CTAO
Cherenkov Telescope Array Observatory

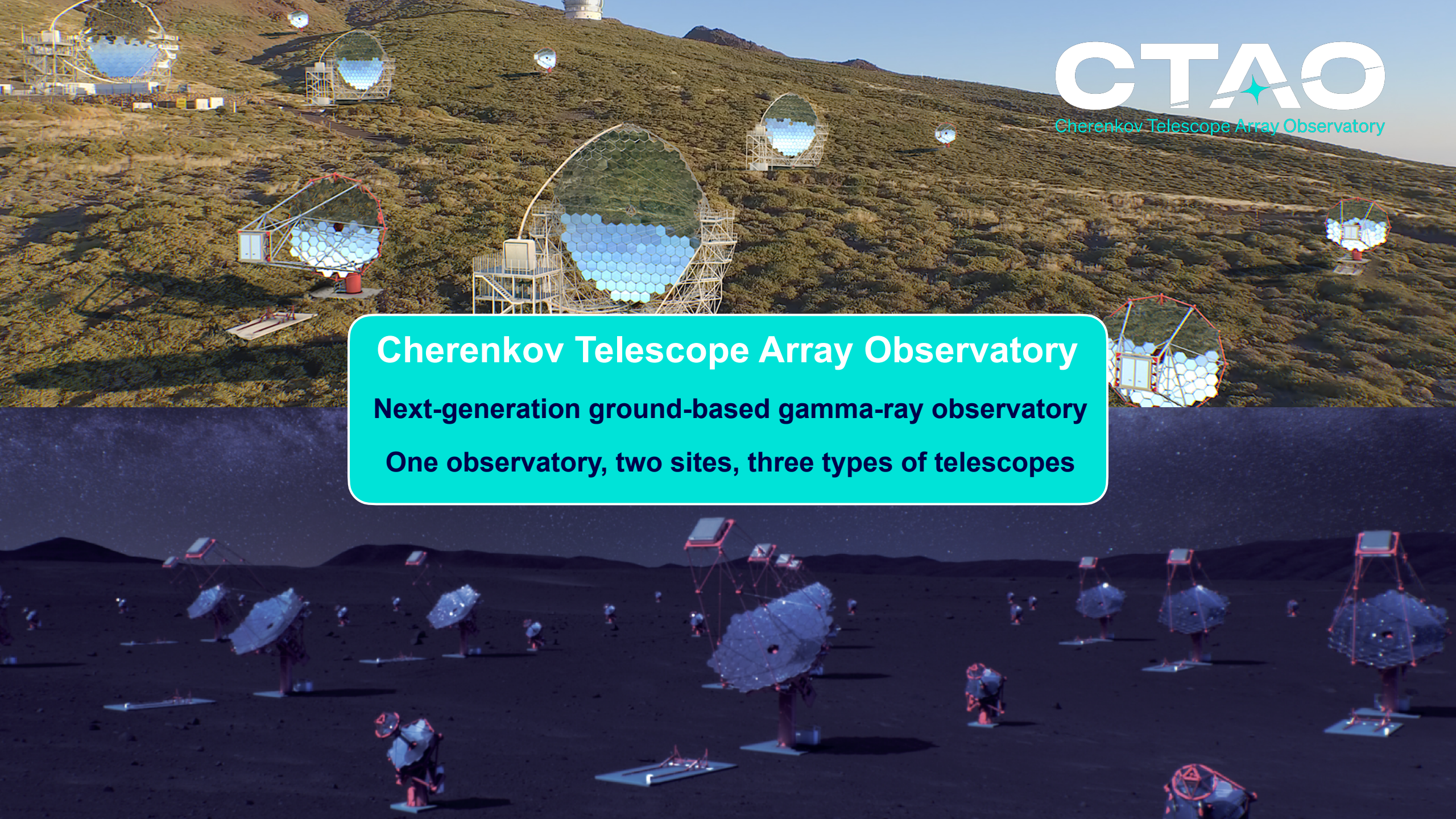
Science with CTAO

Alicia López Oramas (Instituto de Astrofísica de Canarias)
on behalf of the CTAO Consortium

2nd VHEGAM Meeting

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Financiado por la Unión Europea
NextGenerationEU
Plan de Recuperación, Transformación y Resiliencia
AGENCIA ESTATAL DE INVESTIGACIÓN

This work is part of the Project RYC2021-032991-I, funded by MICIU/AEI/ 10.13039/501100011033, and the European Union "NextGenerationEU"/PRTR



Cherenkov Telescope Array Observatory

Next-generation ground-based gamma-ray observatory

One observatory, two sites, three types of telescopes

Three types of telescopes

Medium-Sized Telescope (MST)

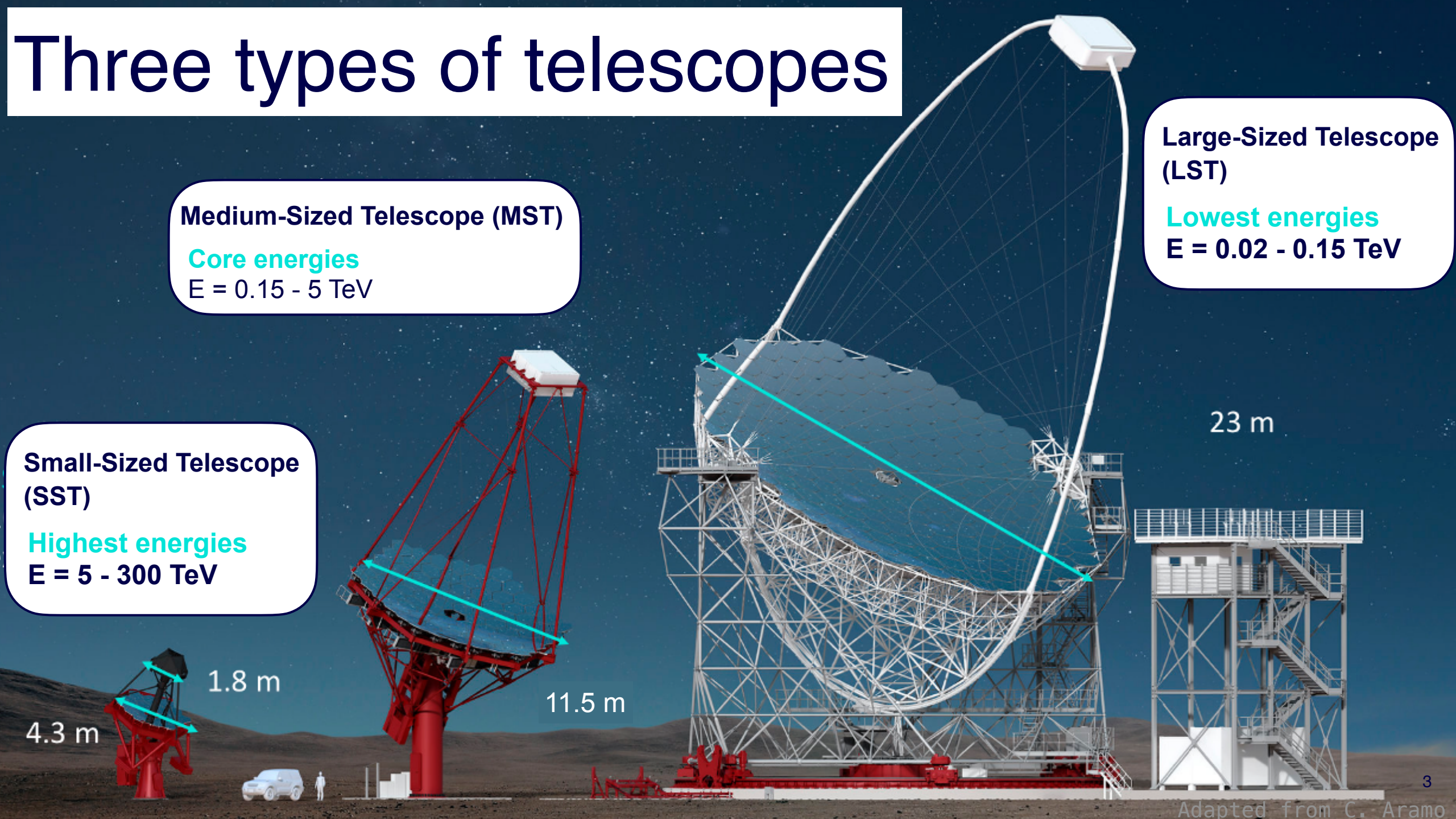
Core energies
E = 0.15 - 5 TeV

Large-Sized Telescope (LST)

Lowest energies
E = 0.02 - 0.15 TeV

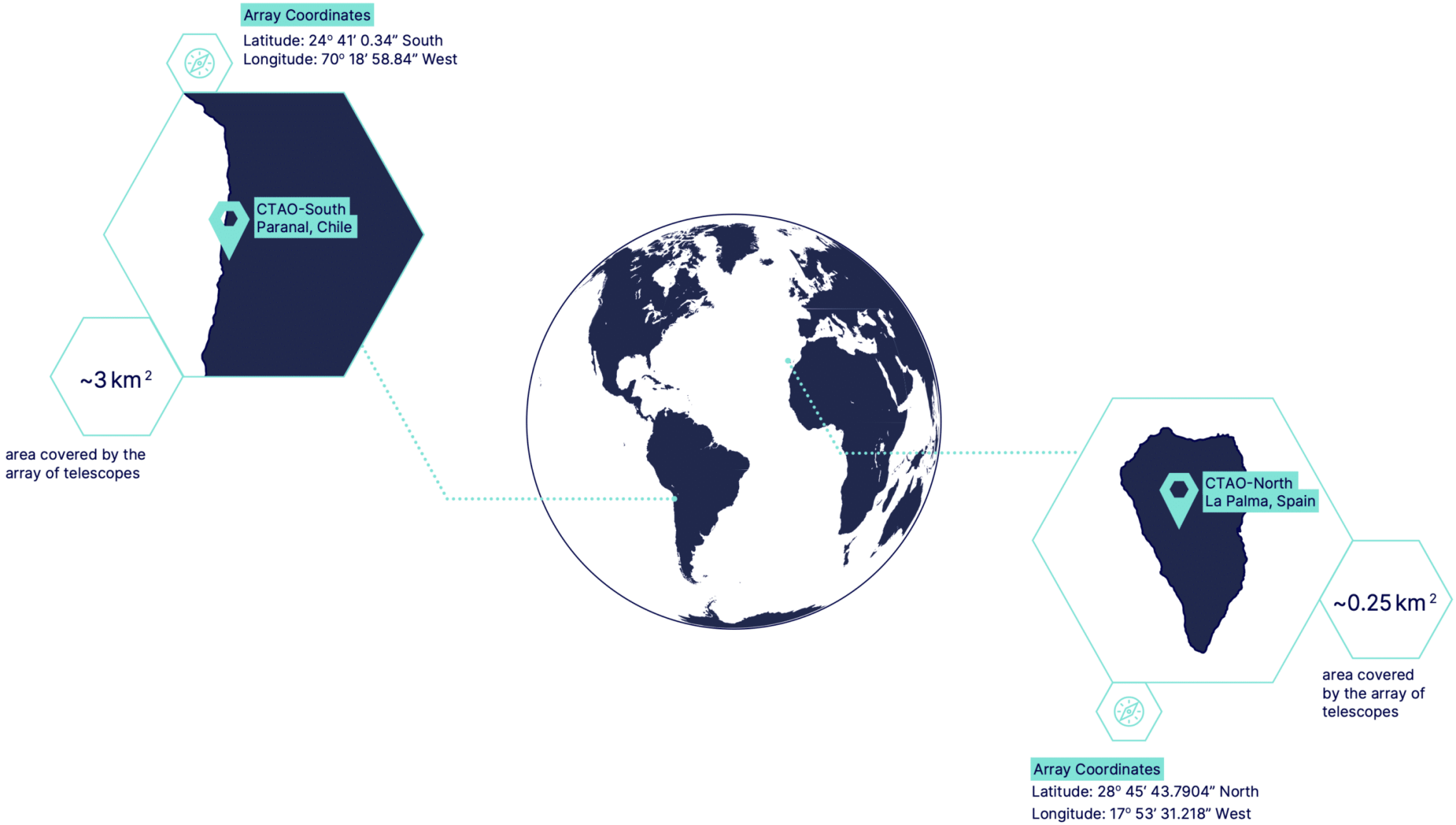
Small-Sized Telescope (SST)

