The ASTRI Mini Array gamma-ray experiment

G. Pareschi (INAF / Osservatorio Astronomico di Brera)

for the ASTRI collaboration

LHAASO 2025
Hong Kong, 24 March 2025

ASTRI: Astrophysics with Italian Replicating Technology Mirrors

ASTRI-Horn Prototype

INAF-led Project funded by Italian Ministry of Research

End-to-end prototype installed and operational on Mount Etna volcano (Sicily, Italy)

First detection of a gamma-ray source (Crab Nebula) above 5σ **with a dual-mirror, Schwarzschild-Couder Chrenkov telescope** (Lombardi et al., 2020)

Array of 9 ASTRI telescopes

INAF-led Project with international partners: Univ. of Sao Paulo/FPESP (Brazil), North-West Univ. (S. Africa), IAC (Spain), FGG, ASI/SSDC, Univ. of Padova, Perugia and INFN

Being deployed at the *Observatorio del Teide* (Spain) in collaboration with IAC and FGG-INAF.

First 4 years → *Core Science*, following 4 years of *Observatory Science.* **Full Science operation → 2026**

Nanni’s fundamental contribution

Mini-Array

Mem. S.A.It. Vol. 75, 70

Memorie della

Ghe minga ASTRI?

The ASTRI mini-array wide-field gamma-ray experiment

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on behalf of the ASTRI collaboration

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Abstract. Over a decade ago, the ASTRI program was initiated with the main purpose of developing compact wide-field IACT telescopes based on mirrors realized with the cold-shaping glass replication technology invented by INAF. These telescopes were designed to serve as a model for the array of small-sized telescopes (SSTs) that would eventually be deployed at the Cherenkov Telescope Array Observatory (CTAO) southern site in Paranal, Chile. Nanni Bignami was the brain behind the ASTRI program. He not only came up with the idea but also coined its acronym, which stands for *Astrofisica con Specchi a Tecnologia Replicante Italiana* (meaning: Astrophysics with Mirrors via Italian Replication Technology). Later, when he became the INAF President, he provided strong support to the project that is mainly funded by the Italian government and, later on, received further support from various international partners (including the University of São Paulo/FAPESP, North-West University/South Africa, IAC, Fundacion Galileo Galilei, and University of Geneva). The program’s initial noteworthy accomplishment was the implementation of the end-to-end ASTRI-Horn prototype and its installation at the INAF astronomical site of Serra La Nave (Sicily, on the Etna volcano slope). The prototype included a novel compact camera based on SiPM sensors. It proved the dual-mirror polynomial optical configuration to be an aplanatic telescope system according to the design and successfully detected the Crab Nebula in gamma rays. The next step was the implementation of the ASTRI mini-array that comprises nine telescopes and is being implemented in Tenerife to study the gamma-ray sky in the energy band (1-100) TeV.

Key words. Gamma-ray astronomy – Cherenkov Telescopes – ASTRI mini-array

Thank you for your attention

The Schwarzschild Aplanatic Telescope

Mini-Array

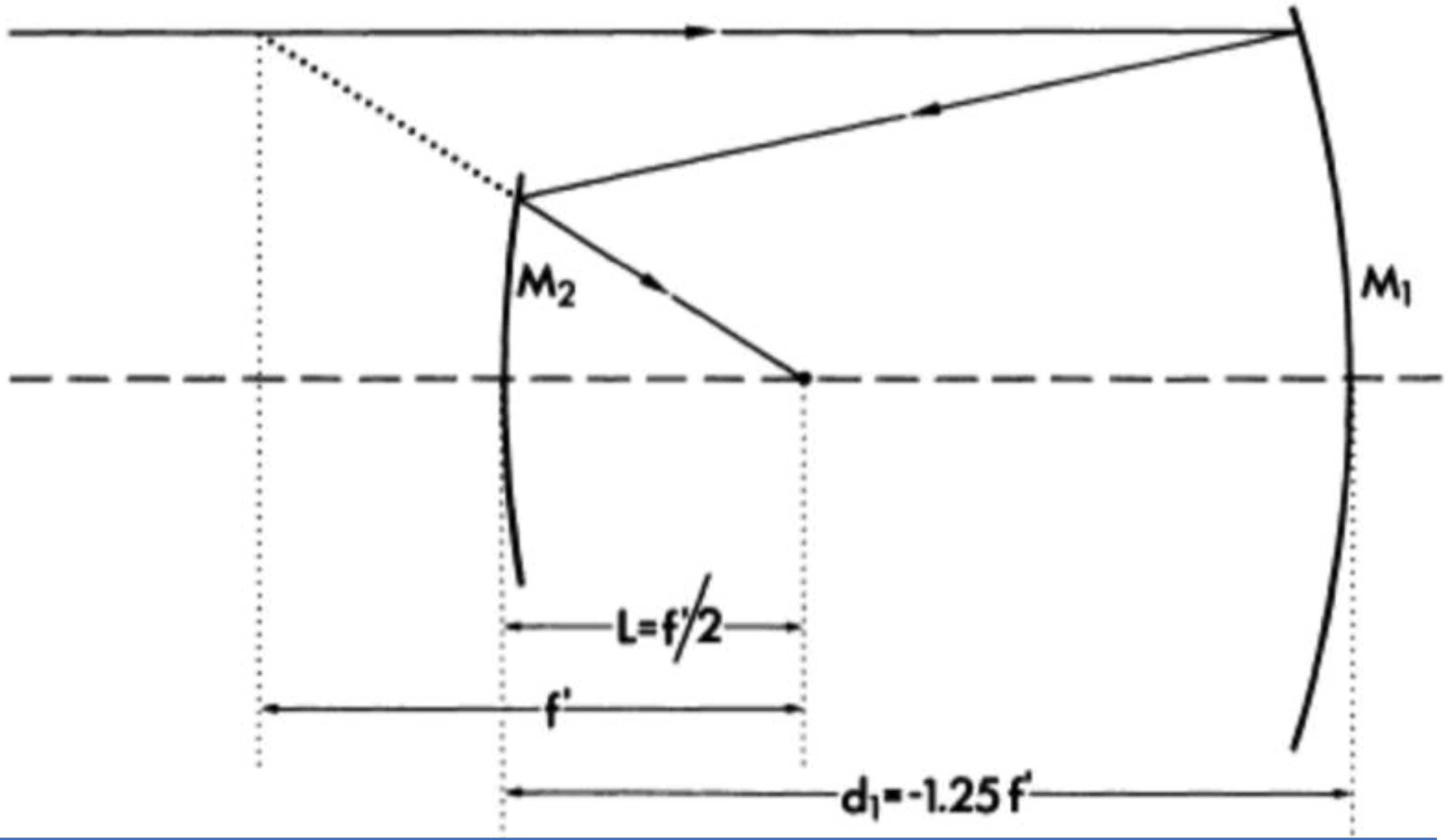

Vladimir Vassiliev, UCLA

1905: Karl Schwarzschild solved the Seidel ‘s equations for **spherical** aberration and **coma** finding a relation between parameters capable to make a telescope **aplanatic**. *(Couder 1926 ➔ also correction of **astigmatism** with curved focal plane)*

“For any geometry, 2 aspheric mirrors allow the correction of SI and SII to give an aplanatic telescope”

Schwarzschild telescope

KS: f/3.0
b_{S1}= -13.5 (Hyperbola)
b_{S2}= 1.963 (Spheroid)
FoV:2.8 deg
RMS_{edge}~12’’



