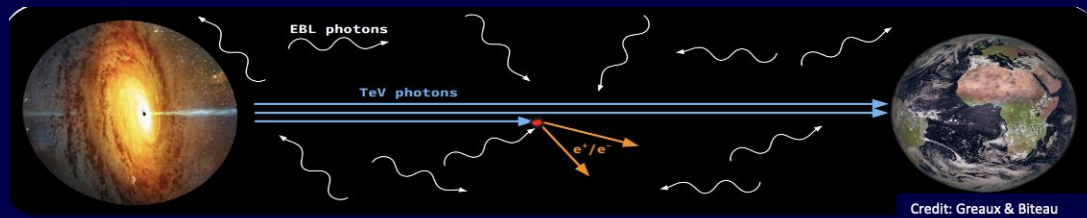


Currently being built!

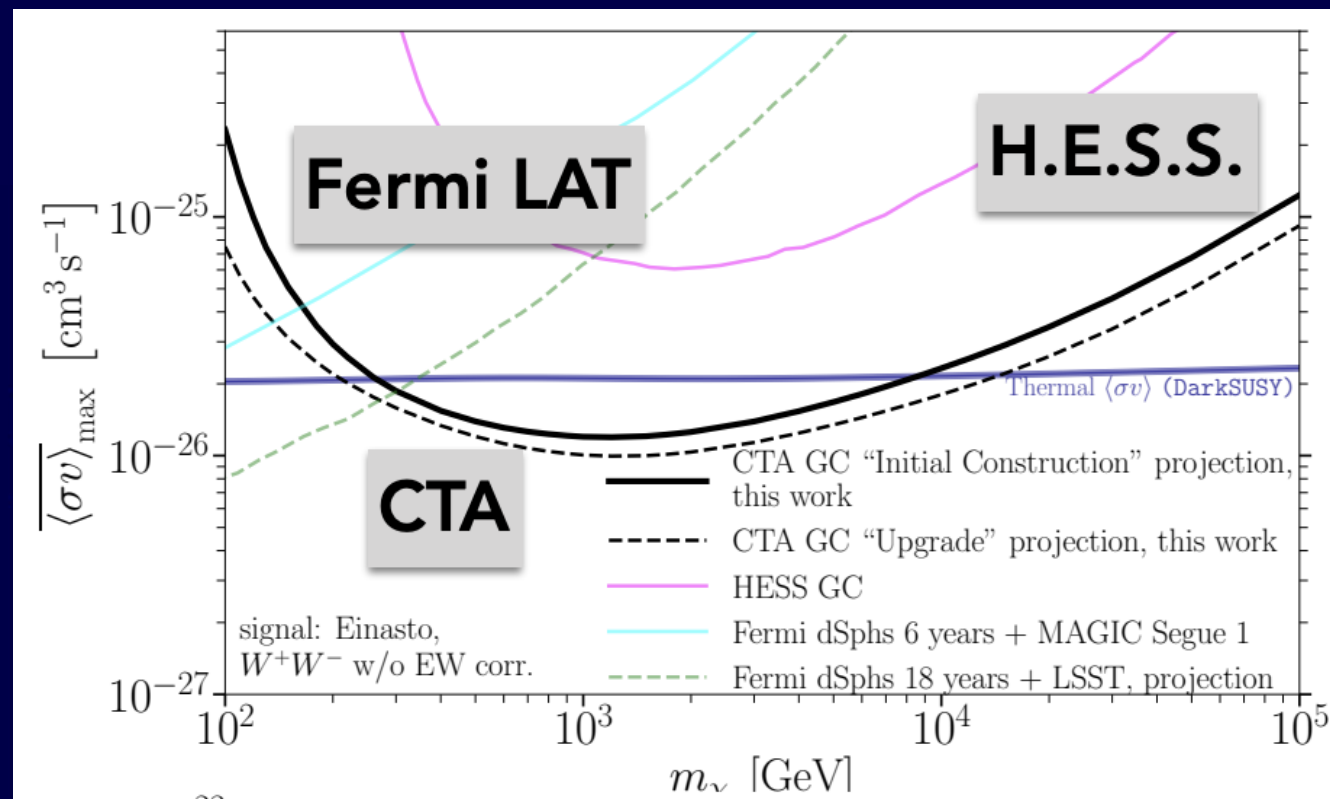
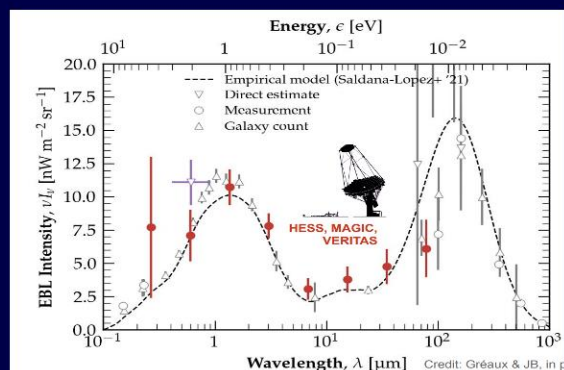
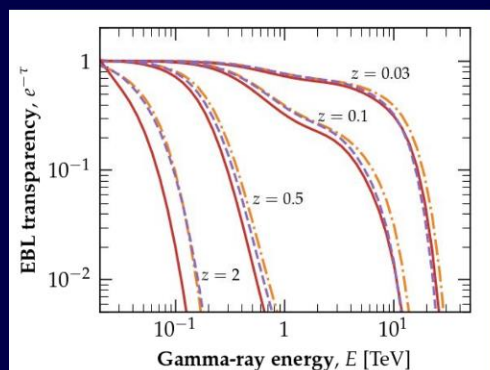
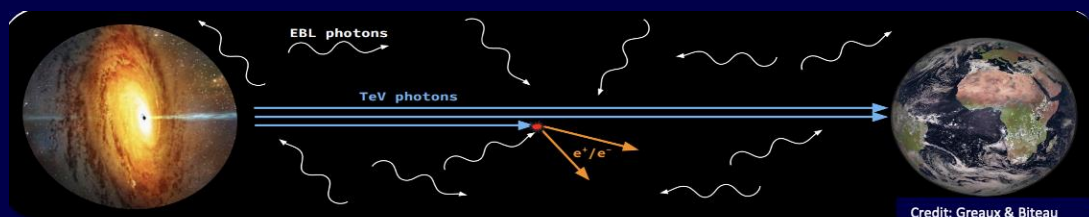
Not only LSTs



Not only LSTs



Not only LSTs



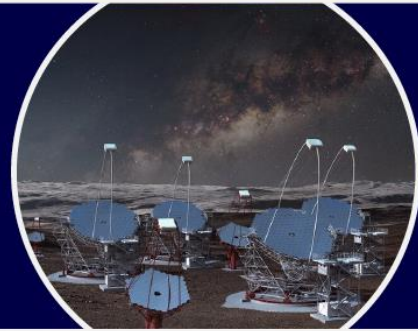
CTAO Timeline

IKC Construction

- Telescopes
- Array Common Elements
- Commission of array elements
- CTAO software