Highest energies
E = 5 - 300 TeV



Adapted from C. Aramo

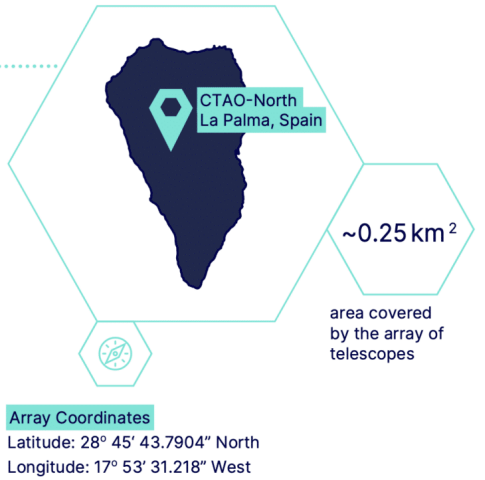
Two array sites

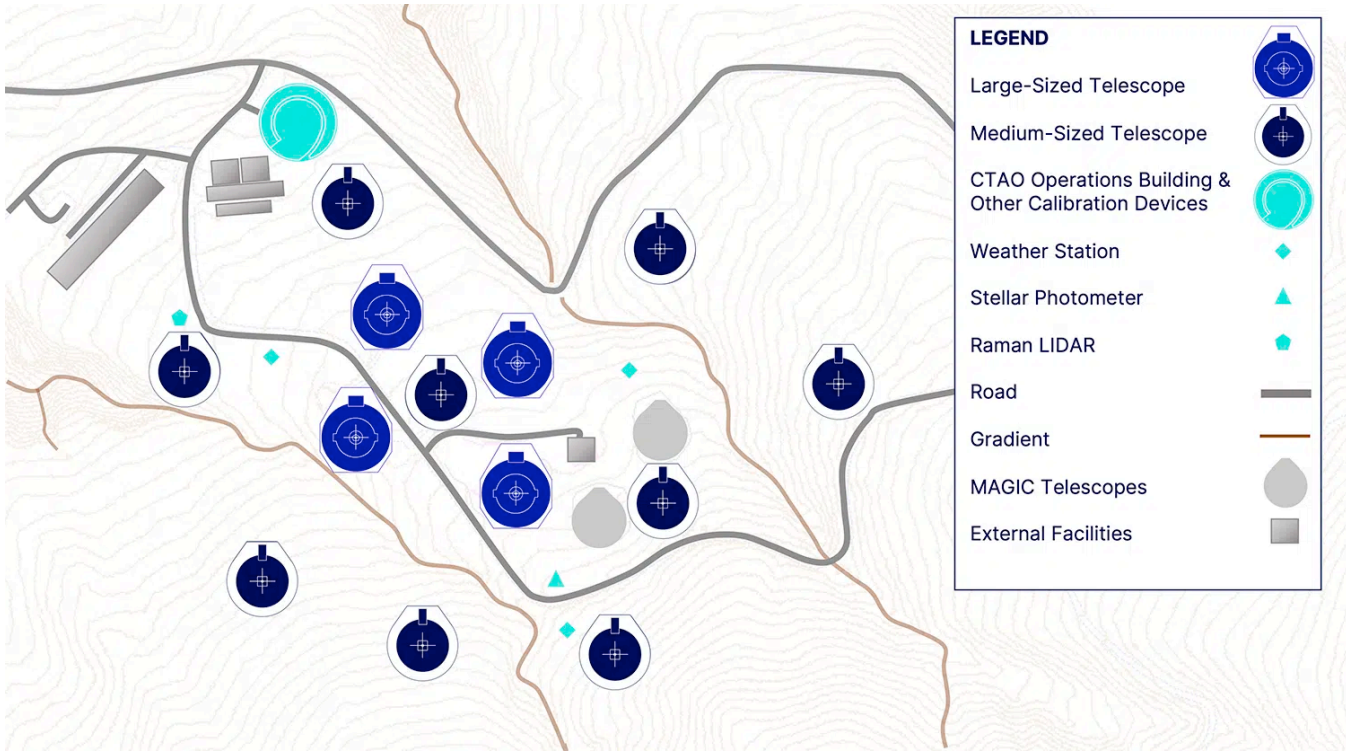


CTAO-Northern Array

Alpha Configuration

Configuration used in most papers*



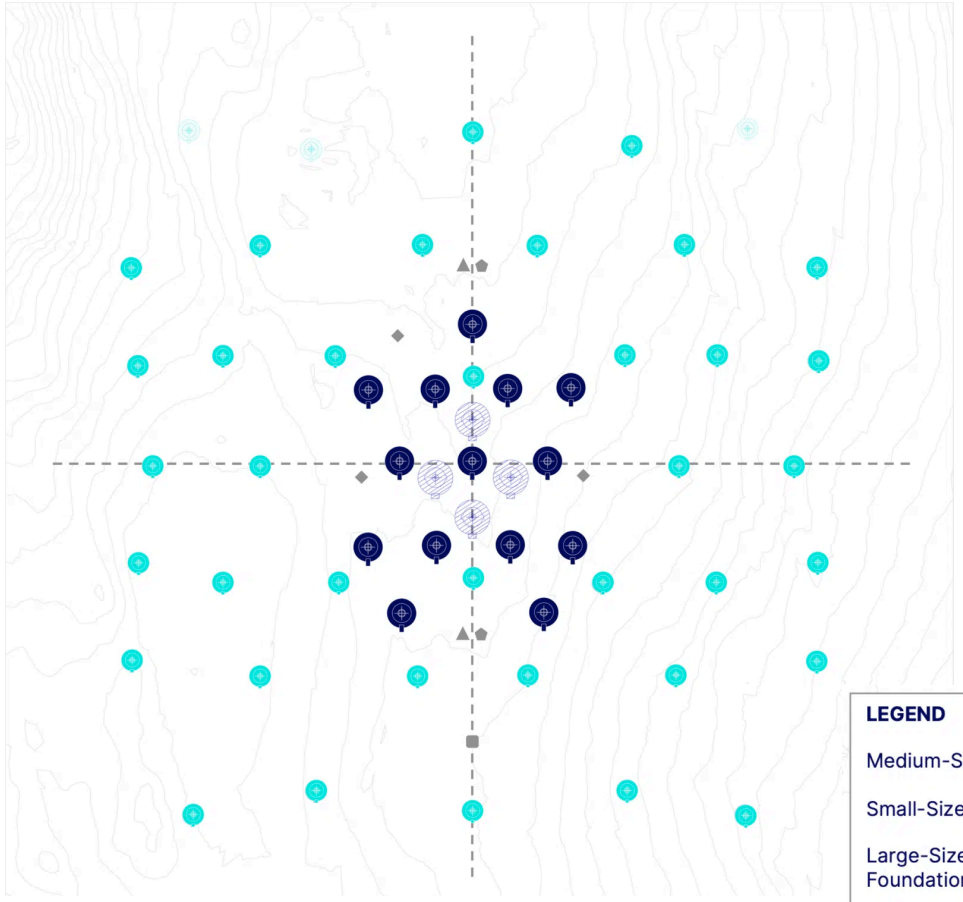


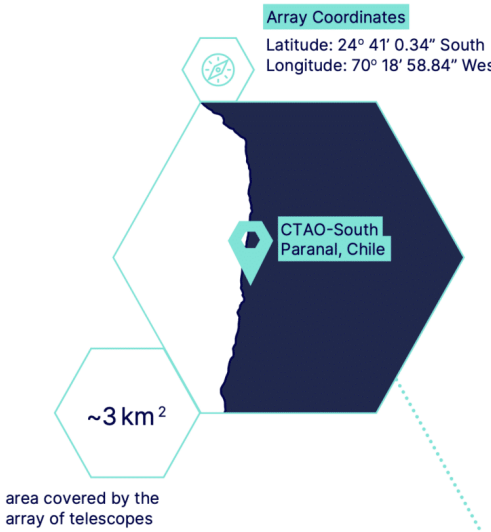
- Located at Observatorio Roque de los Muchachos (ORM), Spain
- 4 LSTs+ 9 MSTs

CTAO-Southern Array

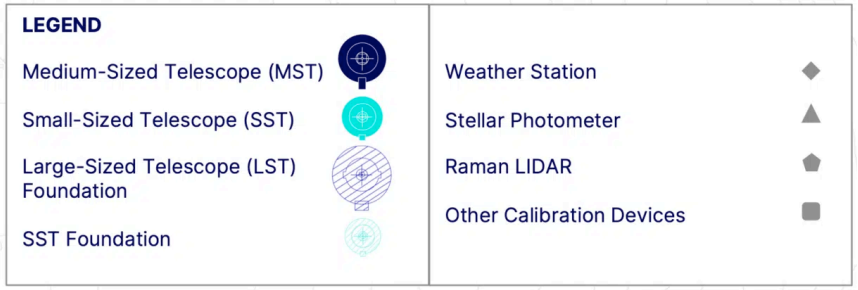
Alpha Configuration

Configuration used in most papers*



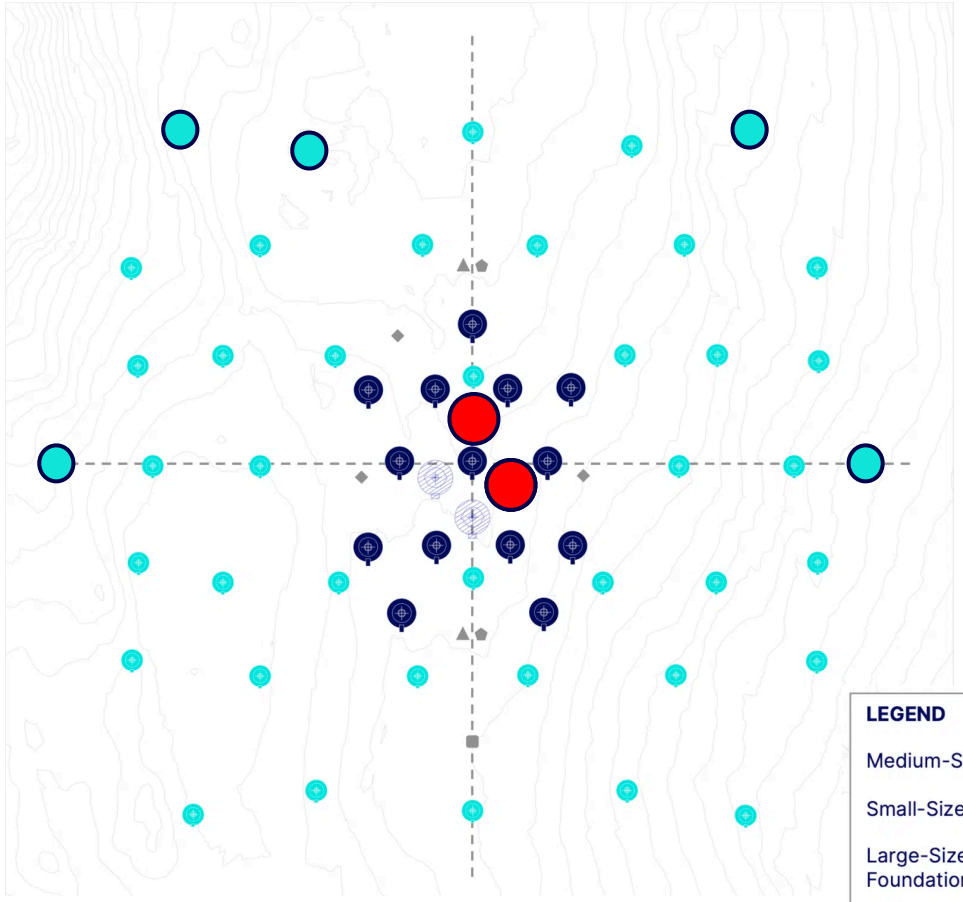


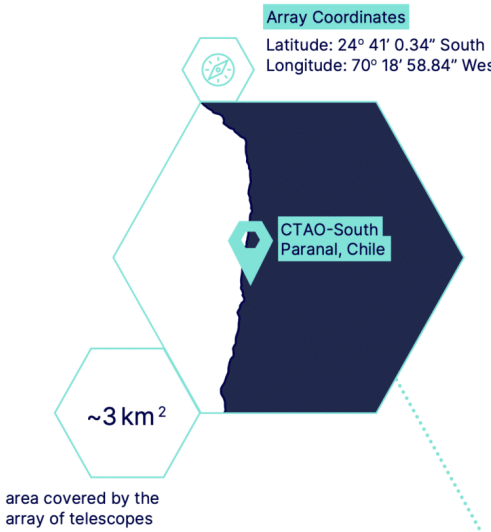
- Located at Atacama Desert, Chile
- 14 MSTs + 37 SSTs