Technology challenge: Aspherical Optics manufacturing + large secondary mirror

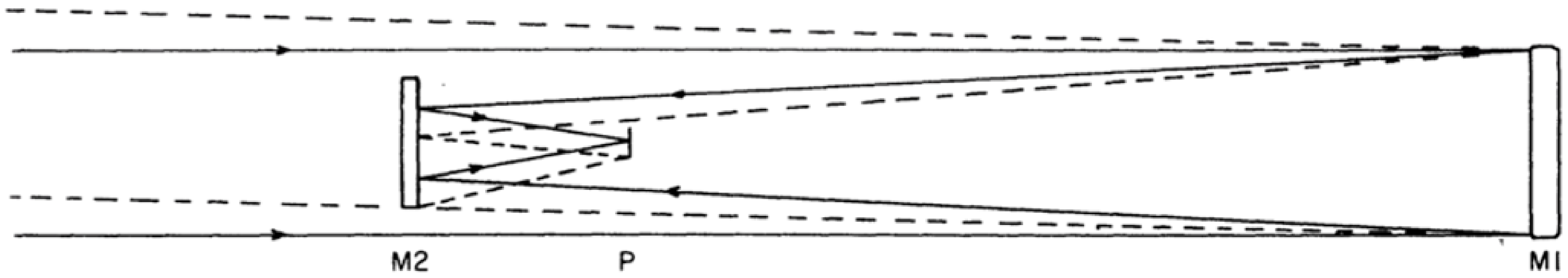
1926: Couder solved the third optics equation for SI, SII, SIII **removing the flat field** condition obtaining **aplanatic anastigmatic** telescope and a generalization of Schwarzschild theorem:

"N aspheric optics allow correcting N Seidel aberrations"

$\sum S_{II} = 0$ Spheric

$\sum S_{II} = 0$ Coma

$\sum S_{III} = 0$ Astigmatism



He obtained a solution with constrain of

- D=2f
- Curved field

Couder telescope

b_{S1}= -14.203 (Hyperbola)

b_{S2}= -0.055 (Spheroid)

FoV:3.0 deg

RMS_{edge}~1"

Technological obstacle: Aspherical Optics and alignment

From X-ray grazing telescopes to SC Cherenkov telescopes

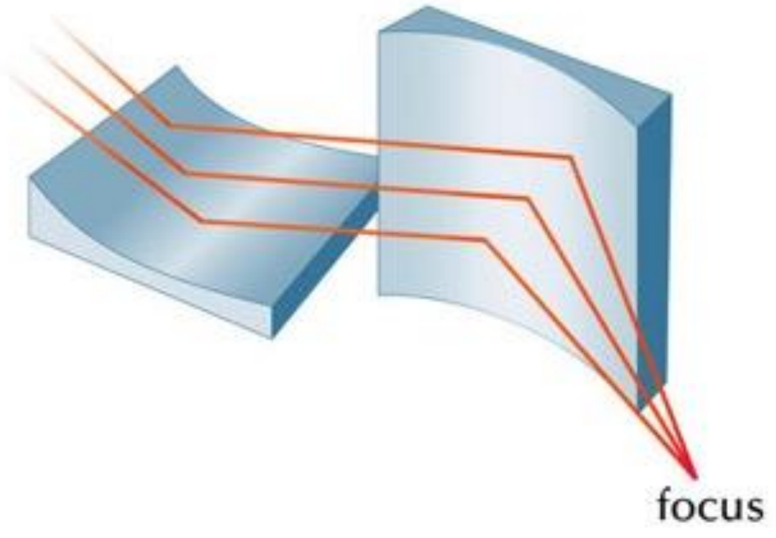
Mini-Array

Specific requirement	First empirical focalization	Analytical solution	RT Polynomial optimization