System Commissioning

- Integration, verification, and validation of array elements and software
- Science verification of system releases



CTAO Construction

- Infrastructure
- Roads, on-site data centers

Guaranteed Early Science

- Guaranteed observing time for Contributors to construction of beta configuration
- Collection of targets for Science Validation

Public Early Science

- Call for proposals
- Start of Host Guaranteed Time
- Use of verified intermediate configuration

Steady State Operations

- Full Beta configuration
- Steady State Operations begin
- KSP begins

Now

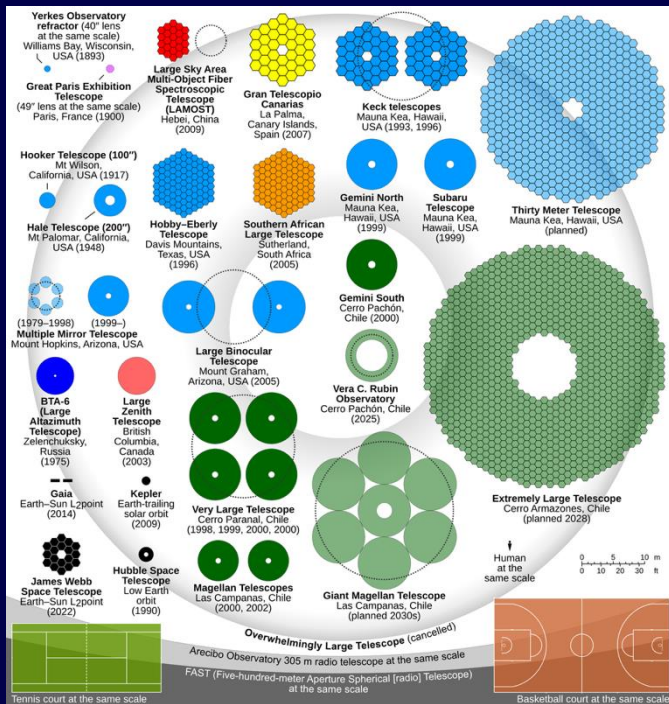
2028

2030

2032+

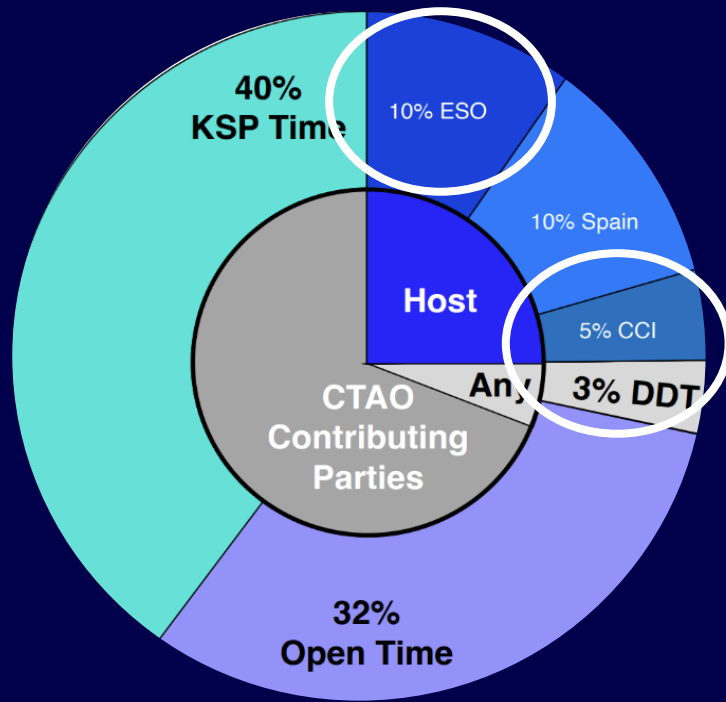
21

Beyond individual observatories: building a discovery network



- In the past decades we have seen birth of MM astrophysics, and strengthen the MWL networks.
- In the next decade, massive amount of precision data: MWL and MM. Challenging but exciting times.
- We need to **coordinate**: alerts, shared programs, shared data access and we will start from our Hosting Observatories