CTAO-Southern Array

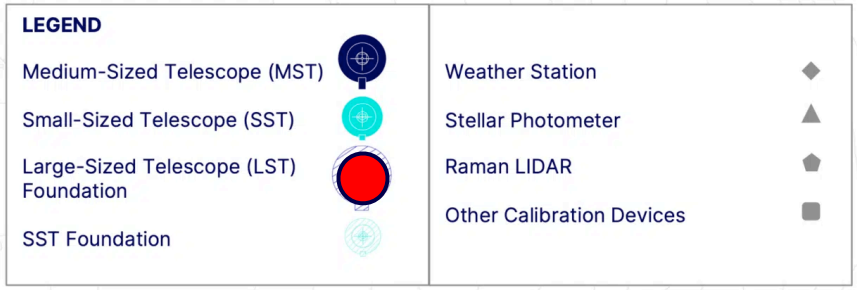
Alpha Configuration+



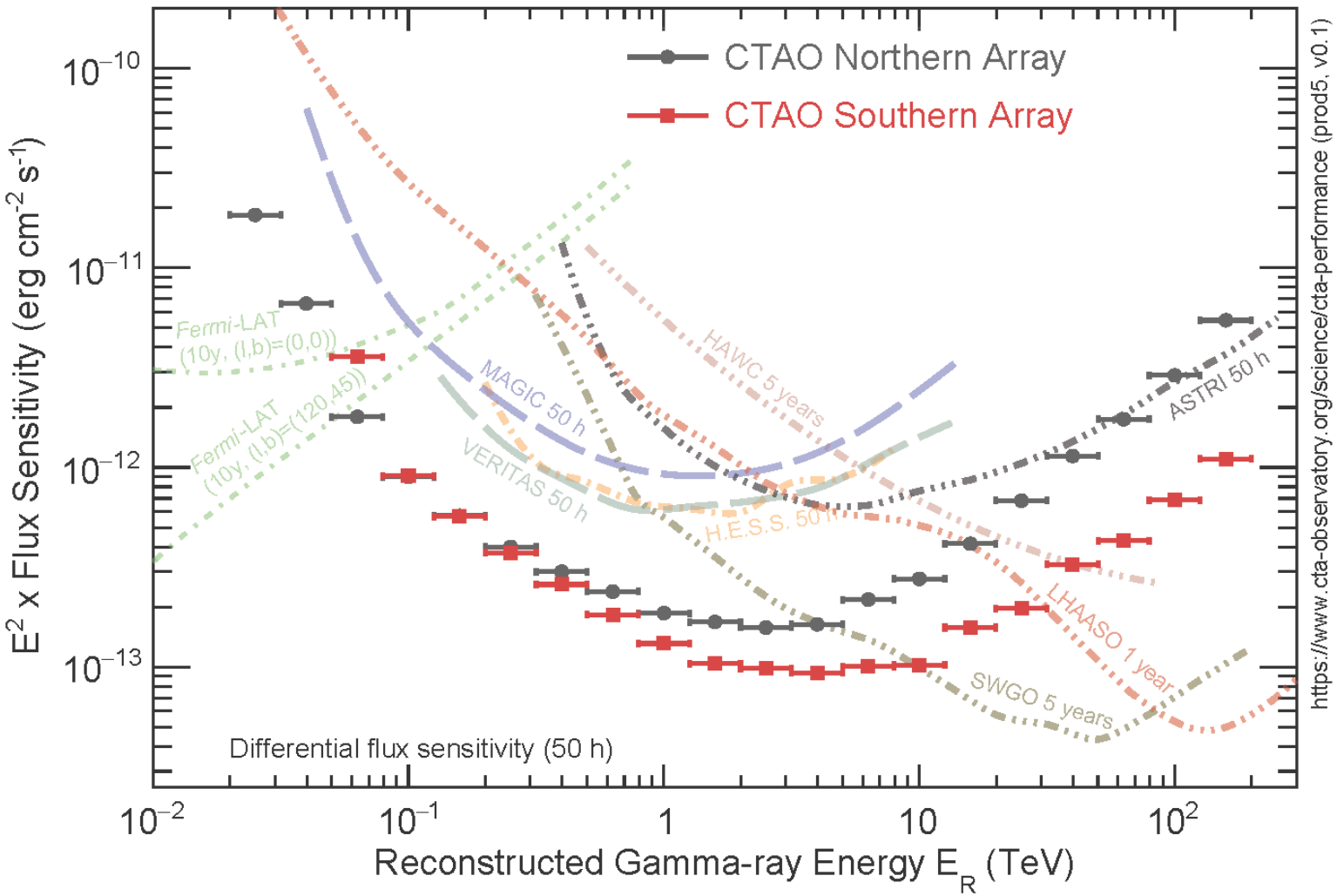


- Located at Atacama Desert, Chile
- 14 MSTs + **42 SSTs** + **2 LSTs**

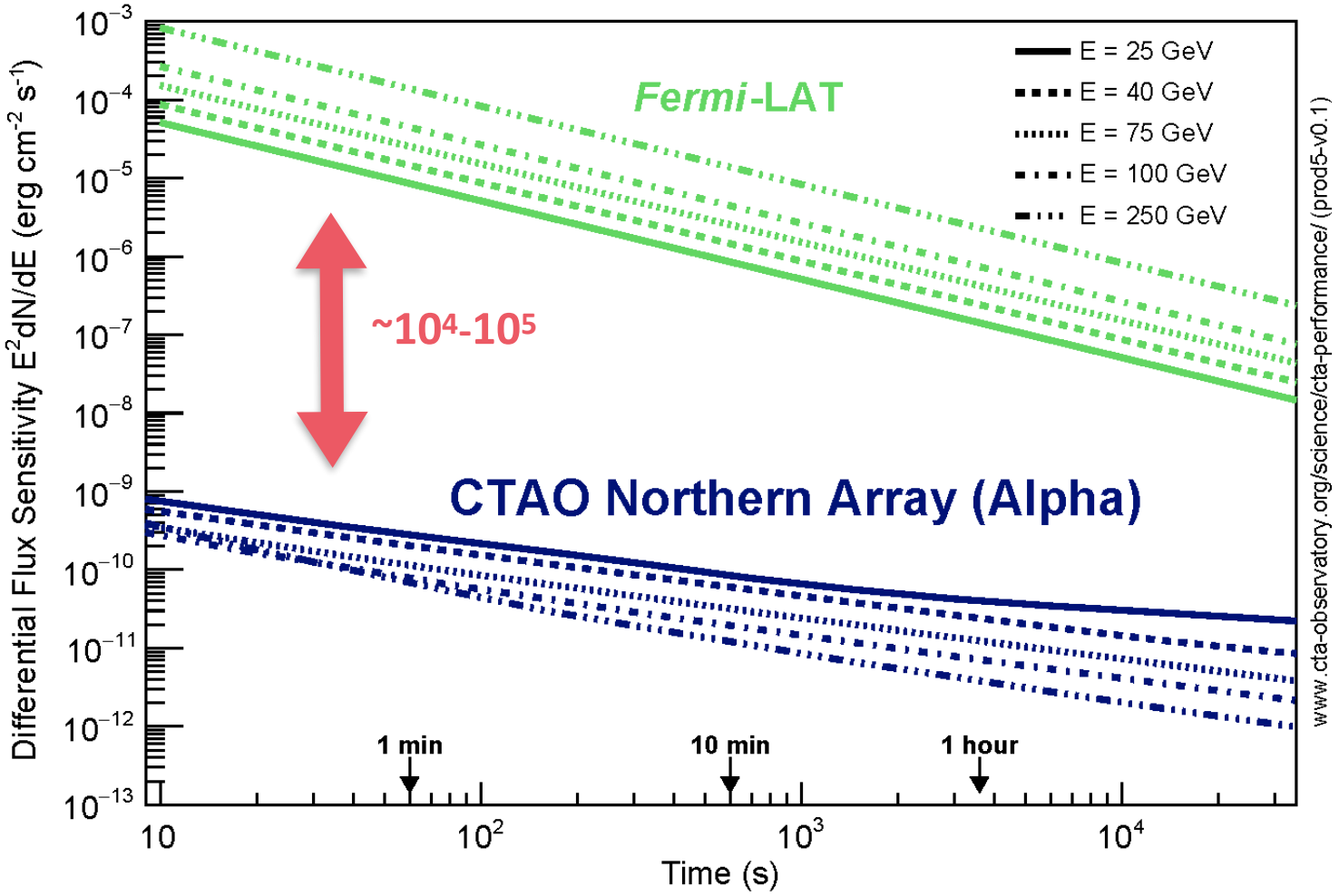
CTA+: see talk by C. Aramo



Sensitivity



Short-time Sensitivity



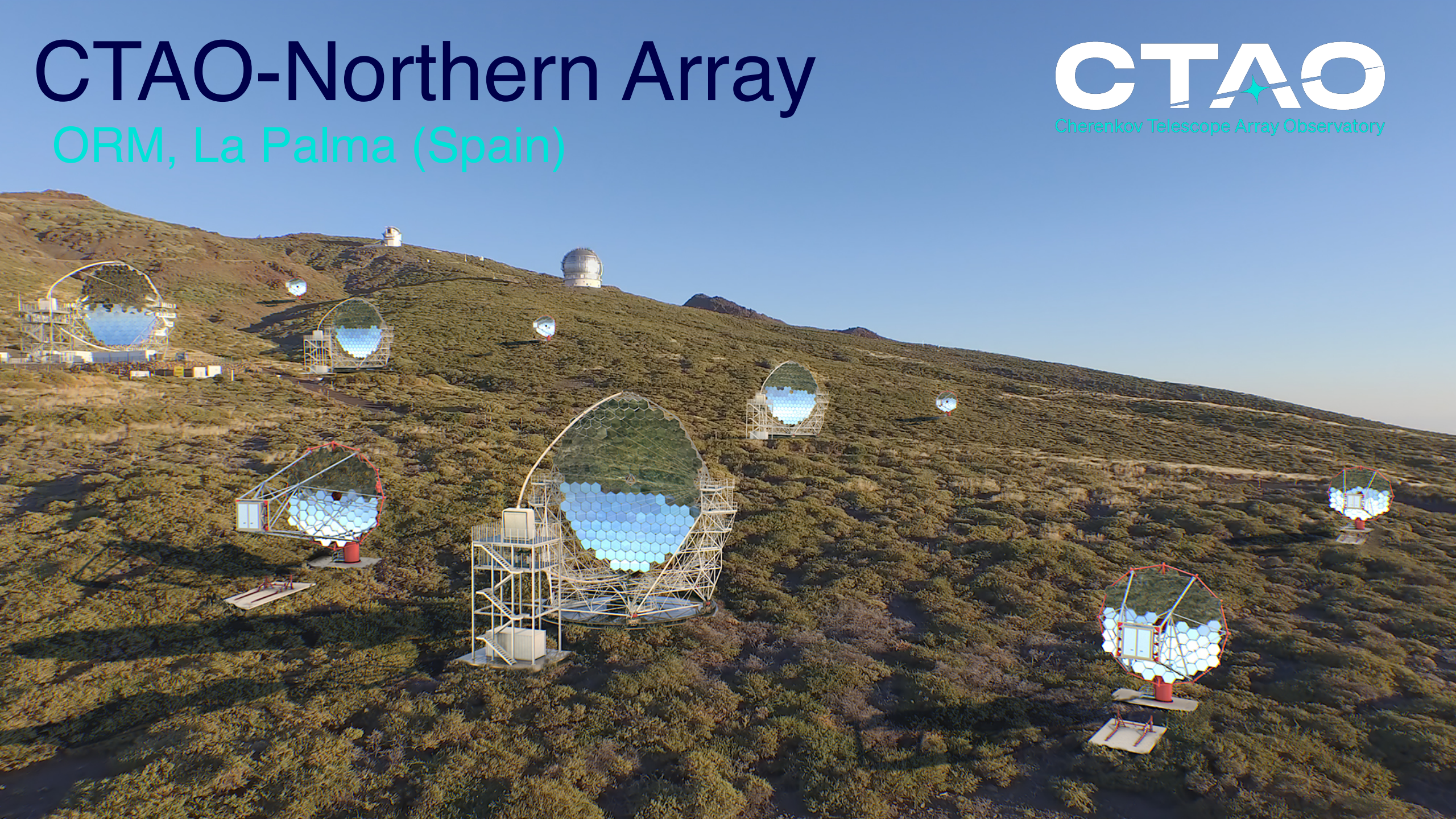
Optimal for transient detection

Current Status

CTAO-Northern Array

ORM, La Palma (Spain)

CTAO
Cherenkov Telescope Array Observatory



CTAO-Northern Array

ORM, La Palma (Spain)

CTAO
Cherenkov Telescope Array Observatory

See talk by A. Berti

CTAO-LST1

- Operational since 2018 at ORM
- Producing Scientific Results

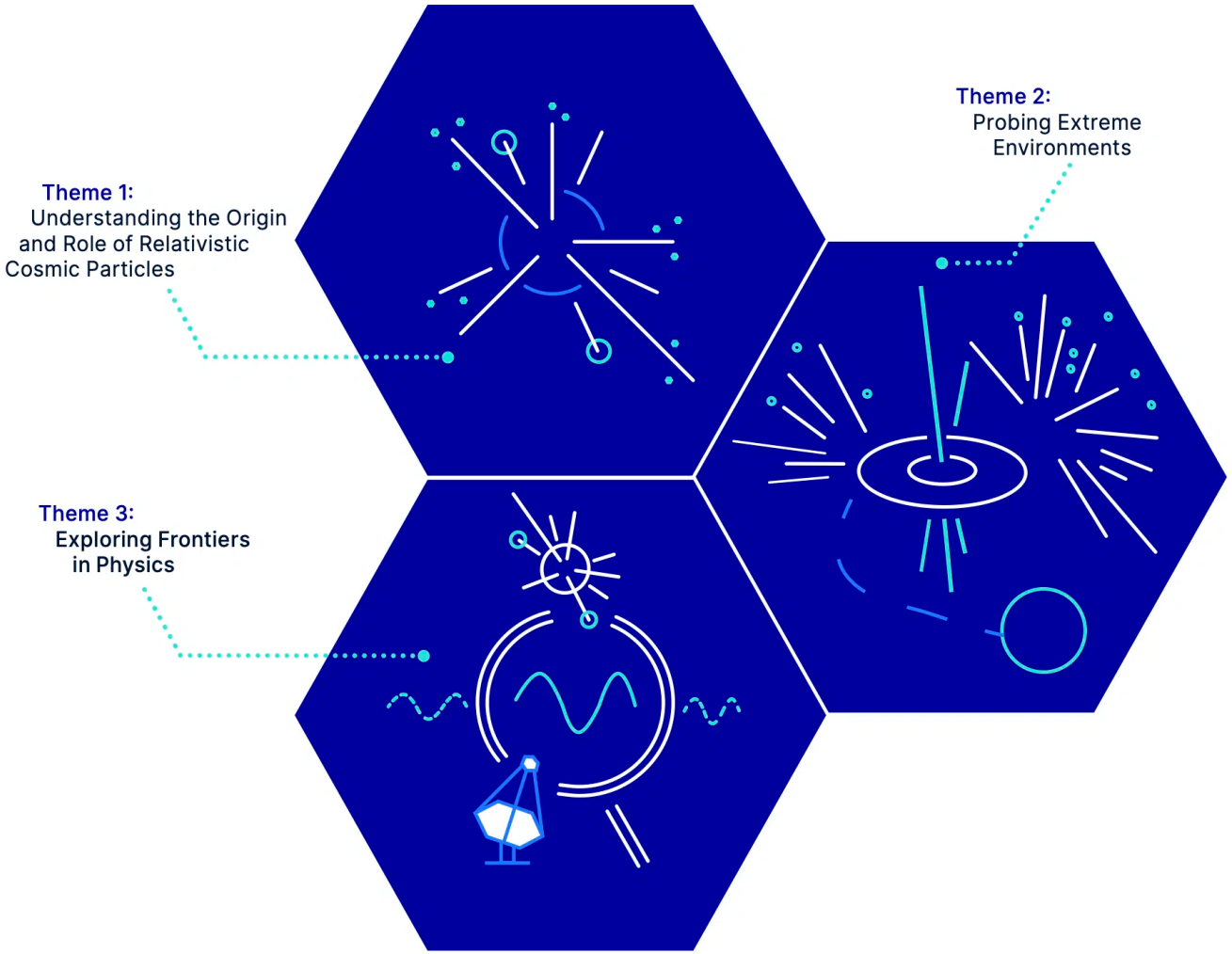
Most recent scientific highlights

- Discovery of **OP313 at z=0.997**
- (LST Coll, Otero-Santos, 11th Fermi Symposium 2024)
- **B.O.A.T. GRB 221009A at 4σ**
- (Abe et al. Subm.)
- **Nova RS Oph 2021 outburst**
  (Abe et al. 2025)

See talk by A. Carosi

Science with CTAO

Science Cases



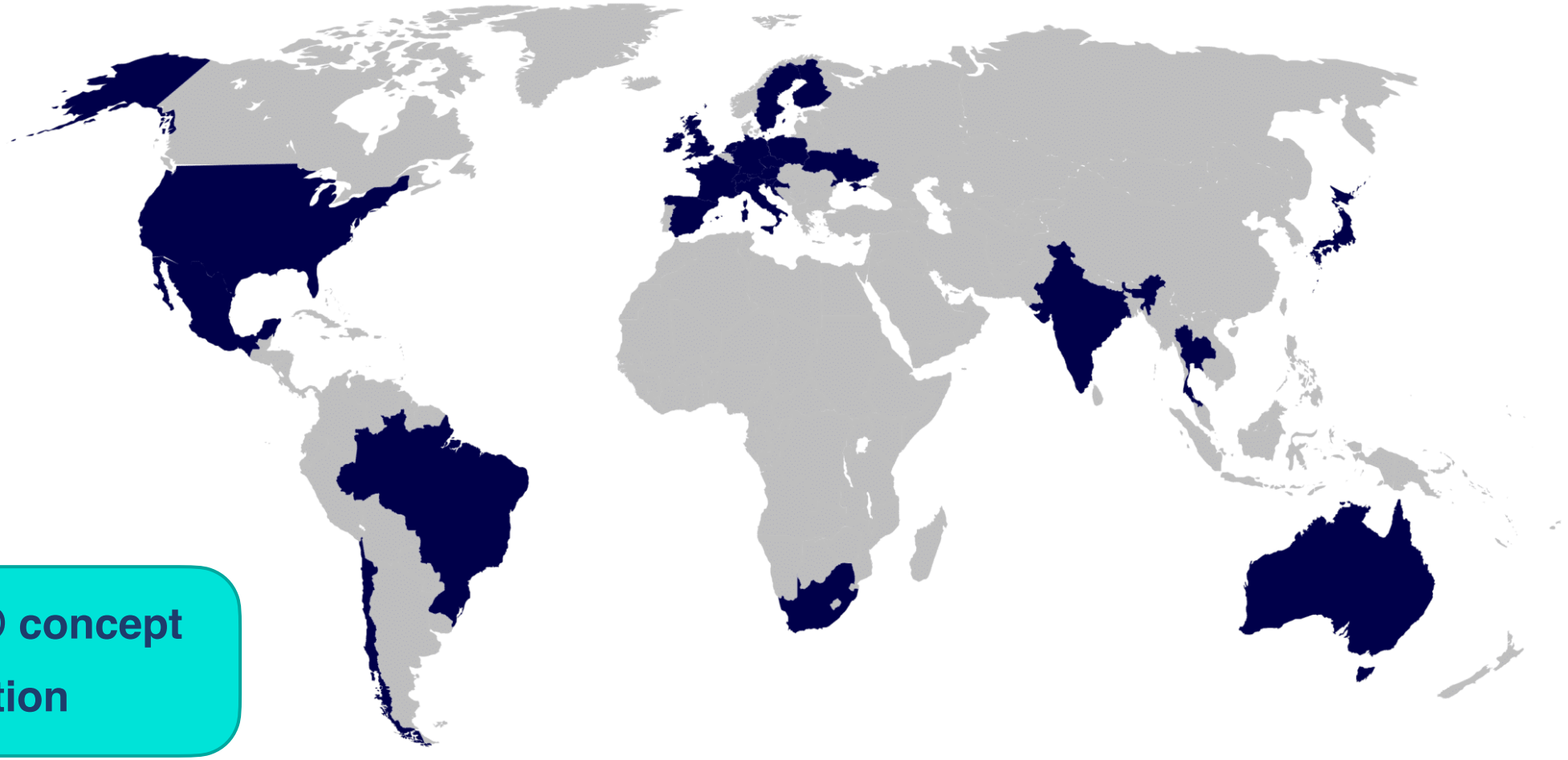
CTAO Consortium

CTAO | CONSORTIUM

+1500 members

~ 200 institutes

25 countries



- Created the CTAO **concept**
- **Science exploitation**

Science Cases

arXiv:1709.07997

- **Key Science Projects**:
  multi-purpose observations designed to efficiently address the science questions of CTAO