High Energy

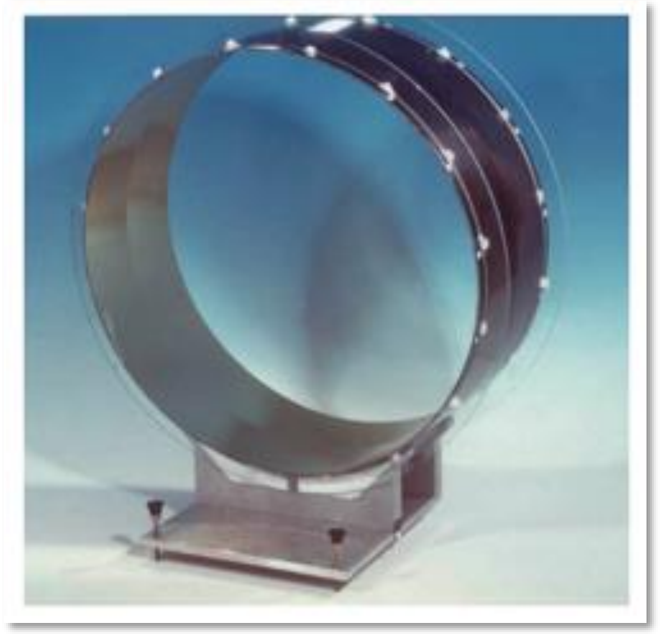
Grazing incidence

Kirkpatrick - Baez



Wolter & Wolter-Schwarzschild

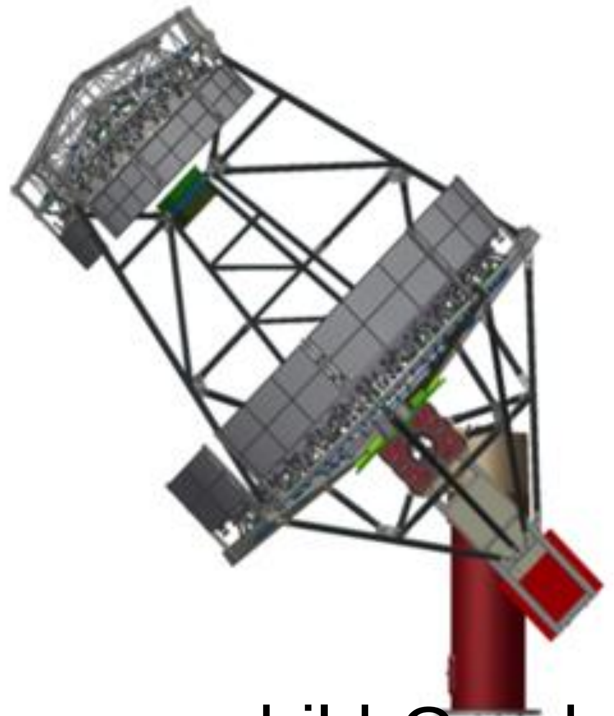
WFXT



Few fast pulses

Large Area

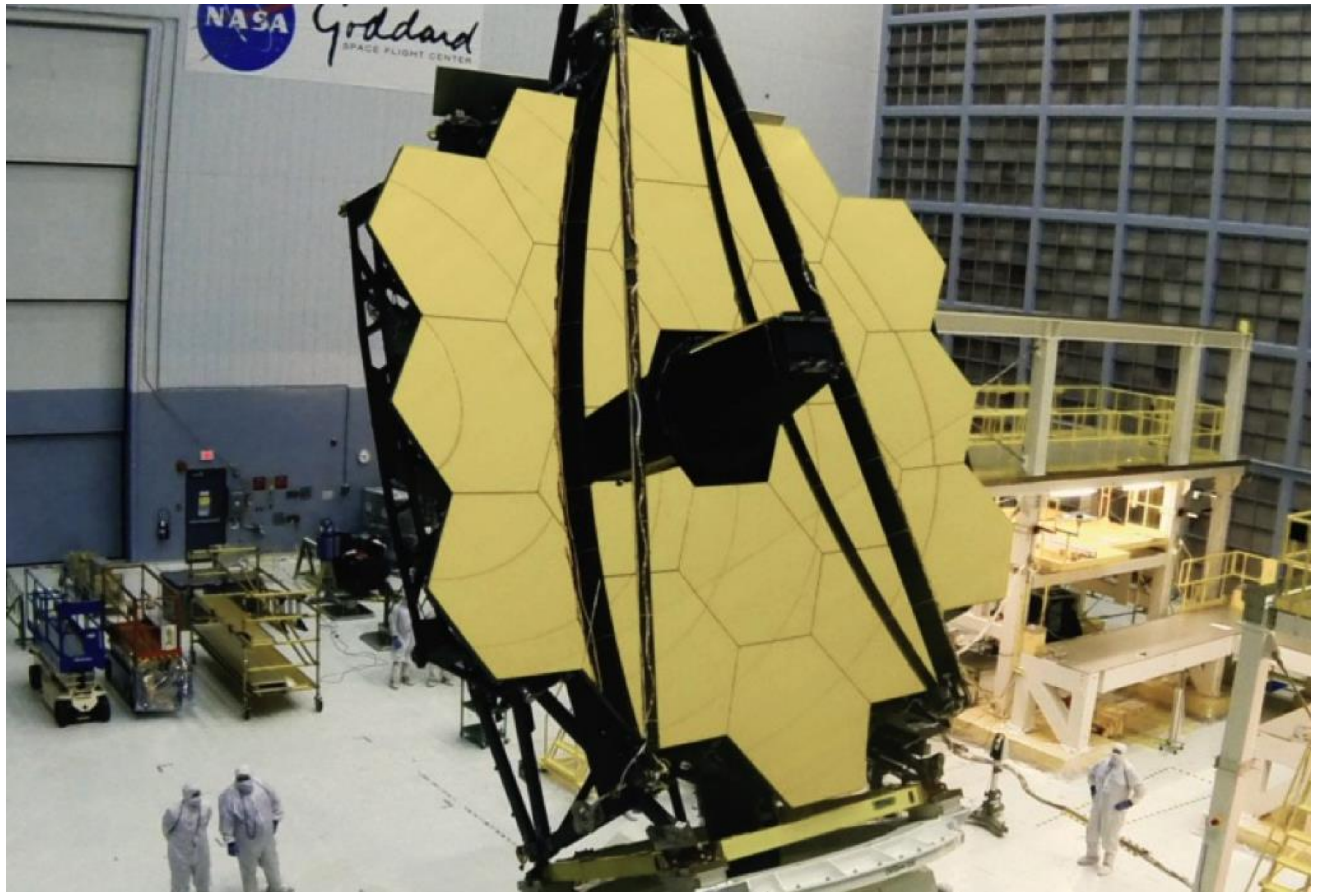
Davies- Cotton



Schwarzschild-Couder

ASTRI/CTA-SST

Segmented reflecting surface



Credits: NASA

JWST, reflecting surface cost: ➔ **a few MEuro/m²**

ASTRI, reflecting surface cost: ➔ **A few KEuro/m²**

He's not fat..just a big-bone guy!

ASTRI Horn mass of about 24 Tons, reduced to 18 Tons after an important diet for ASTRI Mini-Array!

Mirrors production → challenge

M1 panels: cold slumping

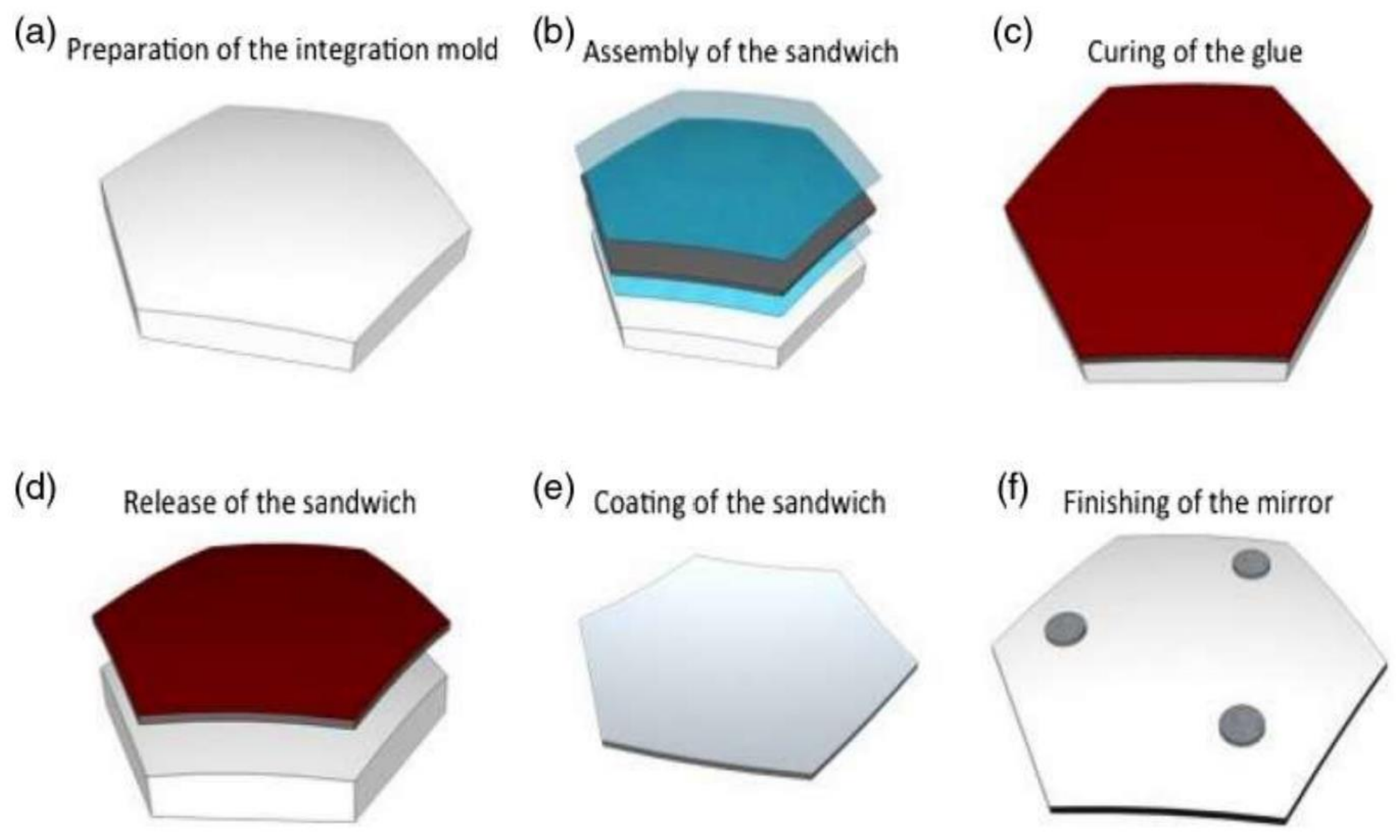
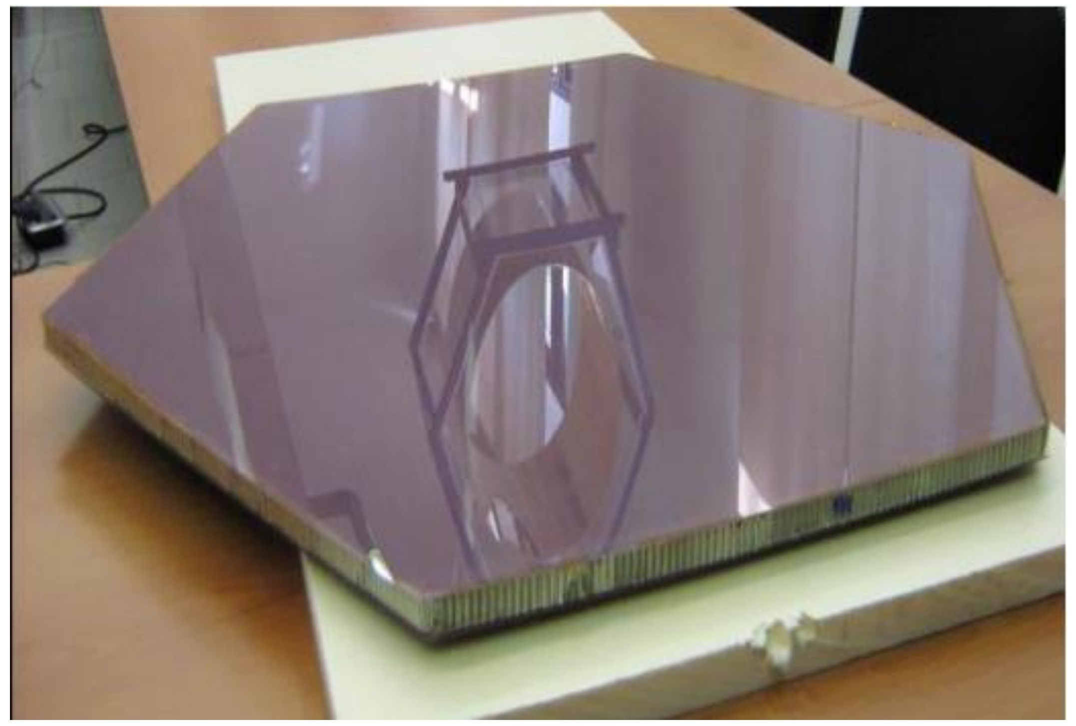


Fig. 1 Conceptual description of the (a)–(f) main steps of the cold-slumping technology.