Beyond individual observatories: building a discovery network

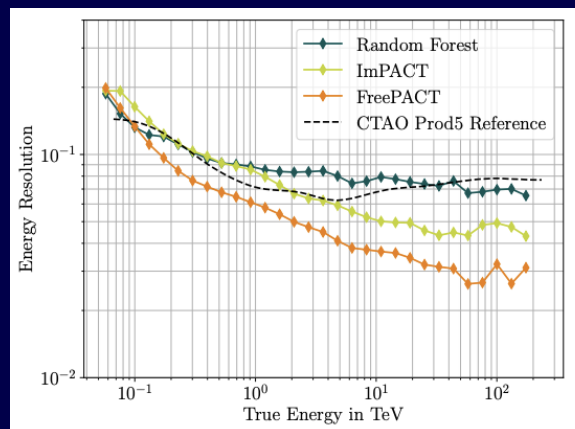


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CTAO



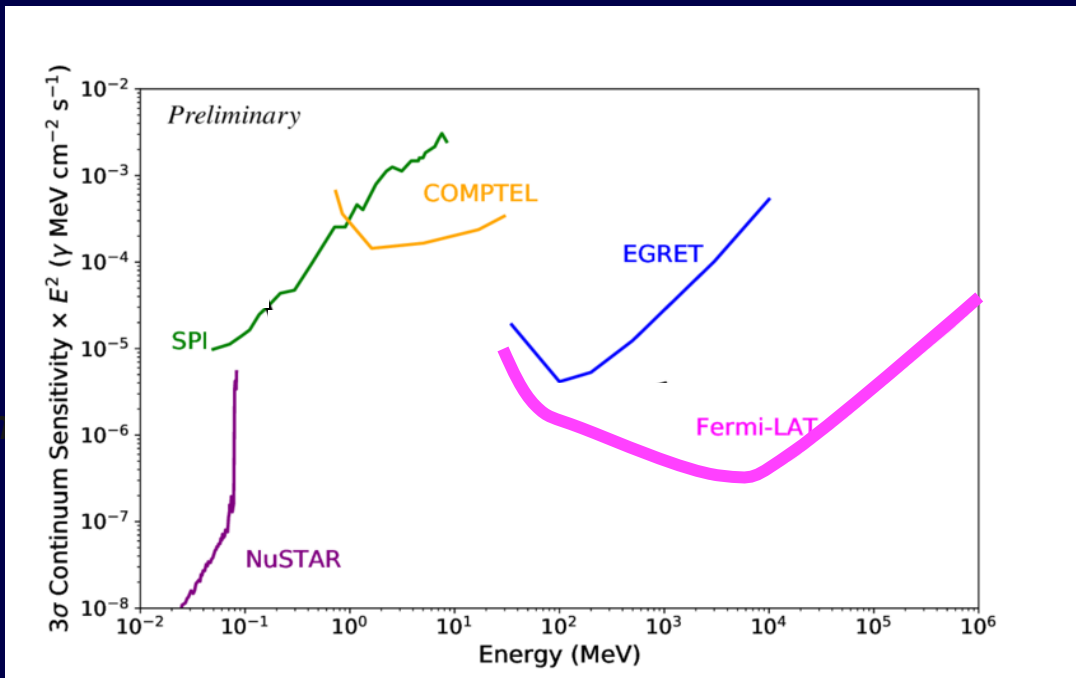
CTAO Consortium



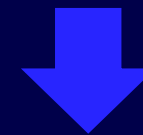
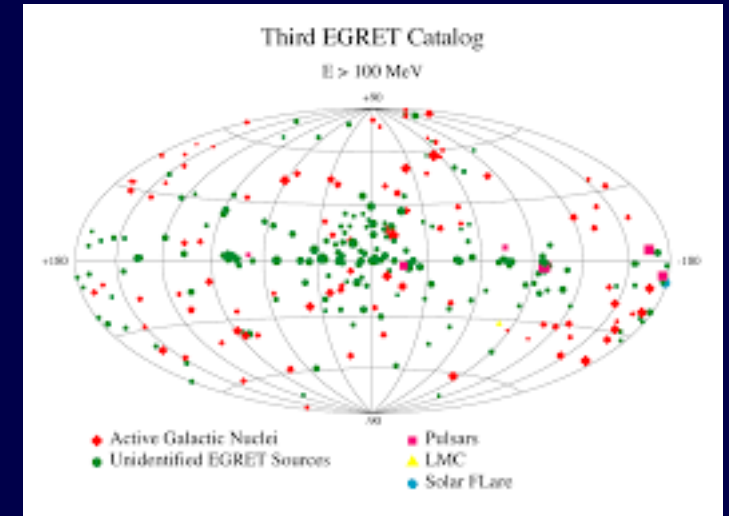
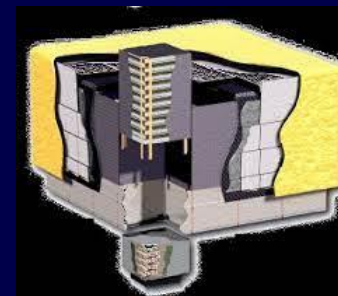
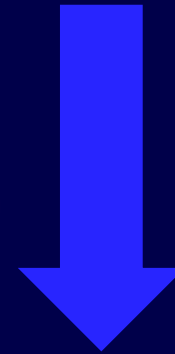
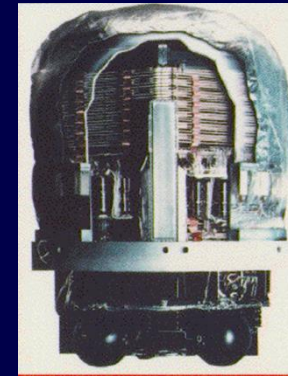
Schwefer + 2025



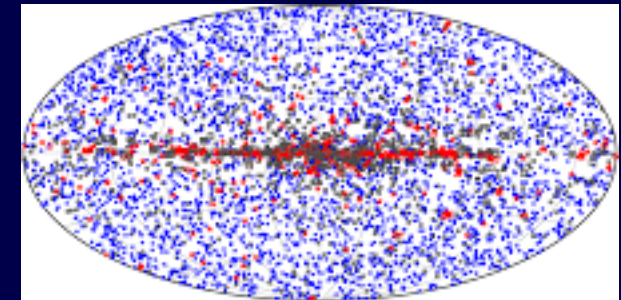
The next breakthrough is in front of us



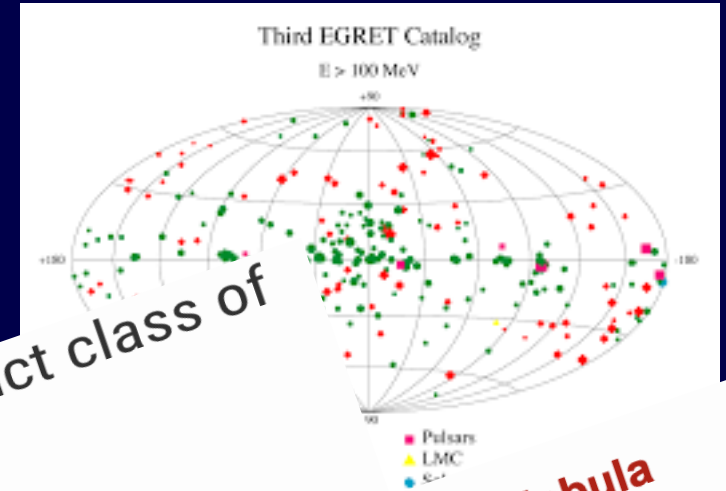
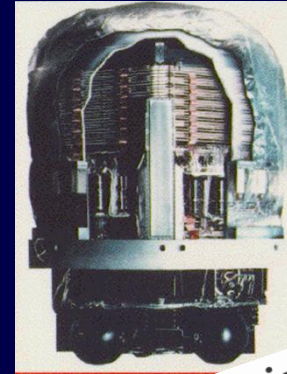
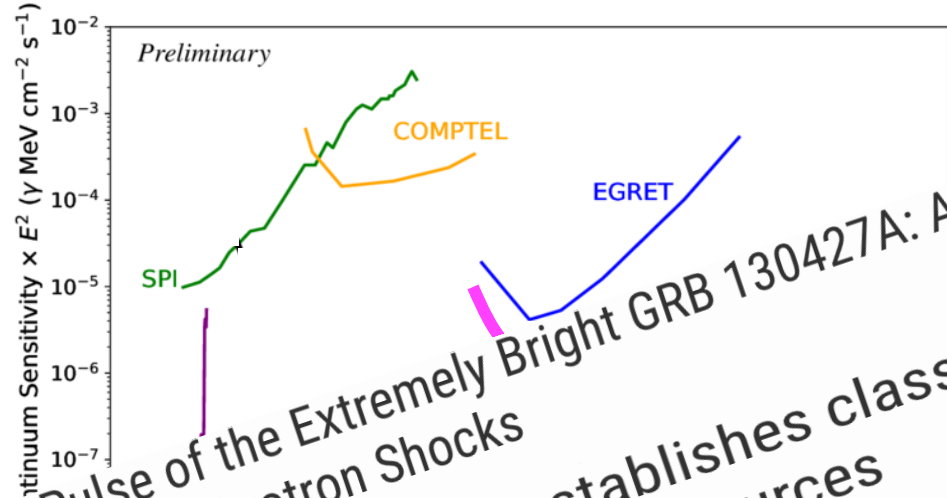
A huge discovery space