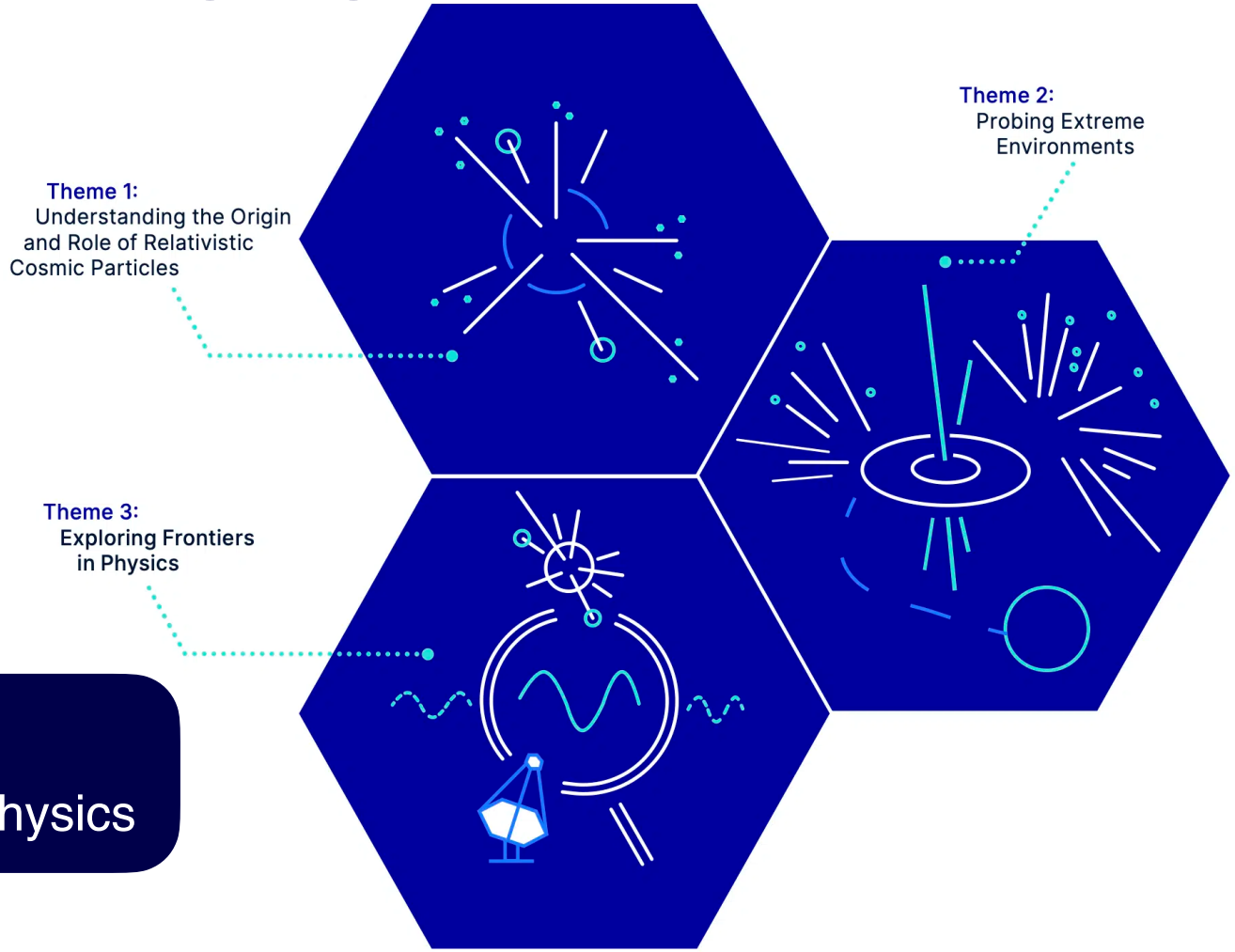
  (CTA Consortium 2018)

- Series of **Consortium publications** focused on these topics

Science Cases

CTAO | CONSORTIUM CTAO

- Cosmic rays
- PeVatrons
- Star-forming regions



- Galactic Plane Survey
- Extragalactic Survey
- LMC Survey

- Dark matter
- Fundamental physics

- Galactic Centre
- Transients
- AGNs
- Galaxy Clusters

- **Key Science Projects**: multi-purpose observations designed to **efficiently address the science questions of CTAO** (CTA Consortium, 2018)

Science Cases

CTAO | CONSORTIUM CTAO

- **Key Science Projects**: multi-purpose observations designed to **efficiently address the science questions of CTAO** (CTA Consortium, 2018)
- **First Consortium papers** on KSPs already **published:**
  - Acharyya et al. 2021
  - Acharyya et al. 2023
  - Acero et al. 2023
  - Abe et al. 2024a
  - Abe et al. 2024b
  - Abe et al. 2024c
  - Abe et al. 2025

- Most papers use **prod5 IRFs** (alpha configuration)
- Older* papers also include prod3 IRFs (omega configuration)

alpha configuration (first phase):

North: 4 LST + 9 MST
South: 14 MST + 37 SST

omega configuration (ultimate goal):

North: 4 LST + 15 MST
South: 4 LST + 25 MST + 70 SST

Science Cases

CTAO | CONSORTIUM CTAO

Journal of Cosmology and Astroparticle Physics

PAPER • OPEN ACCESS

Dark matter line searches with the Cherenkov Telescope Array

S. Abe, J. Abhir, A. Abhishek, F. Acero, A. Acharyya, R. Adam, A. Aguasca-Cabot, I. Agudo, A. Aguirre-Santaella, J. Alfaro ▾ Show full author list

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Journal of Cosmology and Astroparticle Physics, Volume 2024, July 2024

Citation S. Abe *et al* JCAP07(2024)047

DOI 10.1088/1475-7516/2024/07/047

Journal of Cosmology and Astroparticle Physics

PAPER • OPEN ACCESS

Prospects for a survey of the galactic plane with the Cherenkov Telescope Array

S. Abe, J. Abhir, A. Abhishek, F. Acero, A. Acharyya, R. Adam, A. Aguasca-Cabot, I. Agudo, A. Aguirre-Santaella, J. Alfaro ▾ Show full author list

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Journal of Cosmology and Astroparticle Physics, Volume 2024, October 2024

Citation S. Abe *et al* JCAP10(2024)081

DOI 10.1088/1475-7516/2024/10/081

Journal of Cosmology and Astroparticle Physics

PAPER • OPEN ACCESS

Prospects for γ-ray observations of the Perseus galaxy cluster with the Cherenkov Telescope Array

K. Abe, S. Abe, F. Acero, A. Acharyya, R. Adam, A. Aguasca-Cabot, I. Agudo, A. Aguirre-Santaella, J. Alfaro, R. Alfaro ▾ Show full author list

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Journal of Cosmology and Astroparticle Physics, Volume 2024, October 2024

Citation K. Abe *et al* JCAP10(2024)004

DOI 10.1088/1475-7516/2024/10/004

JOURNAL ARTICLE

Sensitivity of the Cherenkov Telescope Array to TeV photon emission from the Large Magellanic Cloud FREE

A Acharyya , R Adam , A Aguasca-Cabot , I Agudo , A Aguirre-Santaella , J Alfaro , R Aloisio , R Alves Batista , E Amato , E O Angüner ... Show more

Monthly Notices of the Royal Astronomical Society, Volume 523, Issue 4, August 2023, Pages 5353–5387, https://doi.org/10.1093/mnras/stad1576

Published: 26 May 2023 **Article history** ▾

JOURNAL ARTICLE

Galactic transient sources with the Cherenkov Telescope Array Observatory

K Abe , S Abe , J Abhir , A Abhishek , F Acero , A Acharyya , R Adam , A Aguasca-Cabot , I Agudo , A Aguirre-Santaella ... Show more

Monthly Notices of the Royal Astronomical Society, Volume 540, Issue 1, June 2025, Pages 205–238, https://doi.org/10.1093/mnras/staf655

Published: 24 April 2025 **Article history** ▾

Journal of Cosmology and Astroparticle Physics

OPEN ACCESS

Sensitivity of the Cherenkov Telescope Array to a dark matter signal from the Galactic centre

A. Acharyya, R. Adam, C. Adams, I. Agudo, A. Aguirre-Santaella, R. Alfaro, J. Alfaro, C. Alispach, R. Aloisio, R. Alves Batista ▾ Show full author list

Published 27 January 2021 • © 2021 The Author(s)

Journal of Cosmology and Astroparticle Physics, Volume 2021, January 2021

Citation A. Acharyya *et al* JCAP01(2021)057

DOI 10.1088/1475-7516/2021/01/057

ELSEVIER

Astroparticle Physics

Volume 150, August 2023, 102850

Sensitivity of the Cherenkov Telescope Array to spectral signatures of hadronic PeVatrons with application to Galactic Supernova Remnants

+ others in prep.