J. Astron. Telesc. Instrum. Syst. 014005-4 Jan–Mar 2022 • Vol. 8(1)

- Dimensions and characteristics (radius of curvature) not a problem
- Sandwich structure made them lightweight (~ 8.5 kg)



M2 mirror: hot slumping

- The mirror is 180 cm in diameter; therefore, too large for slabs as thin as those used in cold slumping.
- Being 19 mm in thickness, even the M2 mirror produced with the hot slumping technique has some criticality (handling)

In collaboration with Media Lario srl, VETROLAMP srl


ULEFONE
SHOT ON ARMOR 11T 5G

ASTRI-Horn results

ASTRI Mini-Array

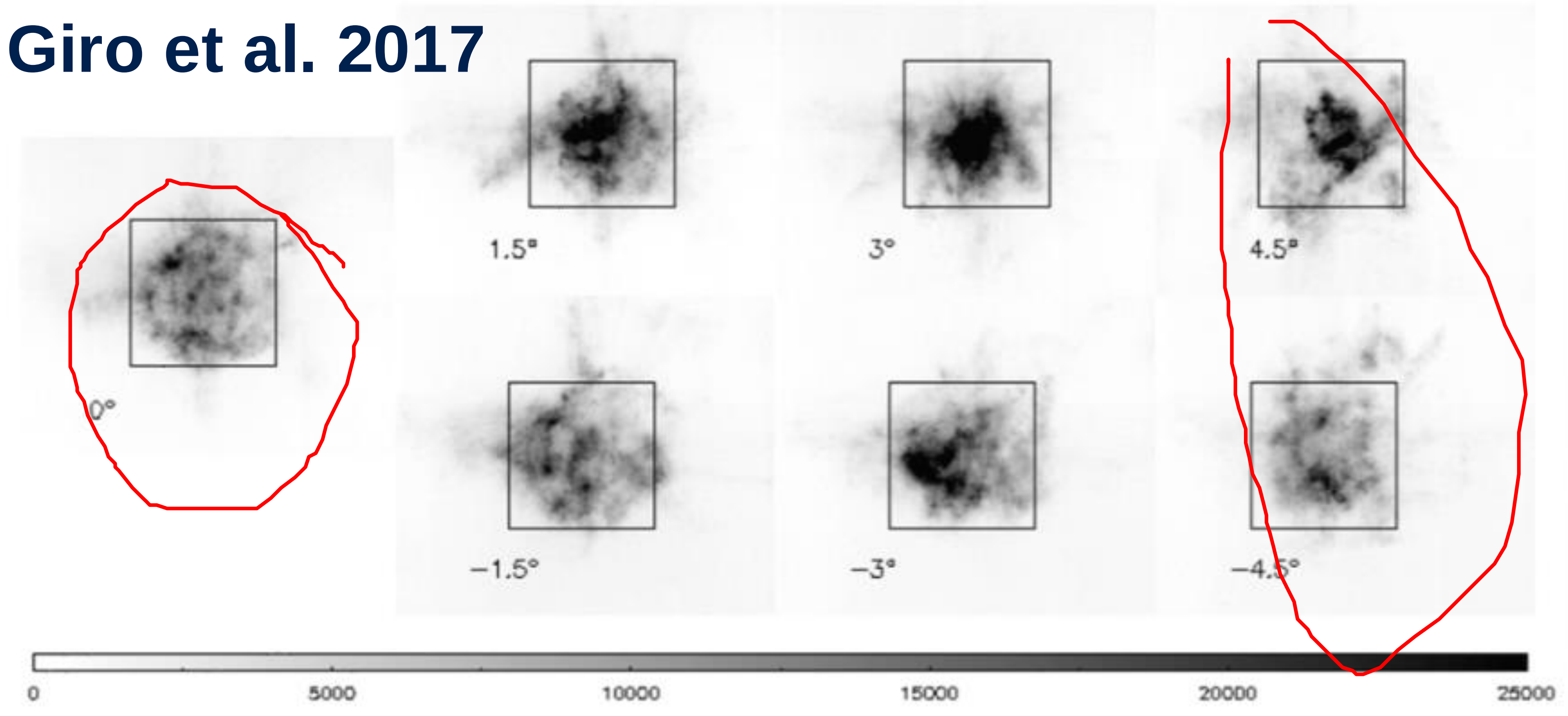
A&A 608, A86 (2017)
DOI: 10.1051/0004-6361/201731602

Astronomy & Astrophysics

First optical validation of a Schwarzschild Couder telescope: the ASTRI SST-2M Cherenkov telescope

E. Giro[1,2], R. Canestrari[2], G. Sironi[2], E. Antolini[3], P. Conconi[2], C. E. Fermino[4], C. Gargano[5], G. Rodeghiero[1,6], F. Russo[7], S. Scuderi[8], G. Tosti[3], V. Vassiliev[9], and G. Pareschi[2]