4FGL, Fermi LAT coll 2024



The next breakthrough is in front of us



The First Pulse of the Extremely Bright GRB 130427A: A Test Lab for Synchrotron Shocks

R. Preece^{1,*}, J. Michael Burgess^{2,*}, A. von Kienli³
 * See all authors and affiliations
 Science 03 Jan 2014;
 Vol. 343, Issue 6166, pp. 51-54
 DOI: 10.1126/science.1242302

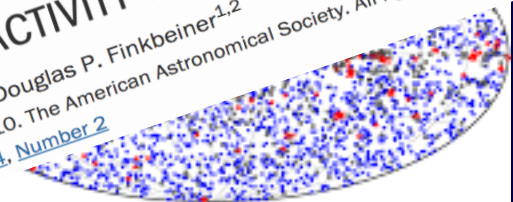
Fermi establishes classical novae as a distinct class of gamma-ray sources

The Fermi-LAT Collaboration^{*,†}
 * See all authors and affiliations
 Science 01 Aug 2014;
 Vol. 345, Issue 6196, pp. 554-558
 DOI: 10.1126/science.125394

Discovery of Powerful Gamma-Ray Flares from the Crab Nebula

M. Tavani^{1,2,3,4}, A. Bulgarelli⁵, V. Vittorini¹, A. Pellizzoni¹⁶, E. Striani^{2,4}, P. Caraveo⁷, M.C. Weisskopf²¹,
 Meng Su¹, Tracy R. Slatyer^{1,2}, and Douglas P. Finkbeiner^{1,2}
 Published 2010 November 10 • © 2010. The American Astronomical Society. All rights reserved.
 Physical Journal, Volume 724, Number 2

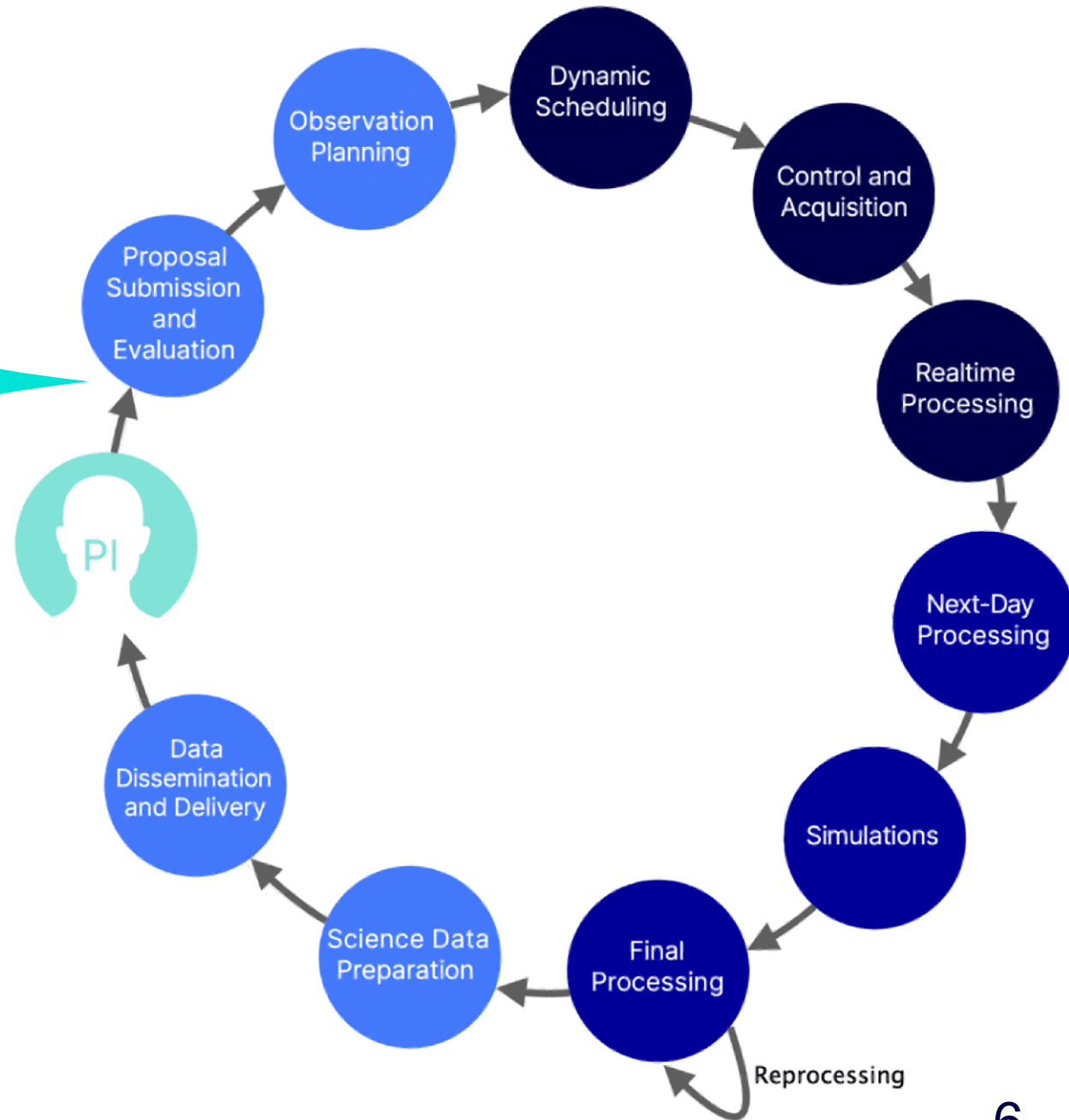
GIANT GAMMA-RAY BUBBLES FROM FERMI-LAT: ACTIVE GALACTIC NUCLEUS ACTIVITY OR BIPOLAR GALACTIC WIND?