Galactic Science

GPS Survey

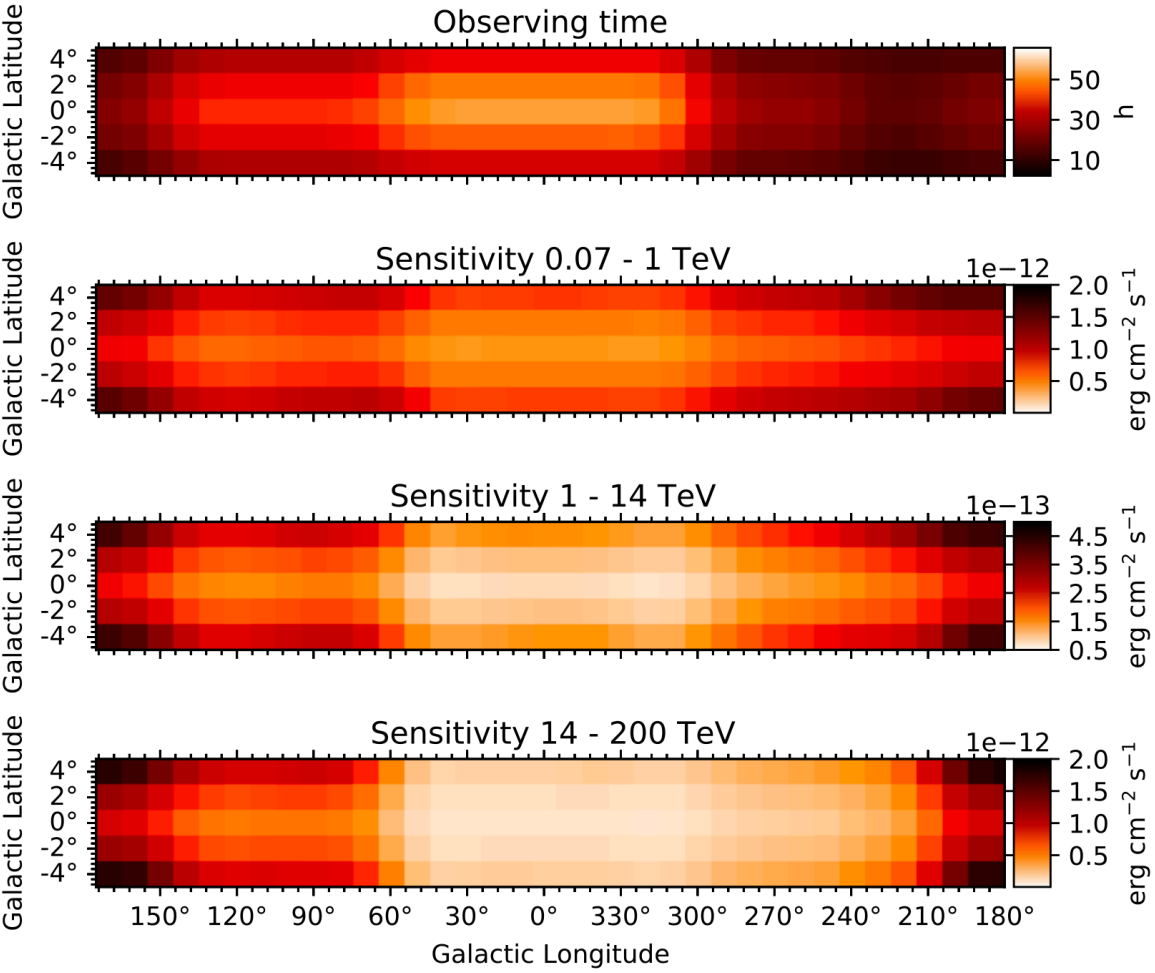
PAPER • OPEN ACCESS

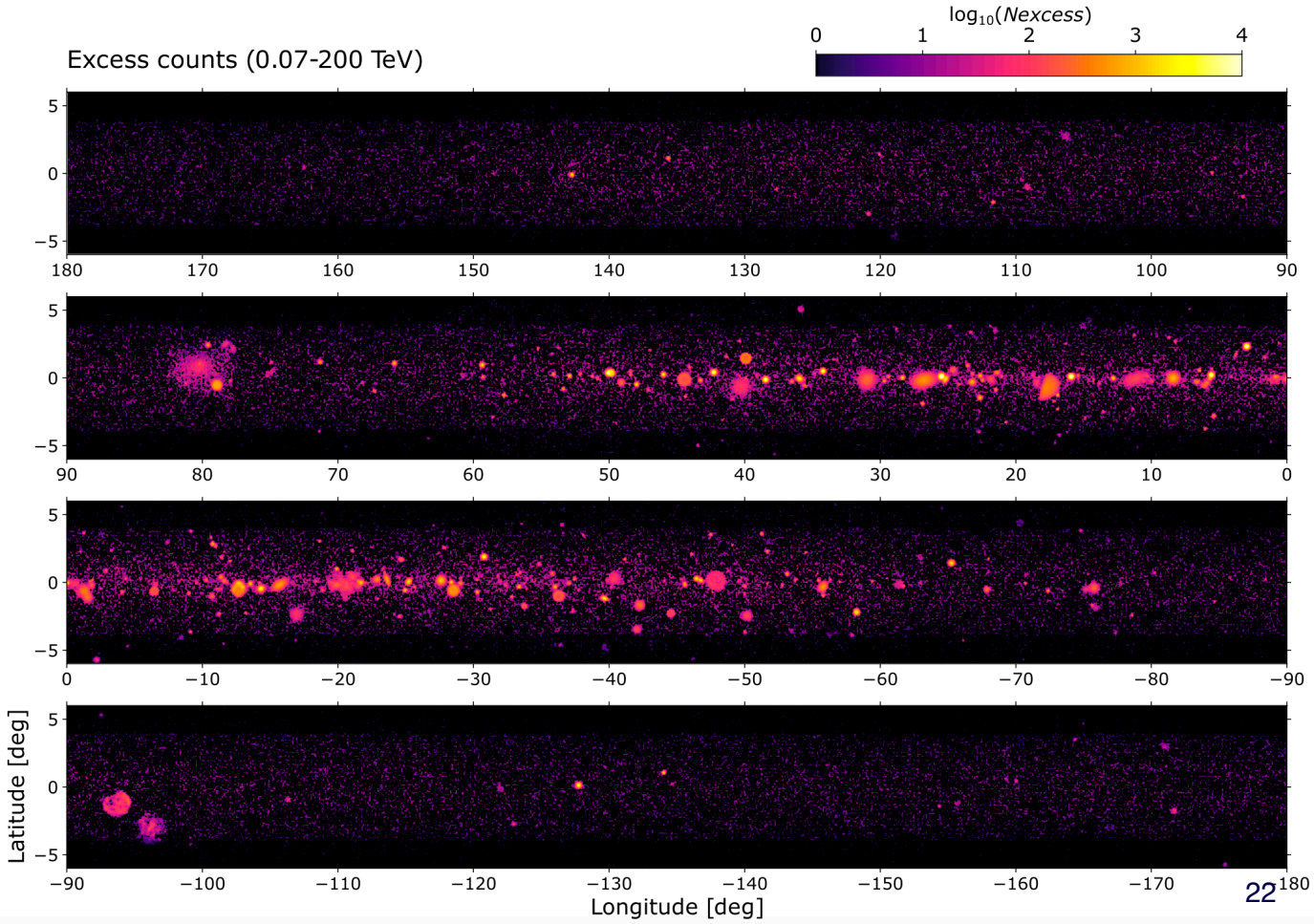
Prospects for a survey of the galactic plane with the Cherenkov Telescope Array

CTAO Consortium (Abe et al. 2024): 10.1088/1475-7516/2024/10/081

- Total of 1620 hours spread over ten years
- Potential to increase the number of Galactic VHE emitters by a ~ factor of five

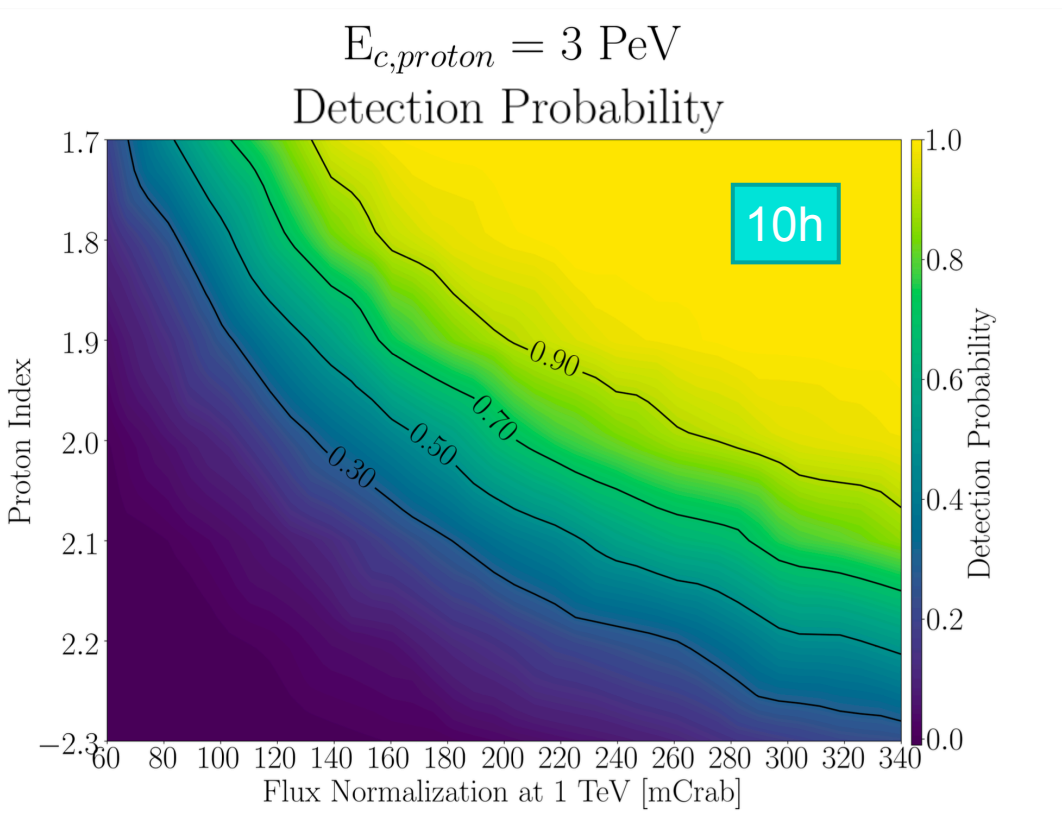
500 sources expected

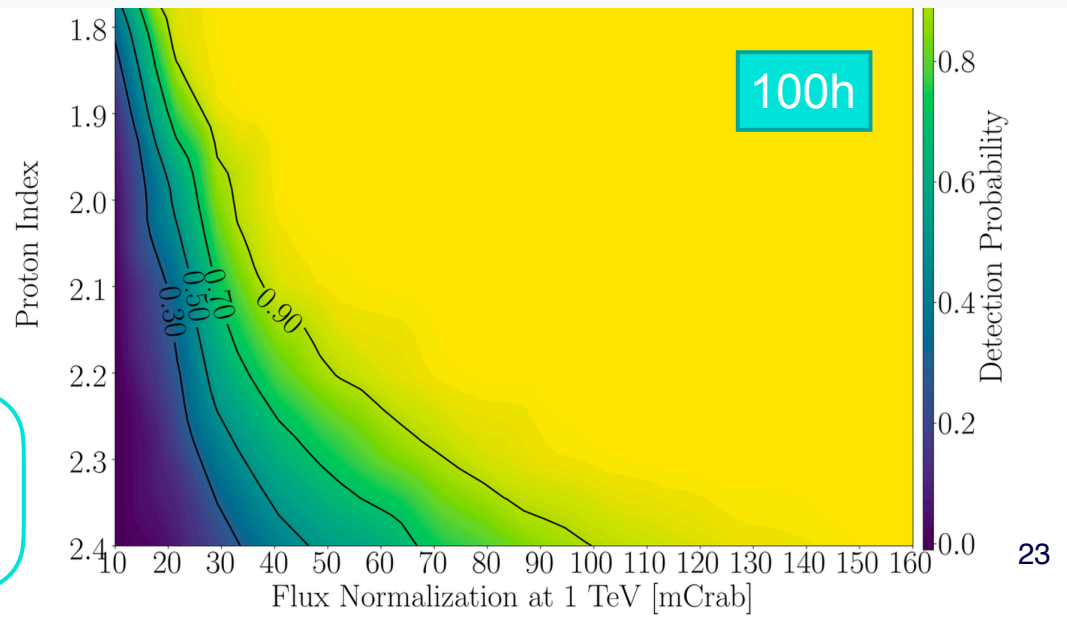




PeVatrons

- Can CTAO identify hadronic PeVatrons?
  - **GPS: limited spectral sensitivity** to search for PeVatrons in scanning mode (~10h)
    - Detection if they have **hard proton spectra and are point like**
  - **Deep observations *O*(100)h** in the case of soft sources ($\Gamma_p \gtrsim 2.3$)
    - Could be done with SSTs during moontime with x2 time



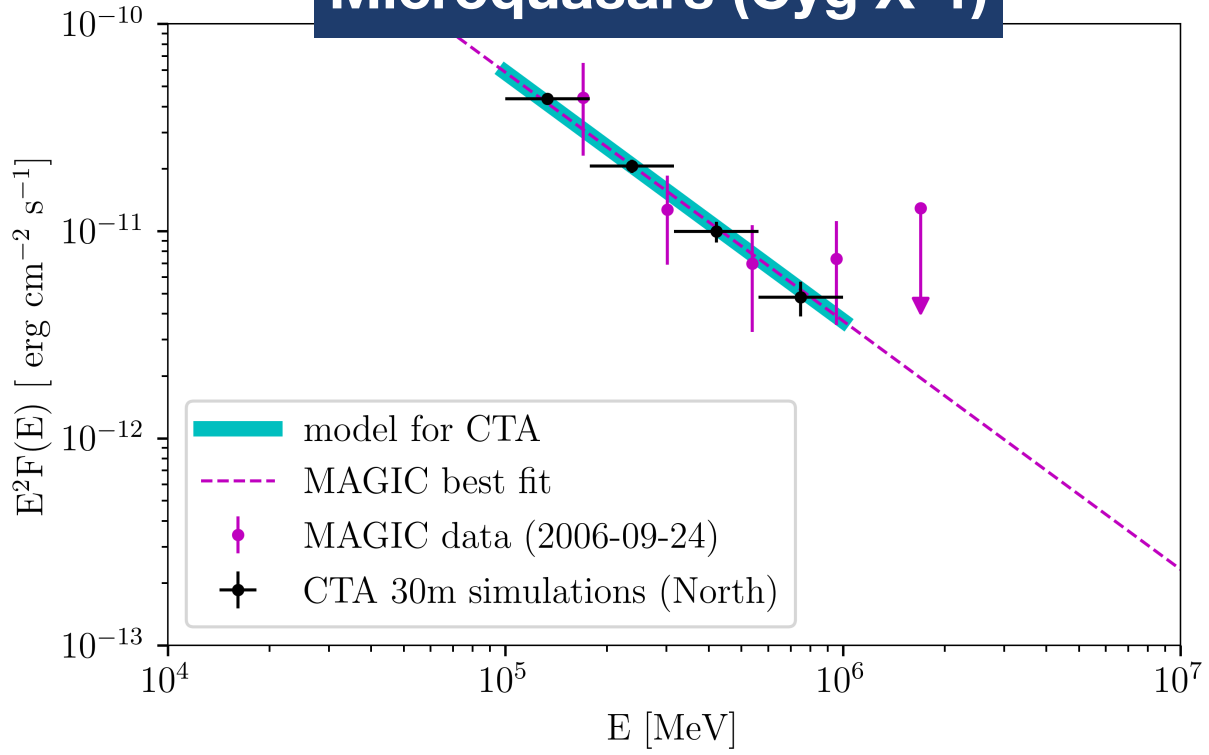


Sensitivity of the Cherenkov Telescope Array to spectral signatures of hadronic PeVatrons with application to Galactic Supernova Remnants

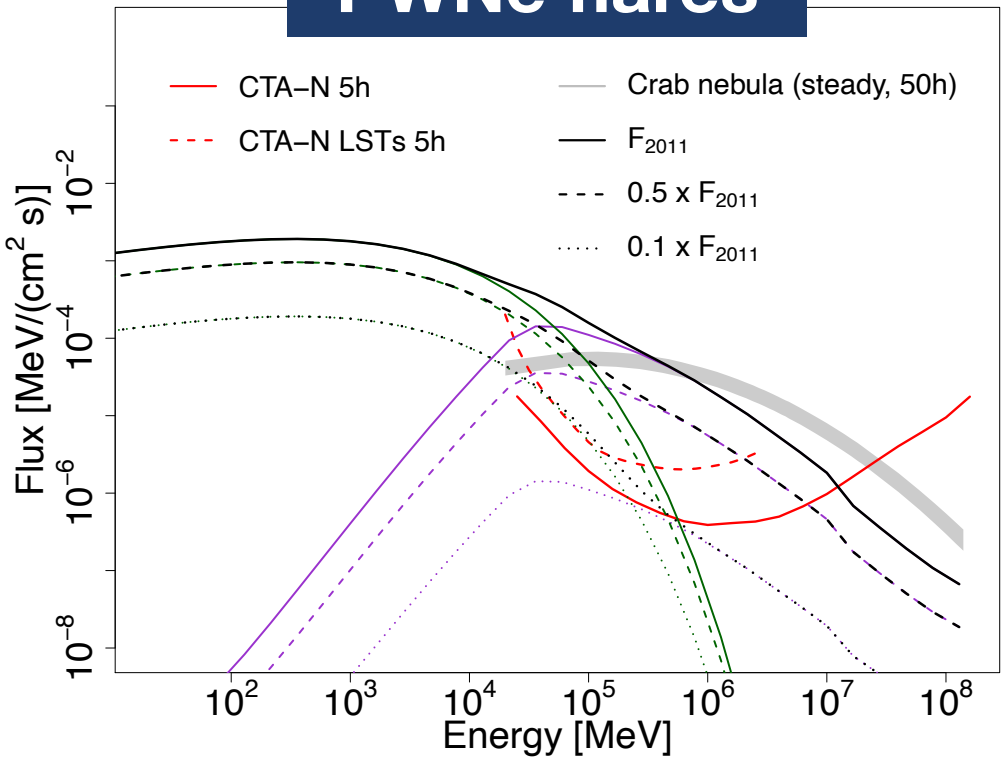
CTA Consortium (Acero et al. 2023)
10.1016/j.astropartphys.2023.102850

Galactic transients

Microquasars (Cyg X-1)



PWNe flares



- Detection of transient emission from:
  - Microquasars
  - Crab Nebula (flares)
  - Novae