Giro et al. 2017

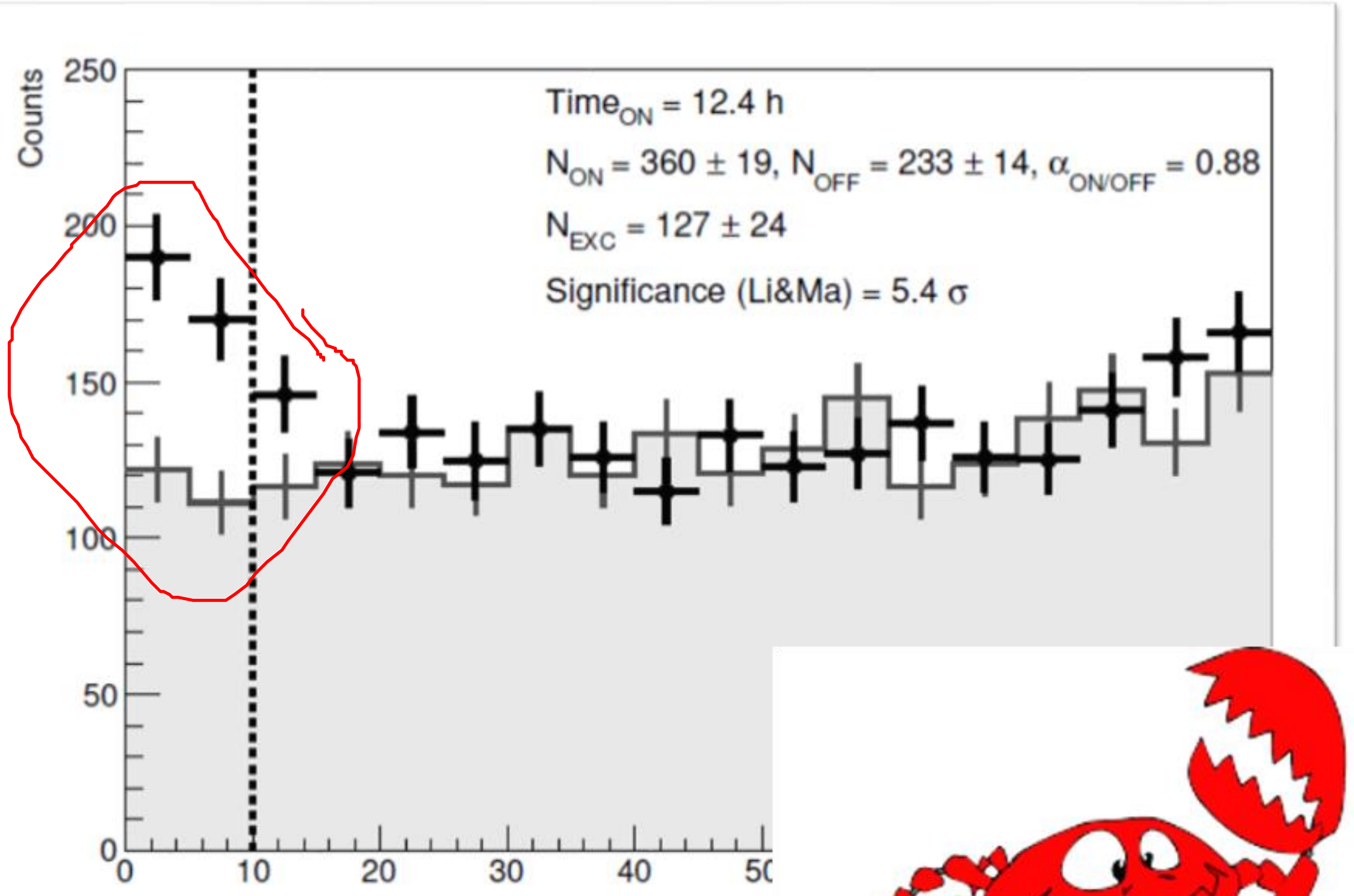


A&A 634, A22 (2020)
https://doi.org/10.1051/0004-6361/201936791

Astronomy & Astrophysics

First detection of the Crab Nebula at TeV energies with a Cherenkov telescope in a dual-mirror Schwarzschild-Couder configuration: the ASTRI-Horn telescope

S. Lombardi[1,2,⋆], O. Catalano[3,⋆], S. Scuderi[4,⋆], L. A. Antonelli[1,2], G. Pareschi[5], E. Antolini[6], L. Arrabito[7], G. Bellassai[8], K. Bernlöhr[9], C. Bigongiari[1], B. Biondo[3], G. Bonanno[8], G. Bonnoli[5], G. M. Böttcher[10], J. Bregeon[11], P. Bruno[8], R. Canestrari[3], M. Capalbi[3], P. Caraveo[4], P. Conconi[5], V. Conforti[12], G. Contino[3], G. Cusumano[3], E. M. de Gouveia Dal Pino[13], A. Distefano[4], G. Farisato[14], C. Fermino[13], M. Fiorini[4], A. Frigo[14], S. Gallozzi[1], C. Gargano[3], S. Garozzo[8], F. Gianotti[12], S. Giarrusso[3], R. Gimenes[13], E. Giro[14], A. Grillo[8], D. Impiombato[3], S. Incorvaia[4], N. La Palombara[4], V. La Parola[3], G. La Rosa[3], G. Leto[8], F. Lucarelli[1,2], M. C. Maccarone[3], D. Marano[8], E. Martinetti[8], A. Miccichè[8], R. Millul[5], T. Mineo[3], G. Nicotra[15], G. Occhipinti[8], I. Pagano[8], M. Perri[1,2], G. Romeo[8], F. Russo[3], F. Russo[12], B. Sacco[3], P. Sangiorgi[3], F. G. Saturni[1], A. Segreto[3], G. Sironi[5], G. Sottile[3], A. Stamerra[1], L. Stringhetti[4], G. Tagliaferri[5], M. Tavani[16], V. Testa[1], M. C. Timpanaro[8], G. Toso[4], G. Tosti[17], M. Trifoglio[12], G. Umana[8], S. Vercellone[5], R. Zanmar Sanchez[8], C. Arcaro[14], A. Bulgarelli[12], M. Cardillo[16], E. Cascone[18], A. Costa[8], A. D'Aì[3], F. D'Ammando[12], M. Del Santo[3], V. Fioretti[12], A. Lamastra[1], S. Mereghetti[4], F. Pintore[4], G. Rodeghiero[14], P. Romano[5], J. Schwarz[5], E. Sciacca[8], F. R. Vitello[8], and A. Wolter[5]