Thank you

Proposal-Driven Observatory

- Observing time access granted mainly to contributing parties
- Proposals will be evaluated on their scientific merit in a double-blind fashion
- Data delivered are science ready data
- Data access fully open after 1 yr of proprietary period
- Focus on user support



Not only CTAO

[MWL] Astrophysical regions emitting at all wavelengths

- (at least) Accelerated electrons + B $\rightarrow$ synchrotron $\rightarrow$ radio to X

[MM] Particle accelerations may generate neutrinos, and in some cases GW

- Protons $\rightarrow$ neutrinos
- Gamma-rays absorbed in emission region, neutrinos escape

[Time] Because it's intrinsically non-thermal, it's much more informative a movie than a snapshot

- Intensity correlation mwl
- Polarization correlations with gamma-rays

Mutual Alert

- Define criteria, MoU

Joint Schedule

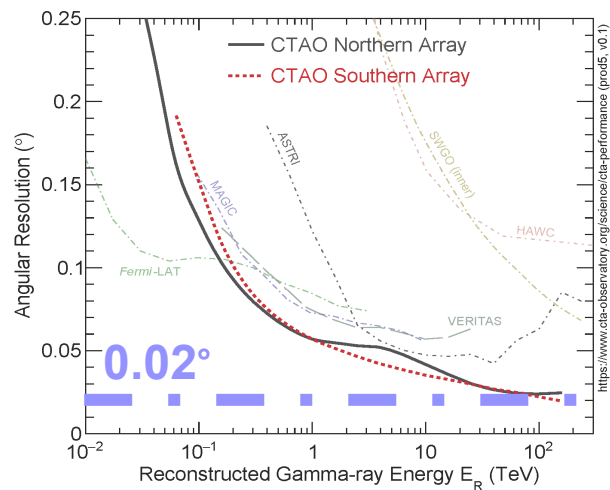
- Monitoring and ToO campaigns

Data ready

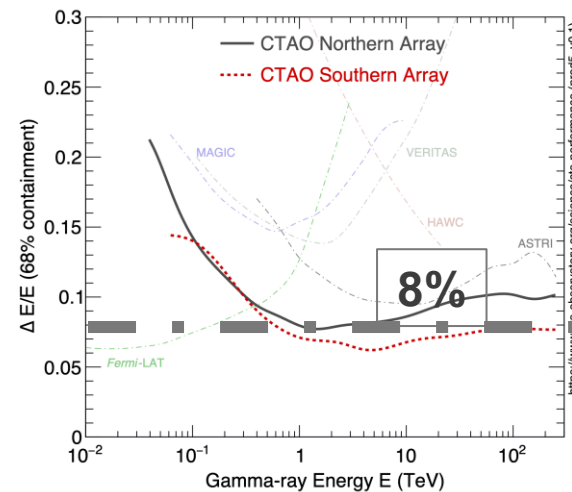
- Quick and easy

CTAO Steady-Source Performance

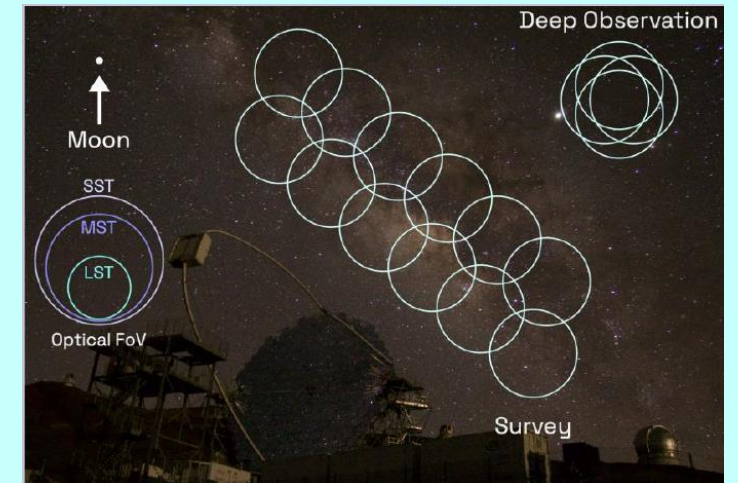
Angular resolution



Energy resolution

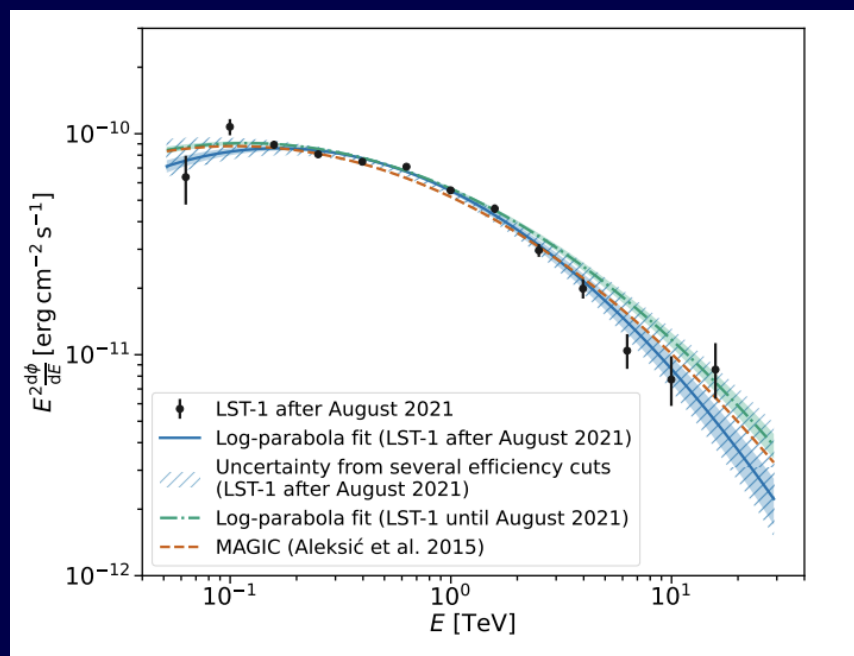


Field of View



LST-1 science performance

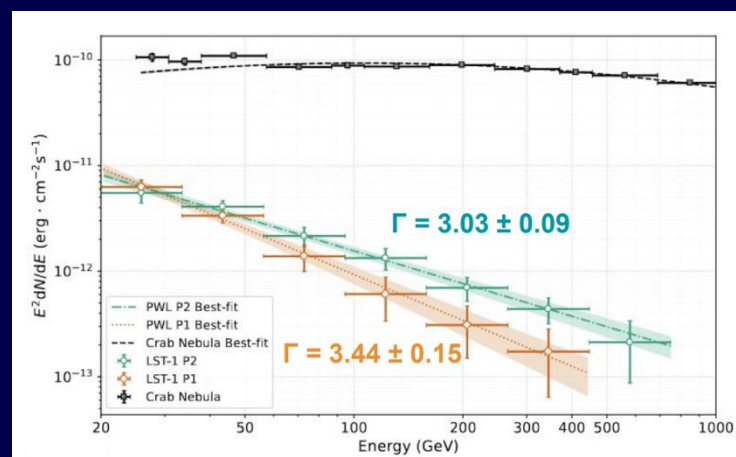
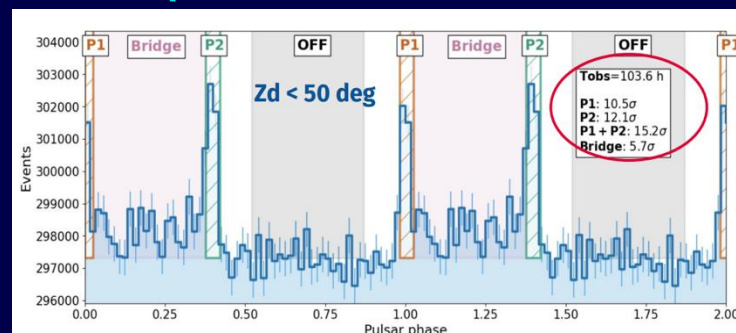
Crab nebula