JOURNAL ARTICLE

Galactic transient sources with the Cherenkov Telescope Array Observatory

CTAO Consortium (Abe et al. 2025)
https://doi.org/10.1093/mnras/staf655

Dark Matter

DM line searches

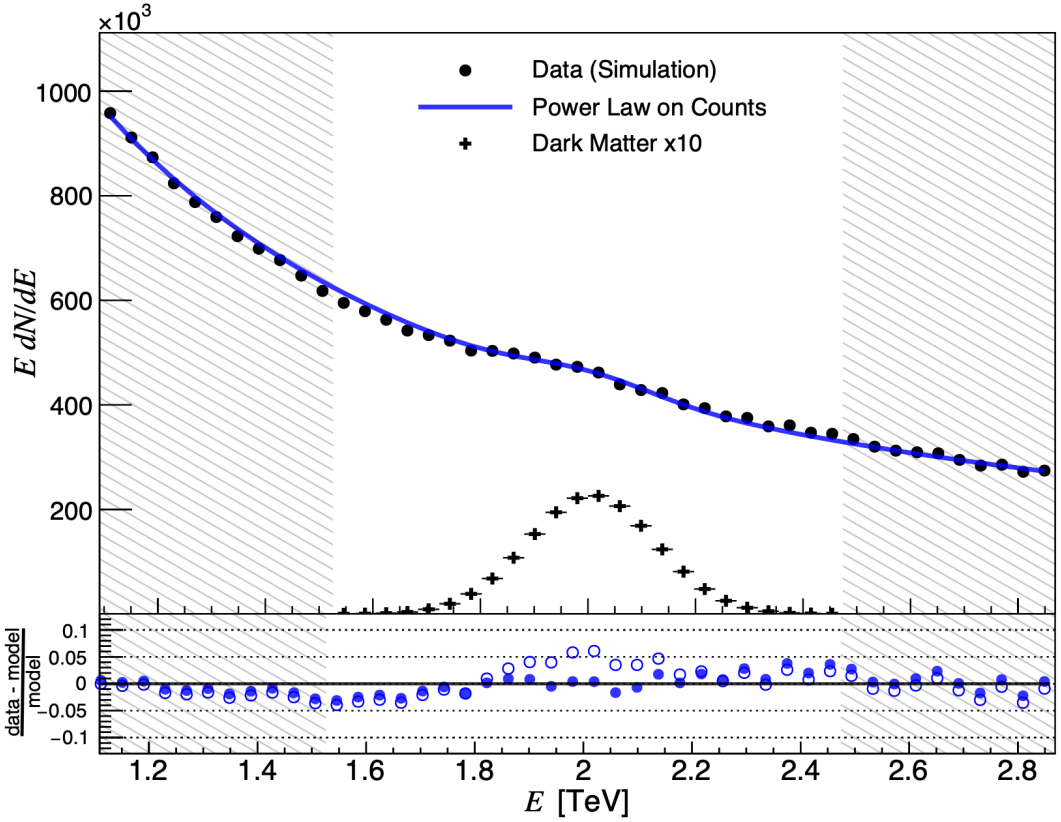
PAPER • OPEN ACCESS

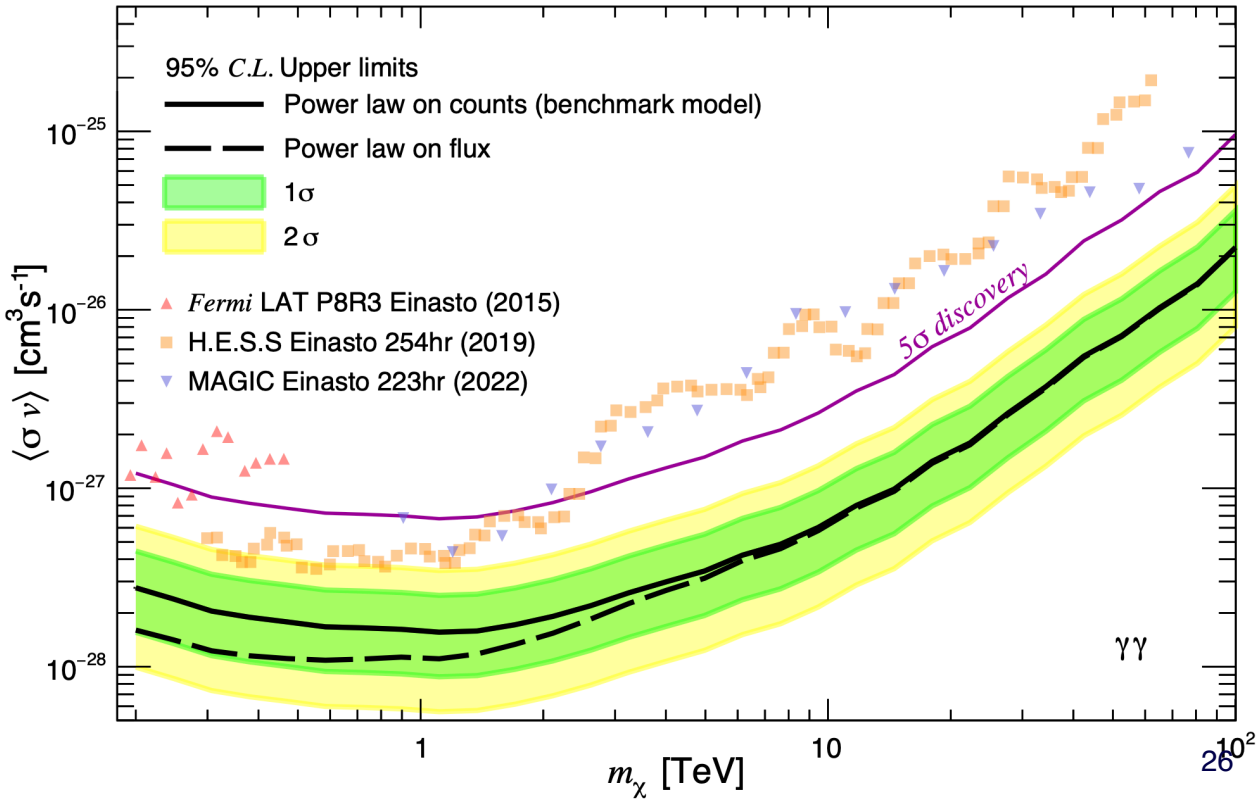
Dark matter line searches with the Cherenkov Telescope Array

CTAO Consortium (Abe et al. 2024)
10.1088/1475-7516/2024/07/047

- Gamma-ray signals -> annihilating or decaying dark matter
- **Galactic centre** (500h) and **dwarf spheroidal galaxies** (600h)

Galactic Centre





Perseus Galaxy Cluster

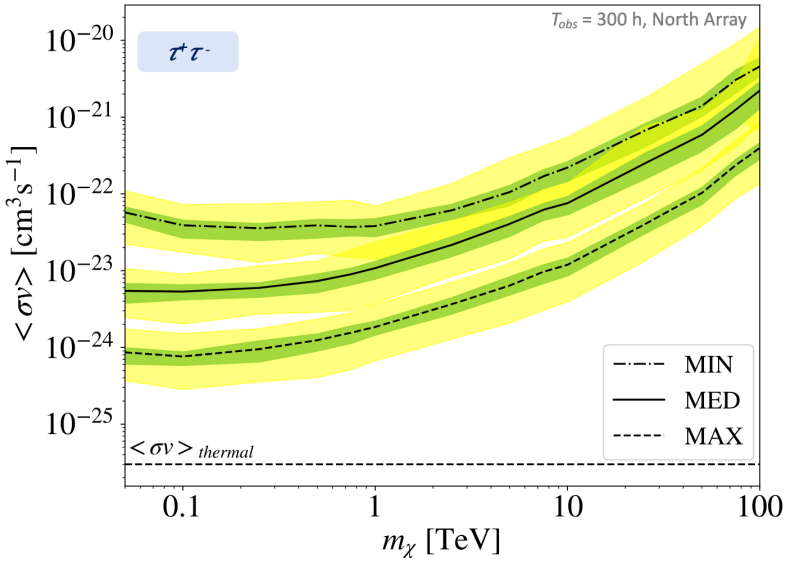
PAPER • OPEN ACCESS

Prospects for γ-ray observations of the Perseus galaxy cluster with the Cherenkov Telescope Array

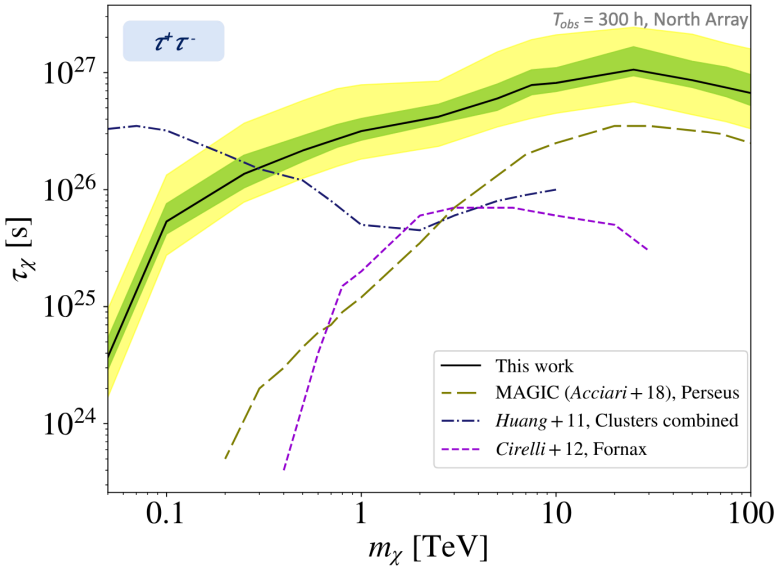
CTAO Consortium (Abe et al. 2024)
10.1088/1475-7516/2024/10/004

- Goal: **Detect diffuse emission**
- Spatial and spectral modeling of the expected signal for both the DM and the CRp components
  - CTAO should improve the current ground-based gamma-ray DM limits
  - In the case of decay of DM particles, **CTAO will explore a new region of the parameter space**, reaching models with $\tau\chi > 10^{27}$ s for DM masses above 1 TeV

Annihilation 95% C.L Upper Limits



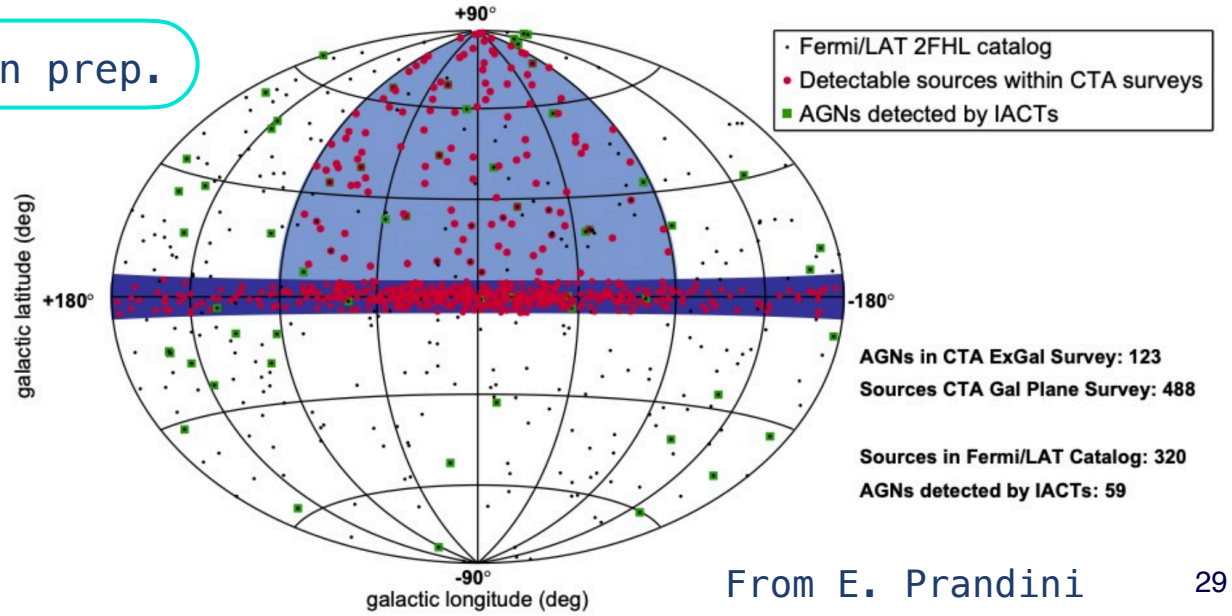
Decay 95% C.L. Lower Limits



Extragalactic Science

Active Galactic Nuclei (AGNs) (+ Cosmology/Fundamental Physics)

- **AGN population**: of gamma-ray emitting, jetted AGNs CTAO Consortium in prep.
- **Variability**: potential to discriminate between different scenarios CTAO Consortium in prep.
- **Gamma-ray propagation:** EBL, IGMF, ALPs, and LIV constraints CTAO Consortium (2021)
- **Redshift determination**: goal is to measure the redshift of blazars taking advantage of large and small worldwide facilities (Non-consortium papers)
- **EGAL survey:** 1000h , 2y CTAO Consortium in prep.
  - Including key targets:
    - Virgo and Coma clusters
    - CenA
    - Fermi bubbles



From E. Prandini

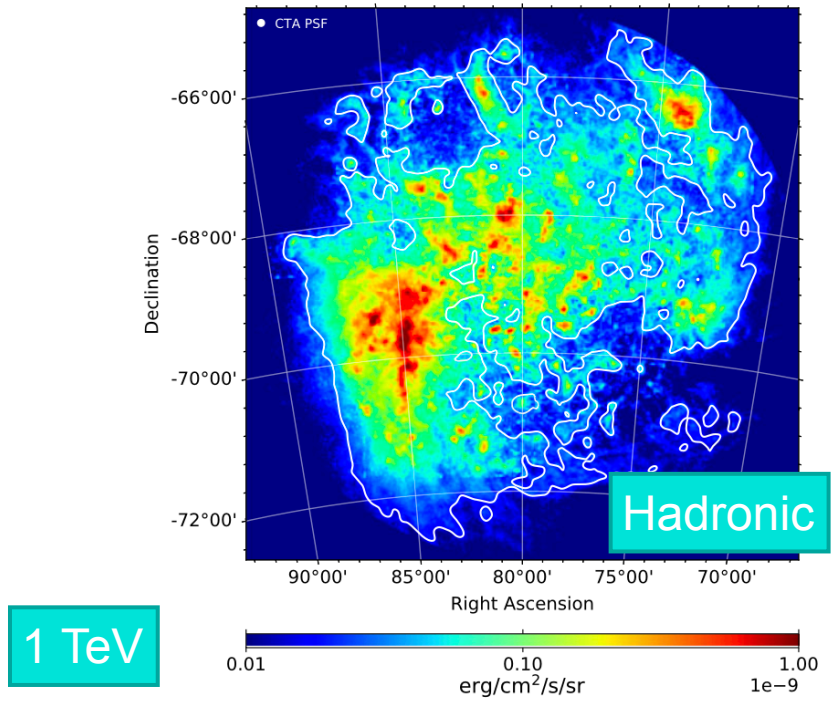
Large Magellanic Cloud Survey

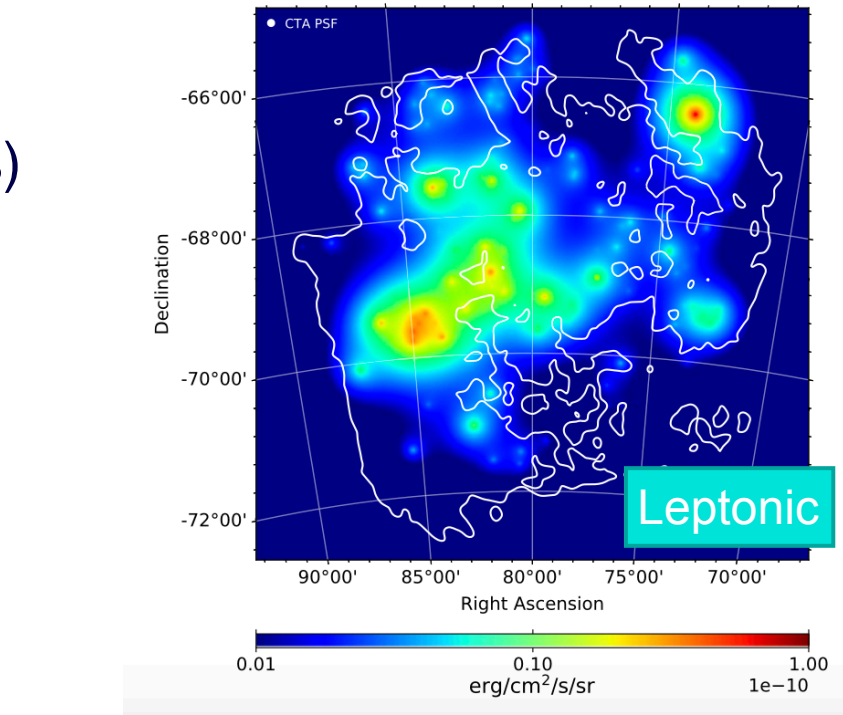
- 340 h survey
- Including prospects for the detectability of:
  - young remnant SN 1987A
  - star-forming region 30 Doradus
  - Known point sources
- Potential detection of extra half dozen sources (PWNe, SNRs)
- DM annihilation