Lombardi et al. 2020

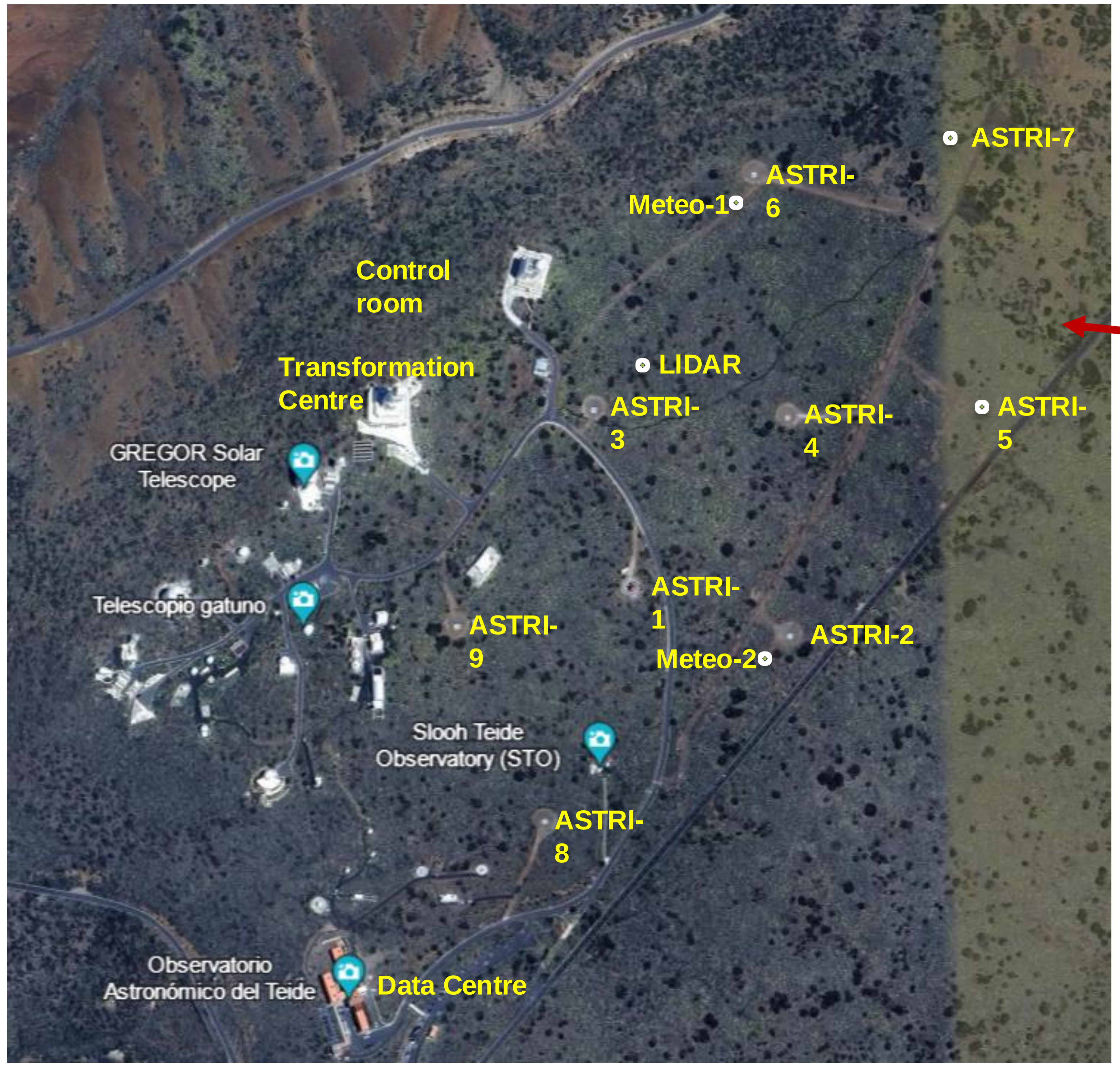
The ASTRI Mini-Array in a nutshell

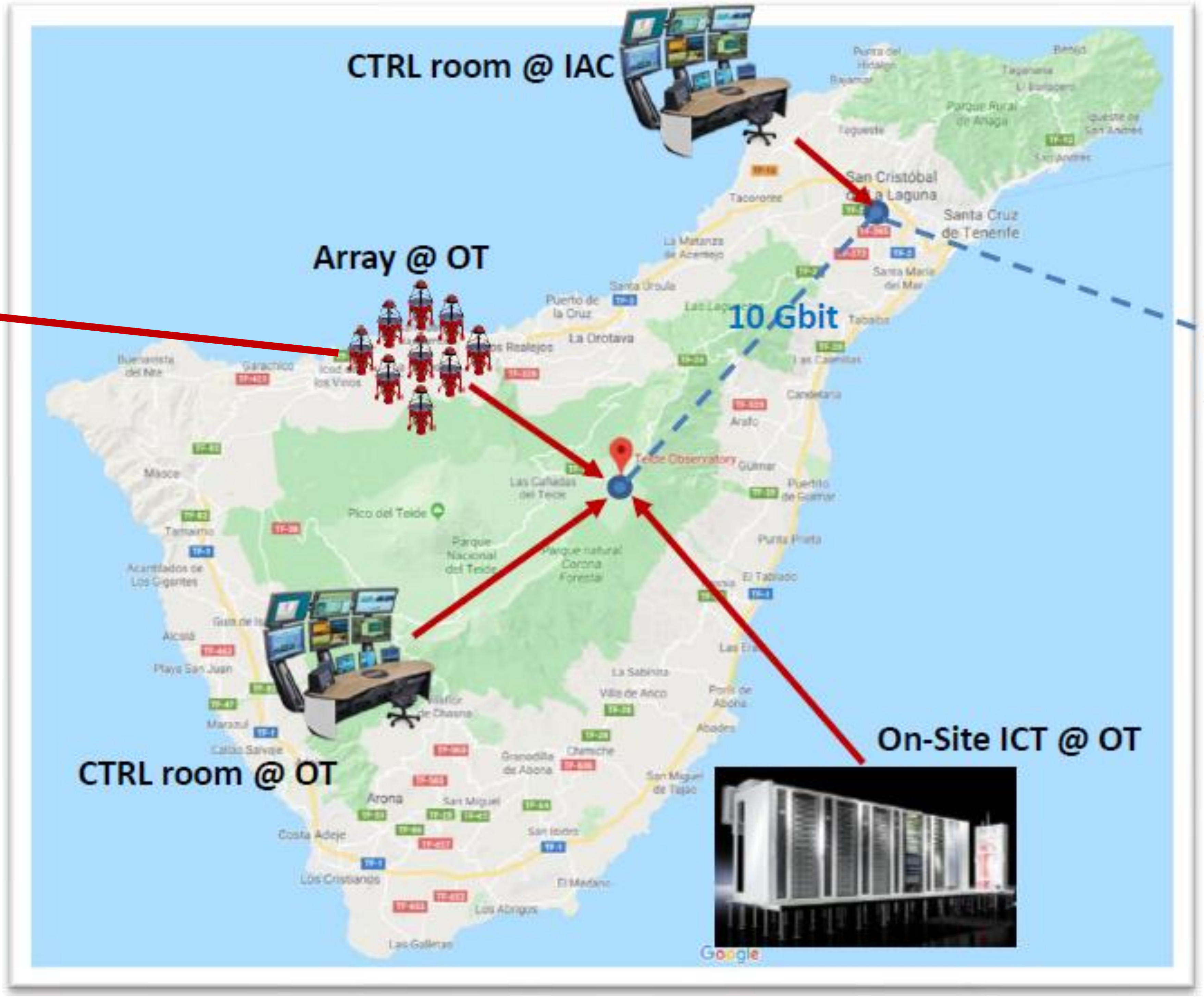
The ASTRI Mini-Array in Tenerife

- Telescope Array & auxiliaries (Observatorio del Teide - OT)
- Local Control Room @THEMIS building (OT)
- On site Data Centre @IAC Residencia (OT)
- Array operation center @IACTEC in La Laguna

The ASTRI Mini-Array in Italy

- Data Centre in Rome
- Remote Array operation centers





The ASTRI White Book

Mini-Array

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Astrophysics

Volume 35, August 2022, Pages 52-68

The ASTRI Mini-Array of Cherenkov telescopes at the Observatorio del Teide

S. Scuderi [a], A. Giuliani [a], G. Pareschi [b], G. Tosti [c], O. Catalano [f], E. Amato [p], L.A. Antonelli [h], J. Becerra Gonzàles [m], G. Bellassai [d], C. Bigongiari [h, u], B. Biondo [f], M. Böttcher [n], G. Bonanno [d], G. Bonnoli [b], P. Bruno [d], A. Bulgarelli [e], R. Canestrari [f], M. Capalbi [f], P. Caraveo [a], M. Cardillo [k], V. Conforti [e], G. Contino [f], M. Corpora [f], A. Costa [d], G. Cusumano [f], A. D'Aì [f], E. de Gouveia Dal Pino [l], R. Della Ceca [b], E. Escribano Rodriguez [o], D. Falceta-Gonçalves [s], C. Fermino [l], M. Fiori [j, g], V. Fioretti [e], M. Fiorini [a], S. Gallozzi [h], C. Gargano [f], S. Garozzo [d], S. Germani [c], A. Ghedina [o], F. Gianotti [e], S. Giarrusso [f], R. Gimenes [f, l], V. Giordano [d], A. Grillo [d], C. Grivel Gelly [o], D. Impiombato [f], F. Incardona [d], S. Incorvaia [a], S. Iovenitti [b], A. La Barbera [f], N. La Palombara [a], V. La Parola [f], A. Lamastra [h], L. Lessio [g], G. Leto [d], F. Lo Gerfo [f], M. Lodi [o], S. Lombardi [h, u], F. Longo [r], F. Lucarelli [h, u], M.C. Maccarone [f], D. Marano [d], E. Martinetti [d], S. Mereghetti [a], A. Micciché [d], R. Millul [b], T. Mineo [f], D. Mollica [f], G. Morlino [q], A. Morselli [i], G. Naletto [j, g], G. Nicotra [t], A. Pagliaro [f], N. Parmiggiani [e], G. Piano [k], F. Pintore [f], E. Poretti [o], B. Olmi [q], G. Rodeghiero [e], G. Rodriguez Fernandez [i], P. Romano [b], G. Romeo [d], F. Russo [e], P. Sangiorgi [f], F.G. Saturni [h], J.H. Schwarz [b], E. Sciacca [d], G. Sironi [b], G. Sottile [f], A. Stamerra [h], G. Tagliaferri [b], V. Testa [h], G. Uman…

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Volume 35, August 2022, Pages 1-42

ASTRI Mini-Array core science at the *Observatorio del Teide*

S. Vercellone [a], C. Bigongiari [b], A. Burtovoi [c], M. Cardillo [d], O. Catalano [e], A. Franceschini [f], S. Lombardi [b, g], L. Nava [a], F. Pintore [e], A. Stamerra [b], F. Tavecchio [a], L. Zampieri [h], R. Alves Batista [i], E. Amato [c, j], L.A. Antonelli [b, g], C. Arcaro [h, k], J. Becerra González [l, m], G. Bonnoli [a], M. Böttcher [k], G. Brunetti [n], A.A. Compagnino [e], S. Crestan [o, p], A. D'Aì [e], M. Fiori [h, f], G. Galanti [o], A. Giuliani [o], E.M. de Gouveia Dal Pino [q], J.G. Green [b], A. Lamastra [b, g], M. Landoni [a], F. Lucarelli [b, g], G. Morlino [c], B. Olmi [r, c], E. Peretti [s], G. Piano [d], G. Ponti [a, t], E. Poretti [a, u], P. Romano [a], F.G. Saturni [b]… Tutone [b], G. Umana [v], J.A. Acosta-Pulido [l, m], P. Barai [q], A. Bonanno [v], G. Bonann… …ano [e], M. Del Santo [e], M.V. del Va… …ani [x, y], R.J. García-López [l, m], A. G… …enitti [a], A. La Barbera [e], N. La Palo… …, M.C. Maccarone [e], S. Mereghett… …ghi [a], J.C. Rodríguez-Ramírez [q], G. … …, G. Tosti [x, y], M. Vázquez Acosta [l]…