Abe et al 2023

Credits to the LST collaboration

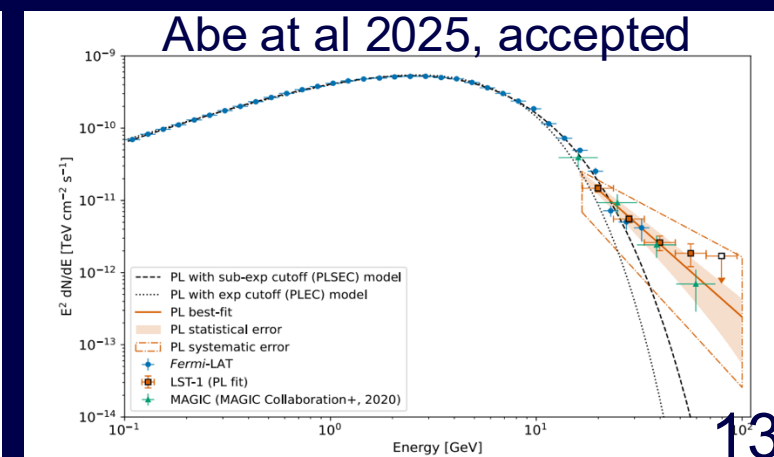
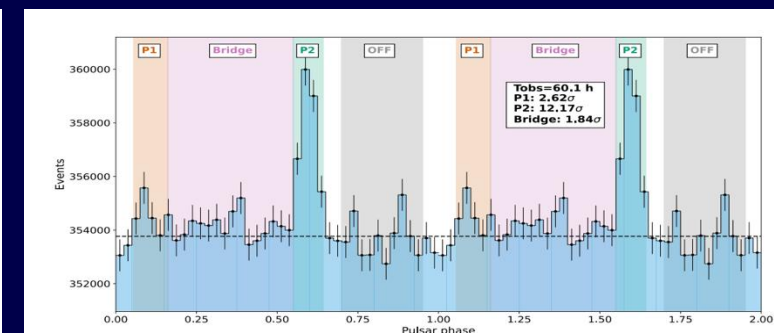
Crab pulsar



Abe et al 2024

Geminga pulsar

P2 at 12σ in 60hr (MAGIC 6σ in 80 hr)



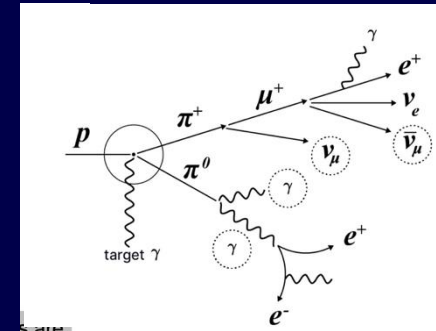
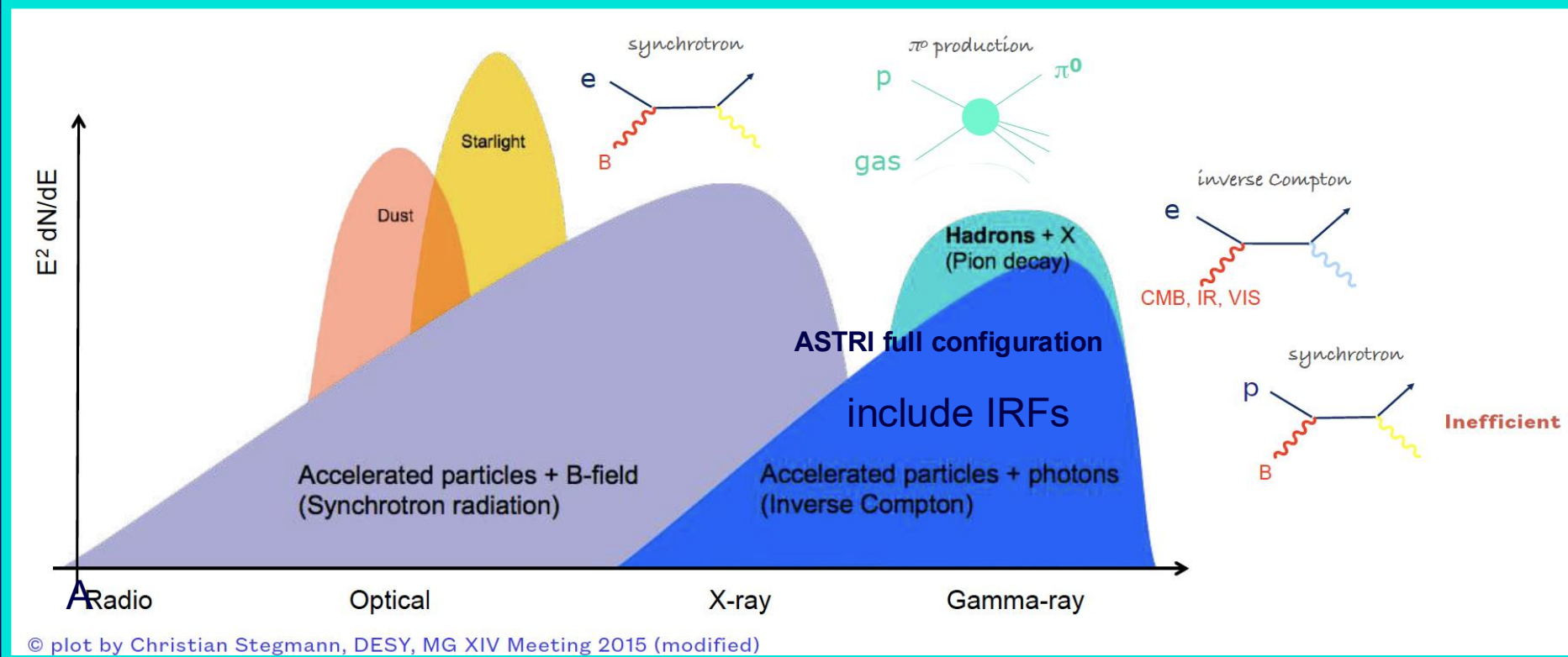
Abe et al 2025, accepted

when a source accelerate CRs, these CRs interact
 --> producing equal fluxes of gamma rays and neutrinos

MM

together with the CRs you get also electrons
 --> correlating with lower frequencies