JOURNAL ARTICLE

Sensitivity of the Cherenkov Telescope Array to TeV photon emission from the Large Magellanic Cloud FREE

CTAO Consortium (Acharyya et al. 2023)
10.1093/mnras/stad1576



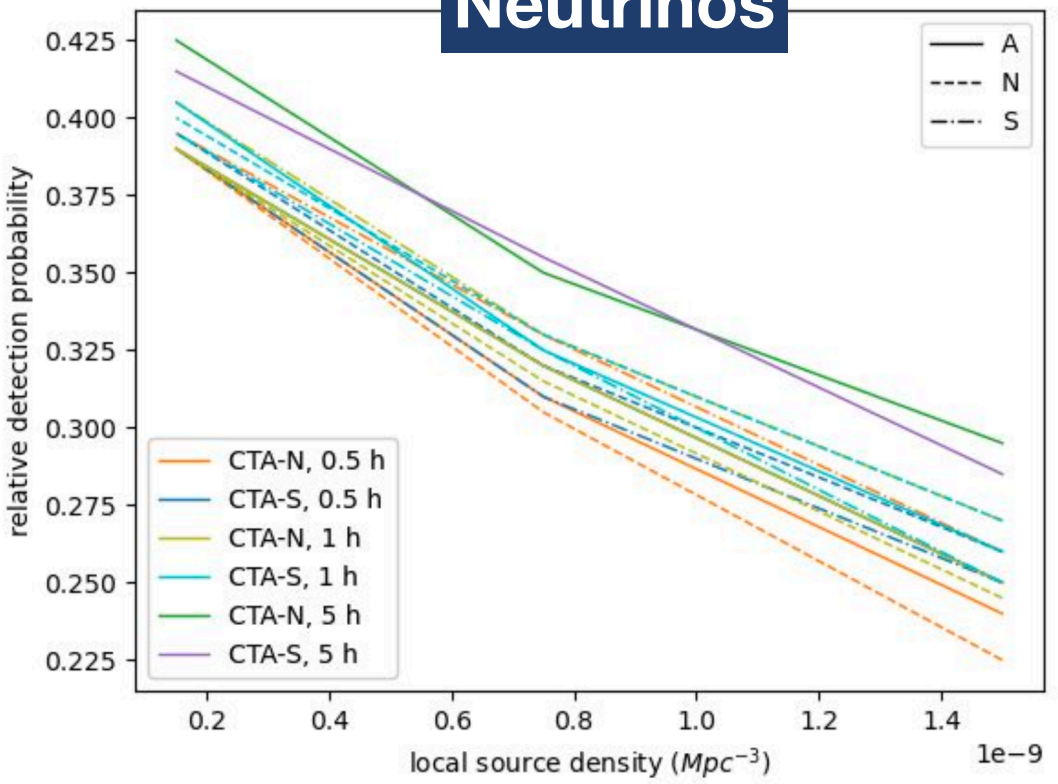


Transient & Multi-messenger: GRBs, neutrinos, gravitational waves

CPs in prep

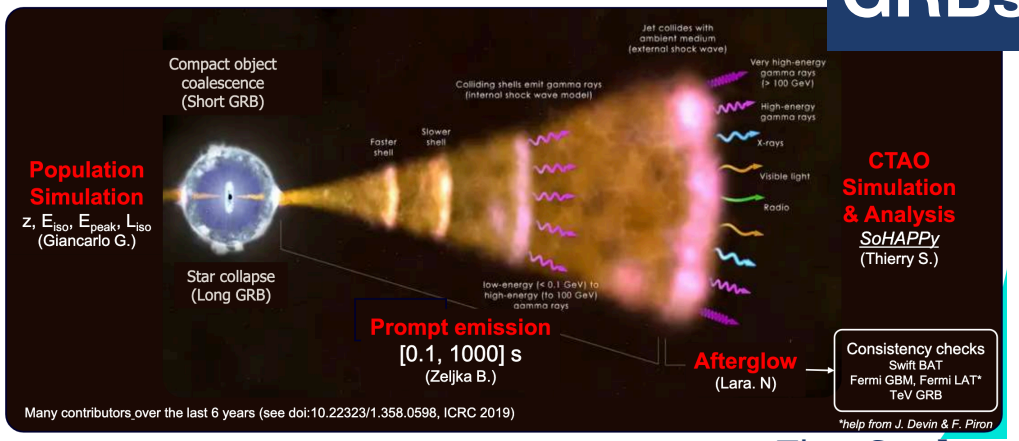
Good prospects of detection

Neutrinos



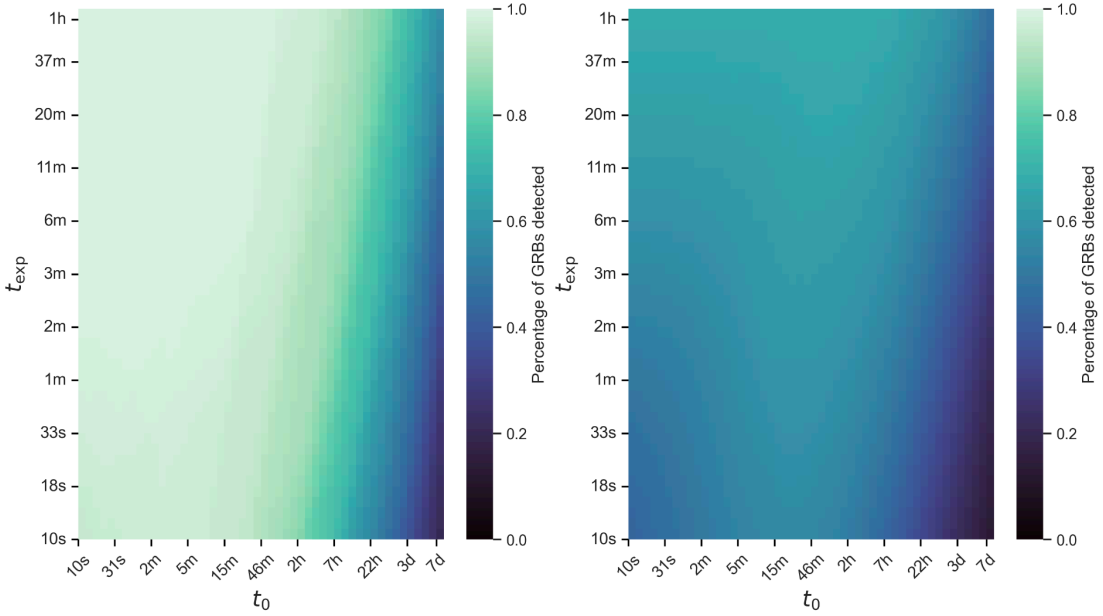
O. Sergijenko et al. 2024

GRBs



Th. Stolarczyk

GWs



(c) CTA North, $\theta_{view} < 10°$ (d) CTA North, $\theta_{view} < 45°$

J. Green et al. 2023

Core-collapse SNe

Paper under internal review

Prospects for detecting extragalactic core-collapse supernovae with the Cherenkov Telescope Array Observatory

The CTAO Science consortium[1]

- Investigating the detection rate of CCSNe with CTAOs

Data Challenge

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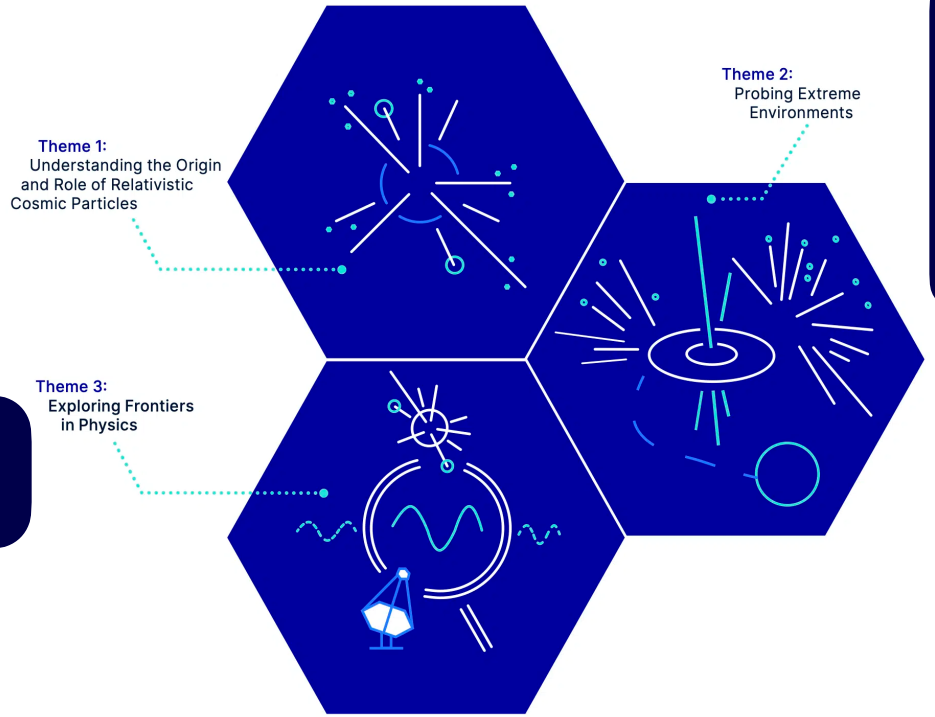
- Cosmic rays
- PeVatrons
- Star-forming



- Galactic Plane Survey
- Extragalactic Survey
- LMC Survey

- Dark matter
- Fundamental

- Galactic Centre
- Transients
- AGNs
- Galaxy Clusters

Science Data Challenge in prep.
Close collaboration between CTAO and CTAO Consortium

See talk by P. Da Vela

- **Internal Science Data challenge** as concept of proof
  - Neutrino, GW follow-up, GRBs, microquasars, AGNs
  - Preliminary results (internal to the Consortium) are promising

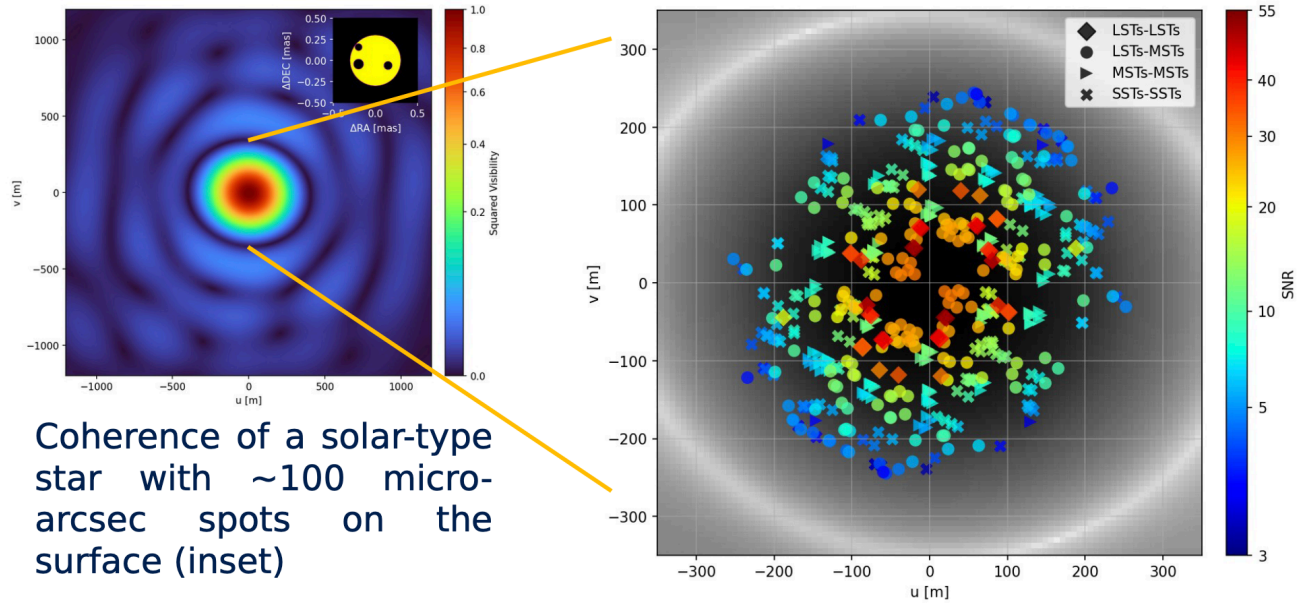
Bonus: Intensity Interferometry

Stellar II

White paper in prep.