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Journal of High Energy Astrophysics

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Extragalactic observatory science with the ASTRI mini-array at the *Observatorio del Teide*

F.G. Saturni [a, b], C.H.E. Arcaro [c, d, e, f], B. Balmaverde [g], J. Becerra González [h, i], A. Caccianiga [j], M. Capalbi [k], A. Lamastra [a], S. Lombardi [a, b], F. Lucarelli [a, b], R. Alves Batista [l], L.A. Antonelli [a, b], E.M. de Gouveia Dal Pino [m], R. Della Ceca [j], J.G. Green [a, b, n], A. Pagliaro [k], C. Righi [o], F. Tavecchio [o], S. Vercellone [o], A. Wolter [j], E. Amato [p], C. Bigongiari [a, b], M. Böttcher [d], G. Brunetti [q], P. Bruno [r], A. Bulgarelli [s], M. Cardillo [t], V. Conforti [s], A. Costa [r], G. Cusumano [k], V. Fioretti [s], S. Germani [u], A. Ghedina [v], F. Gianotti [s], V. Giordano [r], A. Giuliani [w], F. Incardona [r], A. La Barbera [k], G. Leto [r], F. Longo [x, y], G. Morlino [p], B. Olmi [z], N. Parmiggiani [s], P. Romano [o], G. Romeo [r], A. Stamerra [a], G. Tagliaferri [o], V. Testa [a], G. Tosti [j, u], P.A. Caraveo [w], G. Pareschi [o]

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Galactic observatory science with the ASTRI Mini-Array at the *Observatorio del Teide*

A. D'Aì [a], E. Amato [b], A. Burtovoi [b], A.A. Compagnino [a], M. Fiori [c], A. Giuliani [d], N. La Palombara [d], A. Paizis [d], G. Piano [e], F.G. Saturni [f, g], A. Tutone [a, h], A. Belfiore [d], M. Cardillo [e], S. Crestan [d], G. Cusumano [a], M. Della Valle [i, j], M. Del Santo [a], A. La Barbera [a], V. La Parola [a], S. Lombardi [f, g], S. Mereghetti [d], G. Morlino [b], F. Pintore [a], P. Romano [k], S. Vercellone [k], A. Antonelli [f], C. Arcaro [l], C. Bigongiari [f, g], M. Böettcher [m], P. Bruno [n], A. Bulgarelli [o], V. Conforti [o], A. Costa [n], E. de Gouveia Dal Pino [p], V. Fioretti [o], S. Germani [q], A. Ghedina [r], F. Gianotti [o], V. Giordano [n], F. Incardona [n], G. Leto [n], F. Longo [s, t], A. López Oramas [u], F. Lucarelli [f, g], B. Olmi [v], A. Pagliaro [a], N. Parmiggiani [o], G. Romeo [n], A. Stamerra [f], V. Testa [f], G. Tosti [o, q], G. Umana [n], L. Zampieri [e], P. Caraveo [d], G. Pareschi [k]

ASTRI IRF on Zenodo

«ASTRI Project. (2022). ASTRI Mini-Array Instrument Response Functions (Prod2, v1.0)»