MWL



EHT 1.3 mm
 50 μ as
 0.004 pc

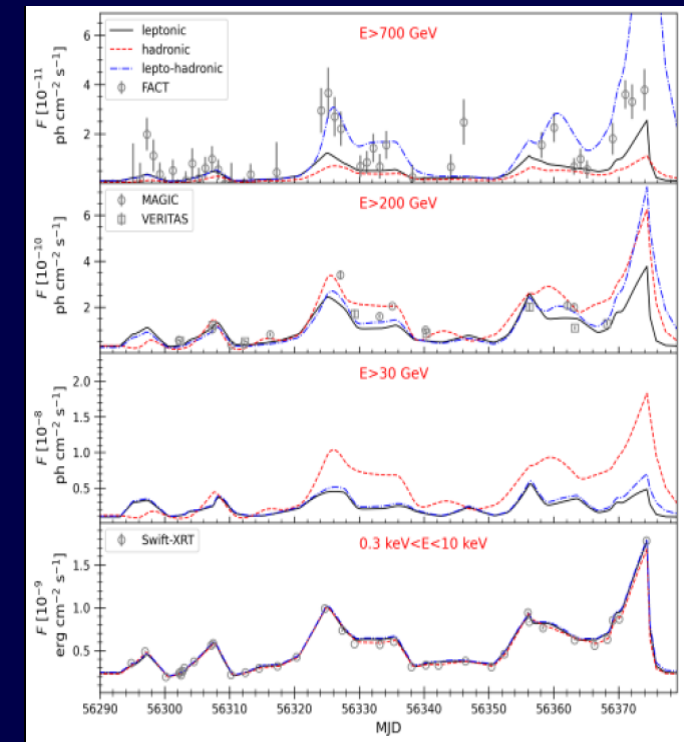
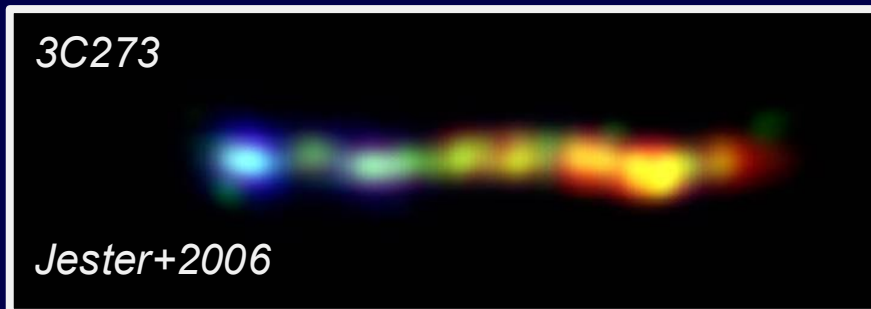
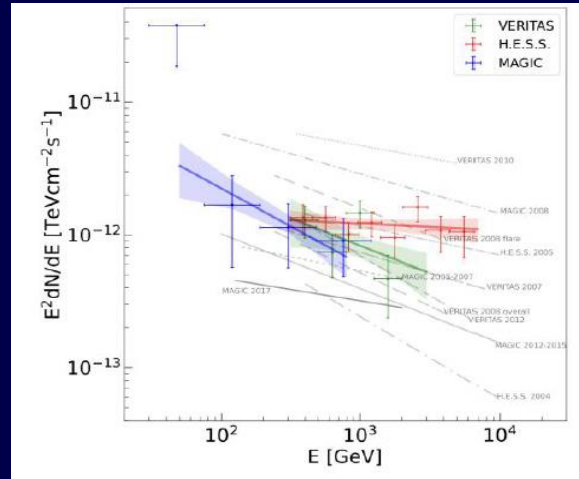
GMVA+ALMA+GLT 3.5 mm
 1 mas
 0.08 pc