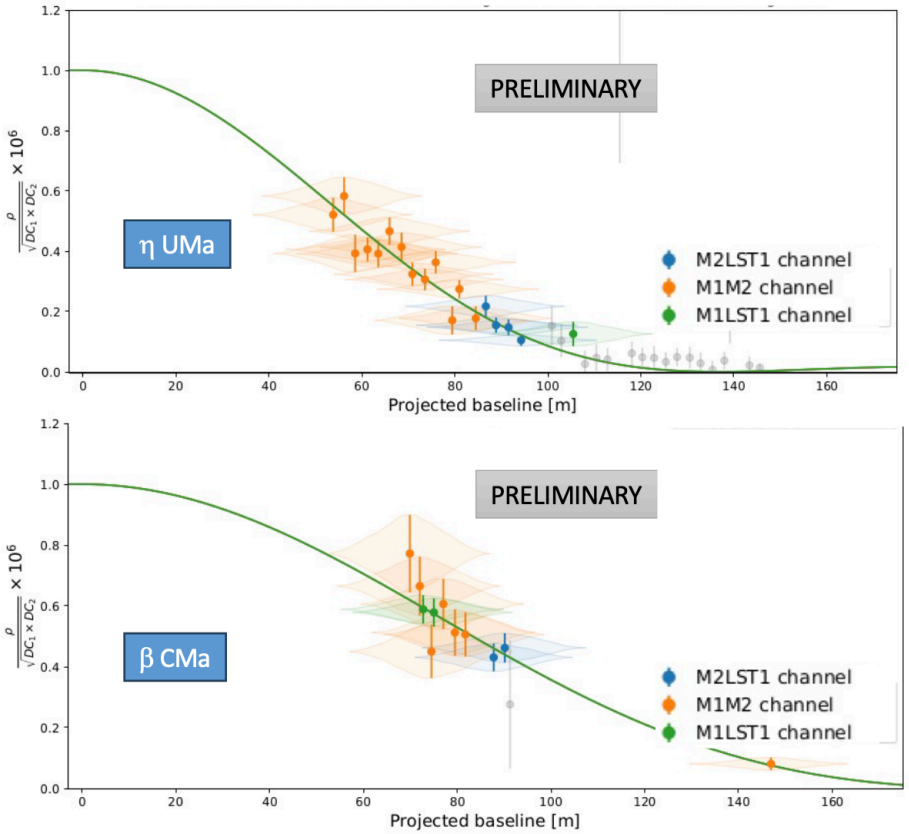
Data Challenge in prep.

- Not included as KSP in CTA Consortium 2018
  - Working towards implementation in CTAO
- submas measurements of star's diameters



Coherence of a solar-type star with ~100 micro-arcsec spots on the surface (inset)

L. Zampieri, CTAO Symposium



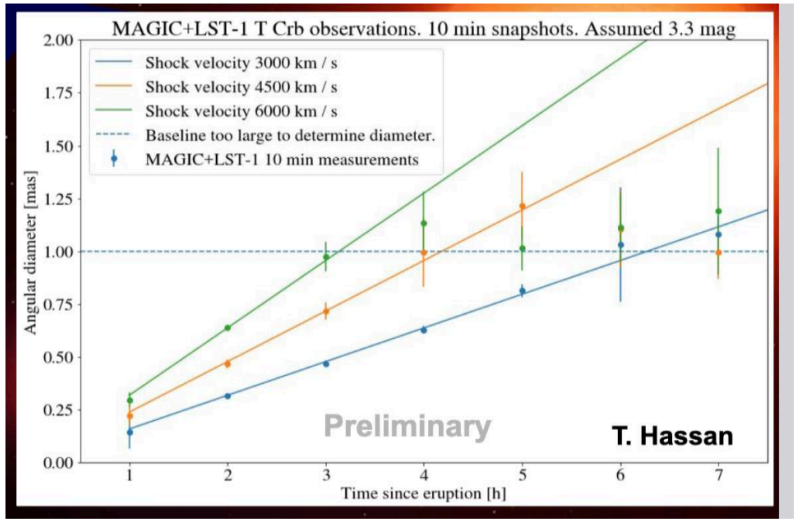
J. Cortina, CTAO Symposium

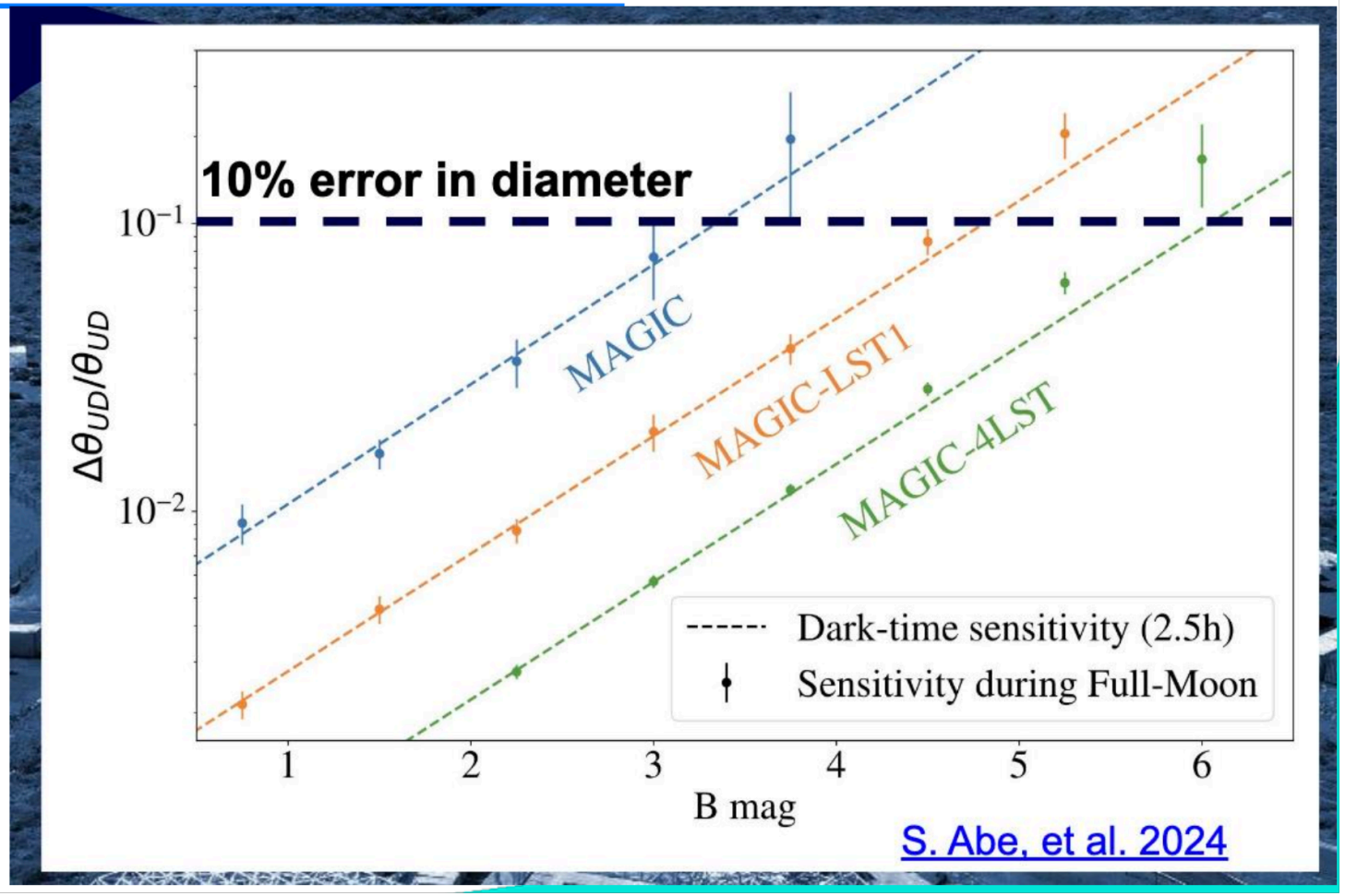
Stellar II

Status of SII in MAGIC and CTAO-LST1

Among science cases:

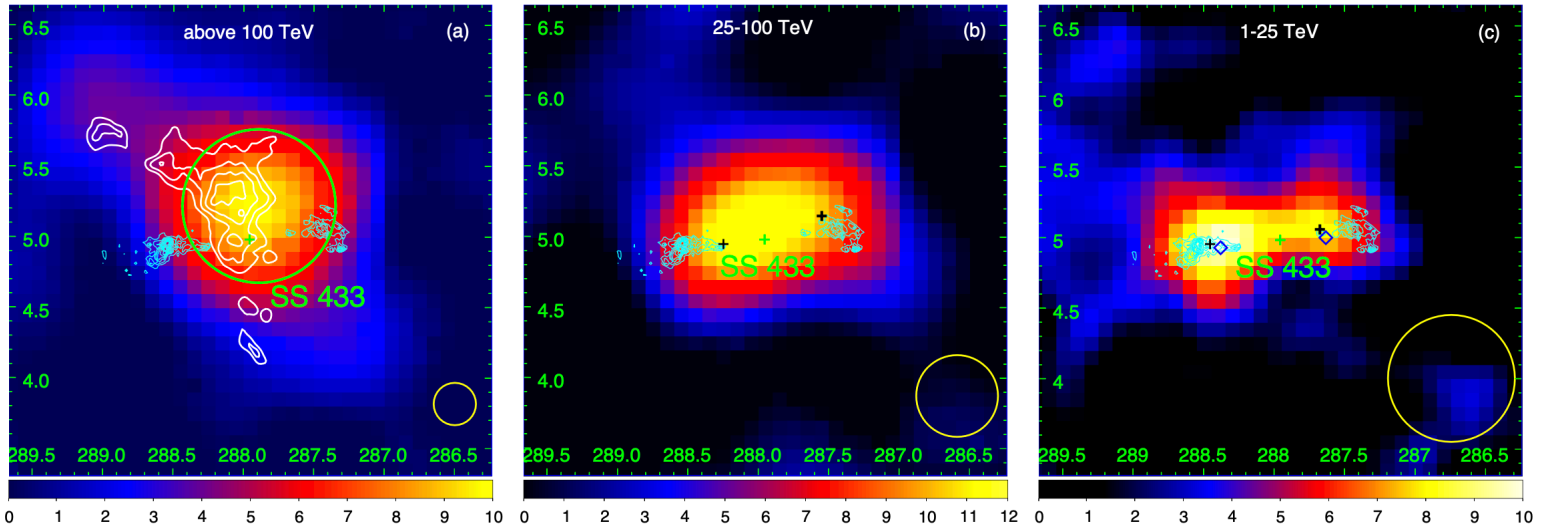
- **Novae**
- Be stars
- Colliding wind binaries

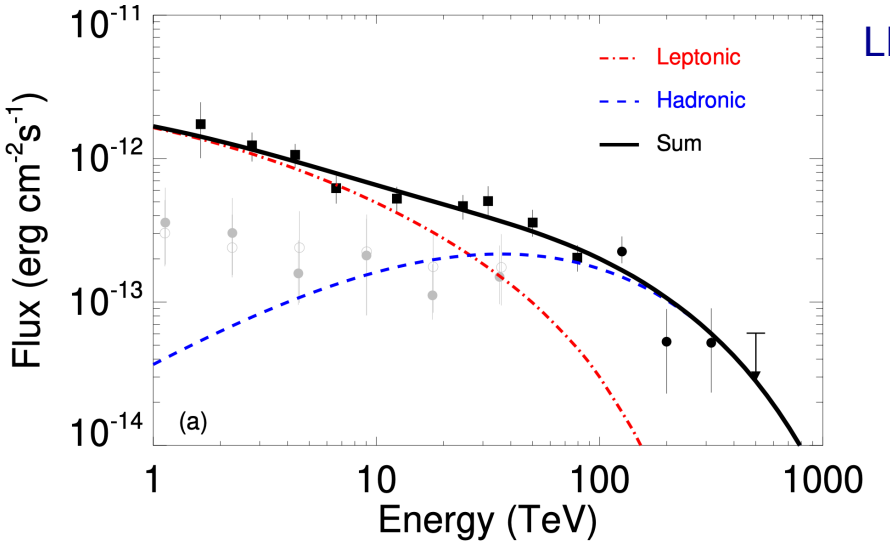




New Science Cases to consider

e.g. Persistent TeV emission from microquasars

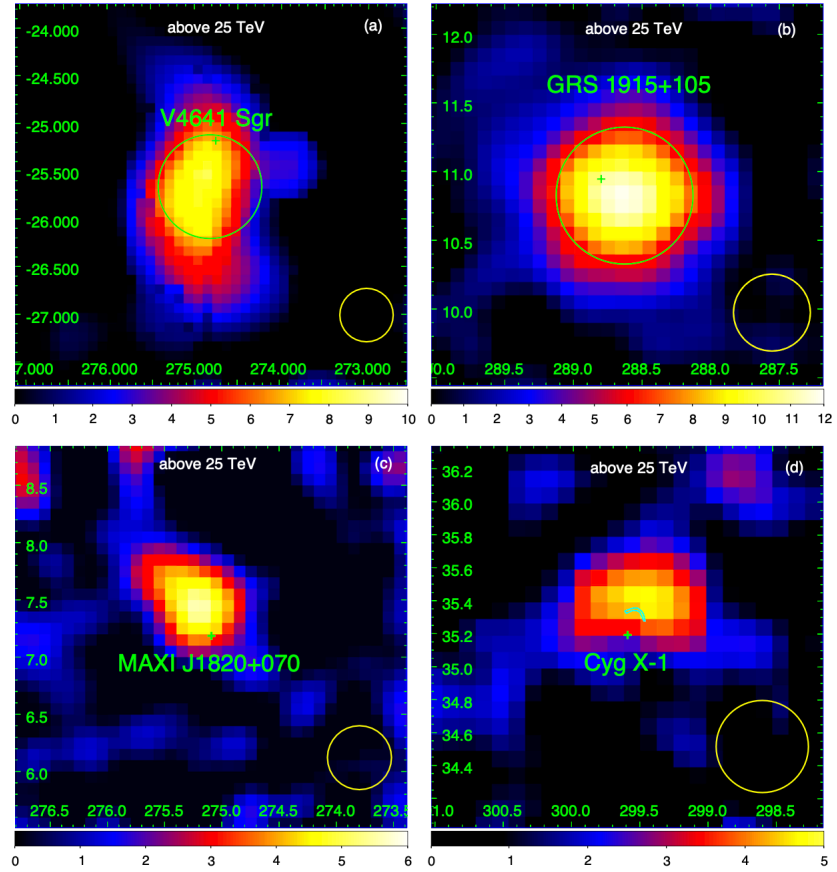




LHAASO 2024 arxiv: 2410.08988

BH-jet binaries are efficient **particle accelerators**

Jet-medium interaction is key



Take-home message

CTAO
Cherenkov Telescope Array Observatory

- **CTAO is happening**!
  - The first VHE observatory
  - Improved sensitivity, short-time sensitivity for transient detection
  - LST1 producing good science, LST2-LST4 coming soon
- CTAO will open a **new era in VHE astrophysics**
  - **New research lines**
  - Rich Science Program and wealth of **new discoveries**
  - Multi-wavelength and multi-messenger **synergies**
  - New Science Cases appearing, **update of scientific cases** needed to **fully exploit the capabilities of CTAO**

CTAO
Cherenkov Telescope Array Observatory

Grazie!

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Science with CTAO

Alicia López Oramas (Instituto de Astrofísica de Canarias)
on behalf of the CTAO Consortium

2nd VHEGAM Meeting

GOBIERNO DE ESPAÑA
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