VLBA 7 mm
 5 mas
 0.4 pc

EAVN 13 mm
 10 mas
 0.81 pc

ALMA 1.3 mm
 5 arcsec
 405 pc

CHANDRA X-rays
 5 arcsec
 405 pc



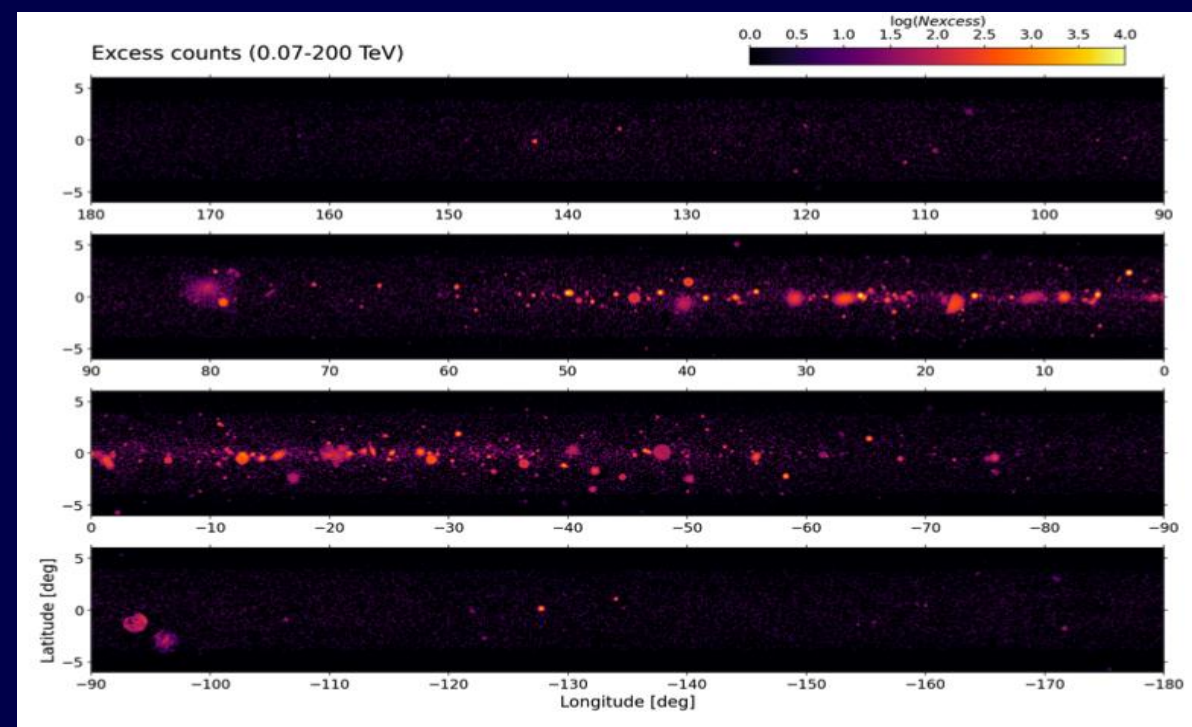
Credits A. Zacharias

Science Data Challenge

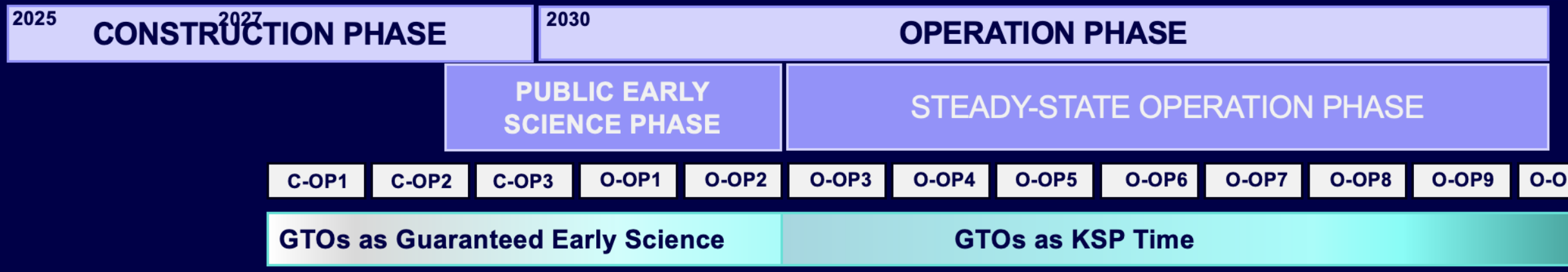
Goals:

- Explain the community the CTAO scientific capabilities.
- Allow the community to familiarize with CTAO data & Science Analysis Tools (SAT) software.
- Test-bench for early data access interfaces.
- Validation of core CTAO software chain.
- Early familiarization with Science Operations.

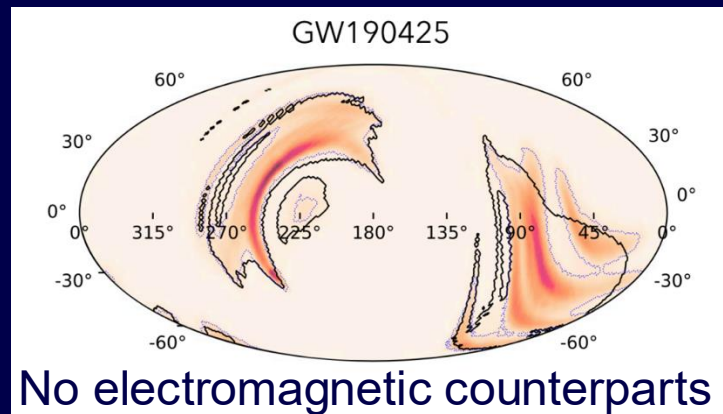
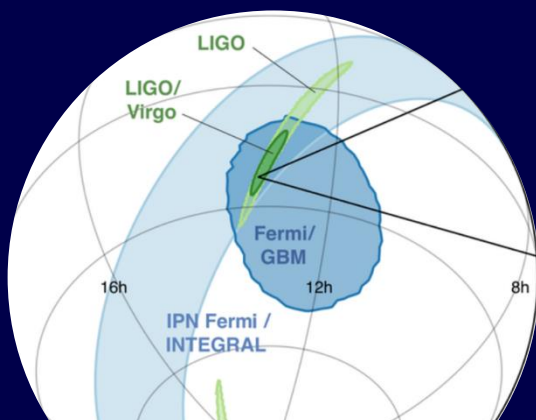
7 years of simulated science-ready data



Scientific exploitation

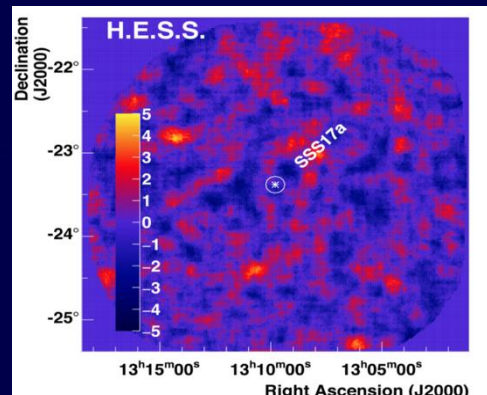
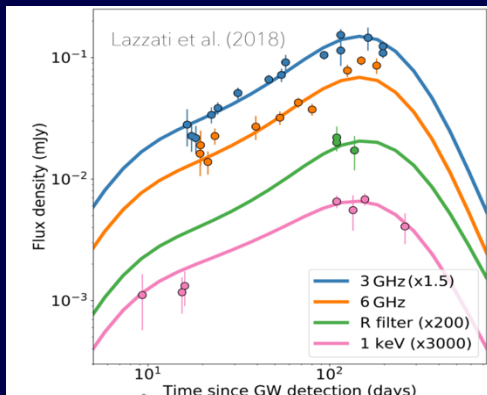
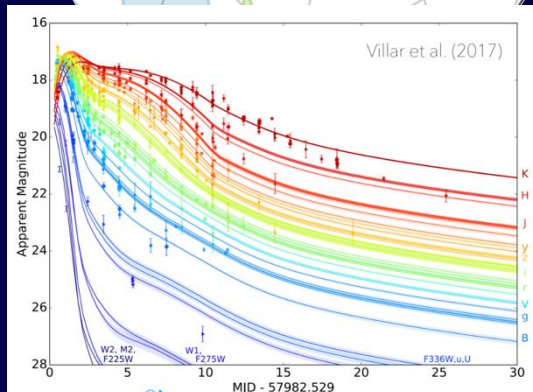


γ -rays & GWs

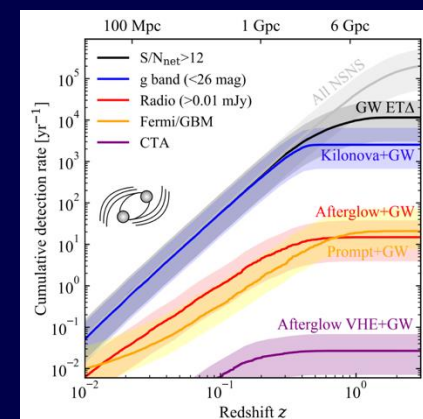


No electromagnetic counterparts

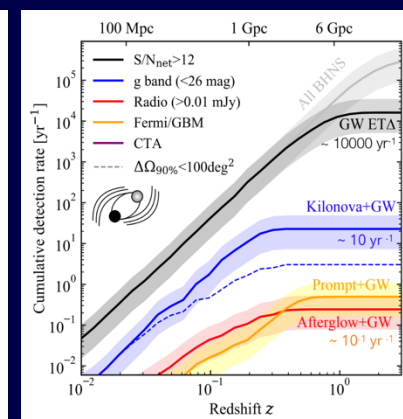
not even in O4!



NSNS



BHNS



with ET will need to choose!

Credits to ET coll