https://zenodo.org/record/6827882#.YtFCjZNBx60

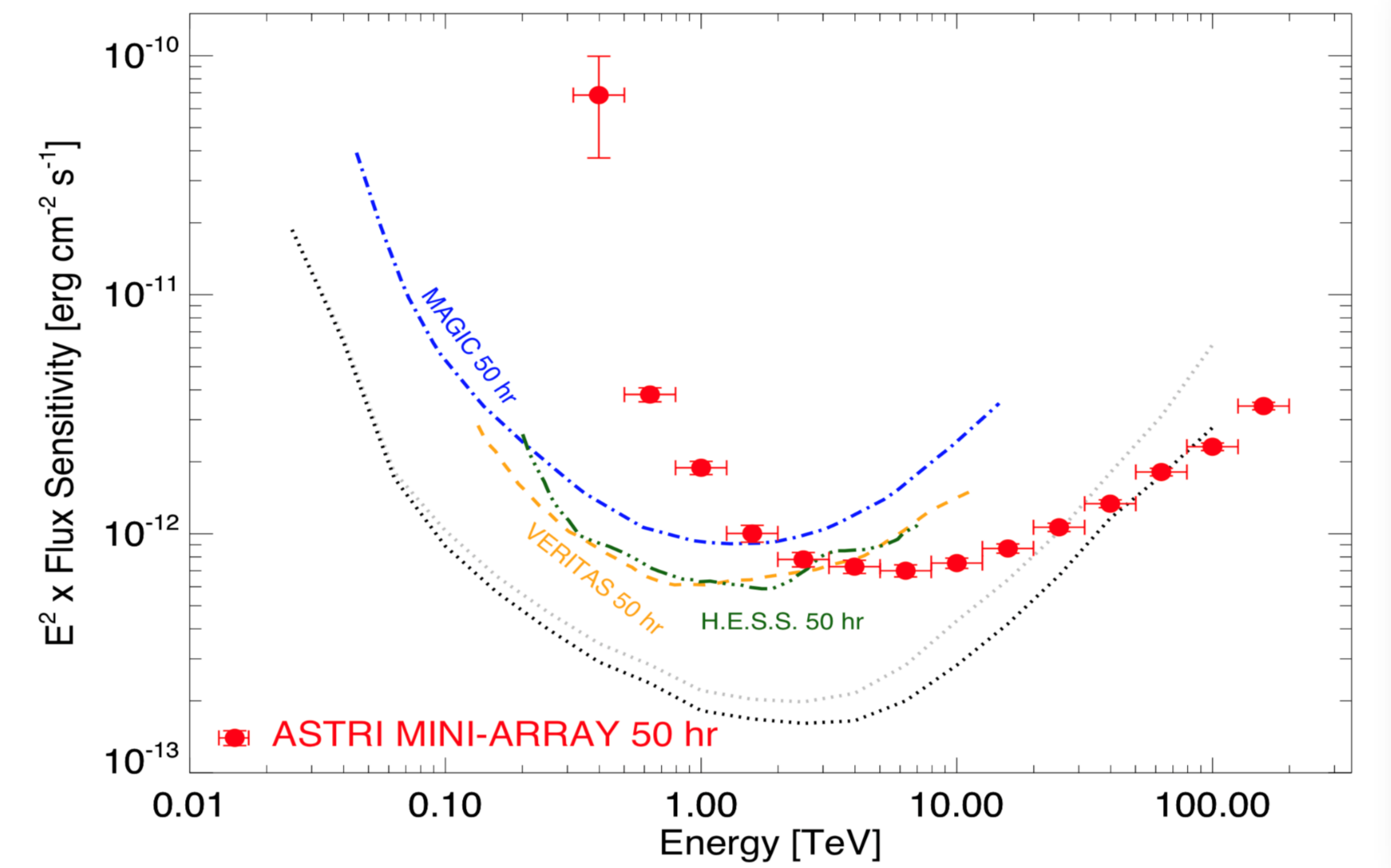
DoI: 10.5281/zenodo.6827882

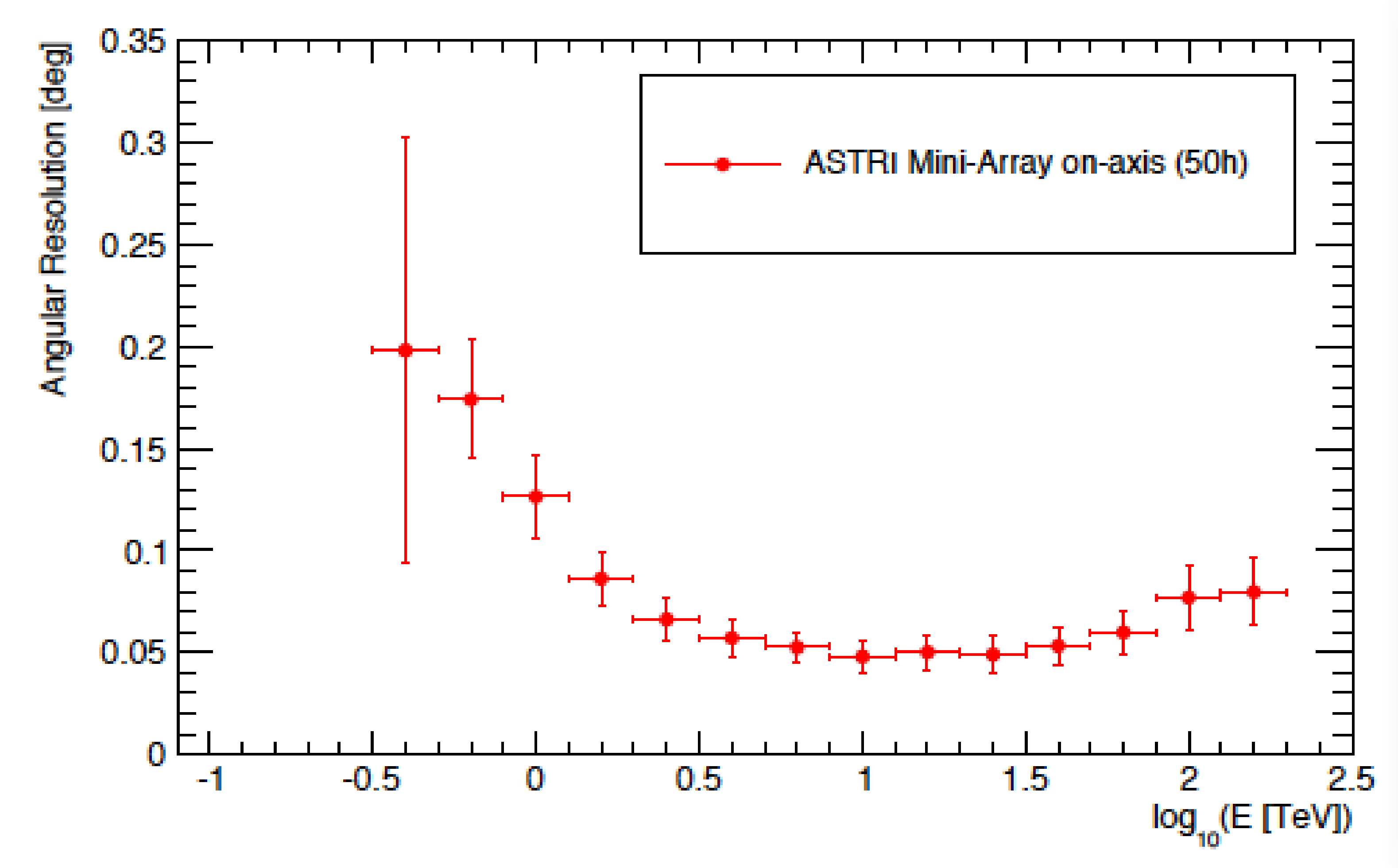
Mini but not small...

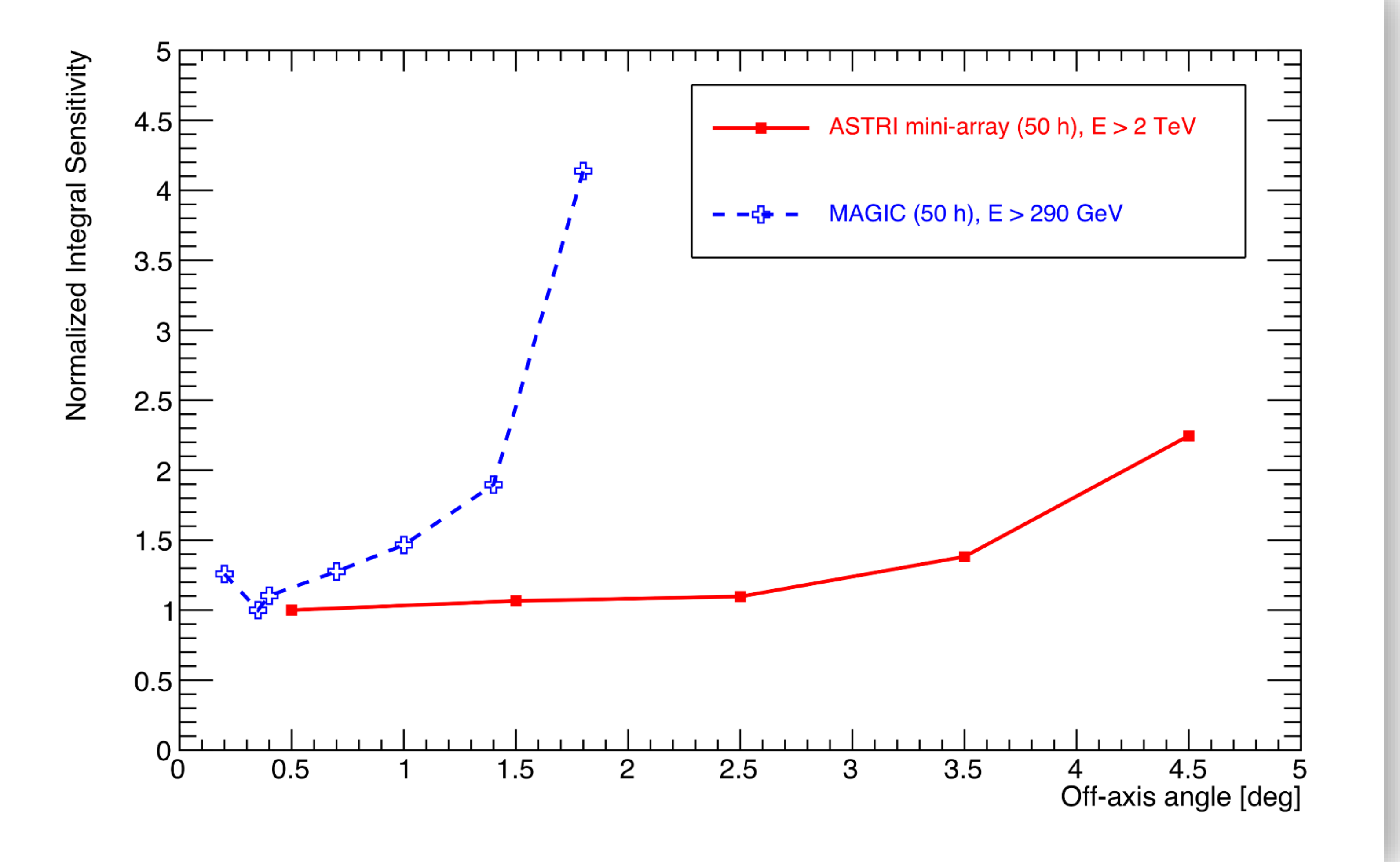
Mini-Array

Largest Imaging Atmospheric Cherenkov Telescopes facility until CTAO will start to operate

ASTRI Mini-Array expected performance







Sensitivity: better than current IACTs (E ≳ 3 TeV):

Extended spectrum and cut-off constraints

Energy/Angular resolution: ~ 10% / ~ 0.05° (E > a few TeV)

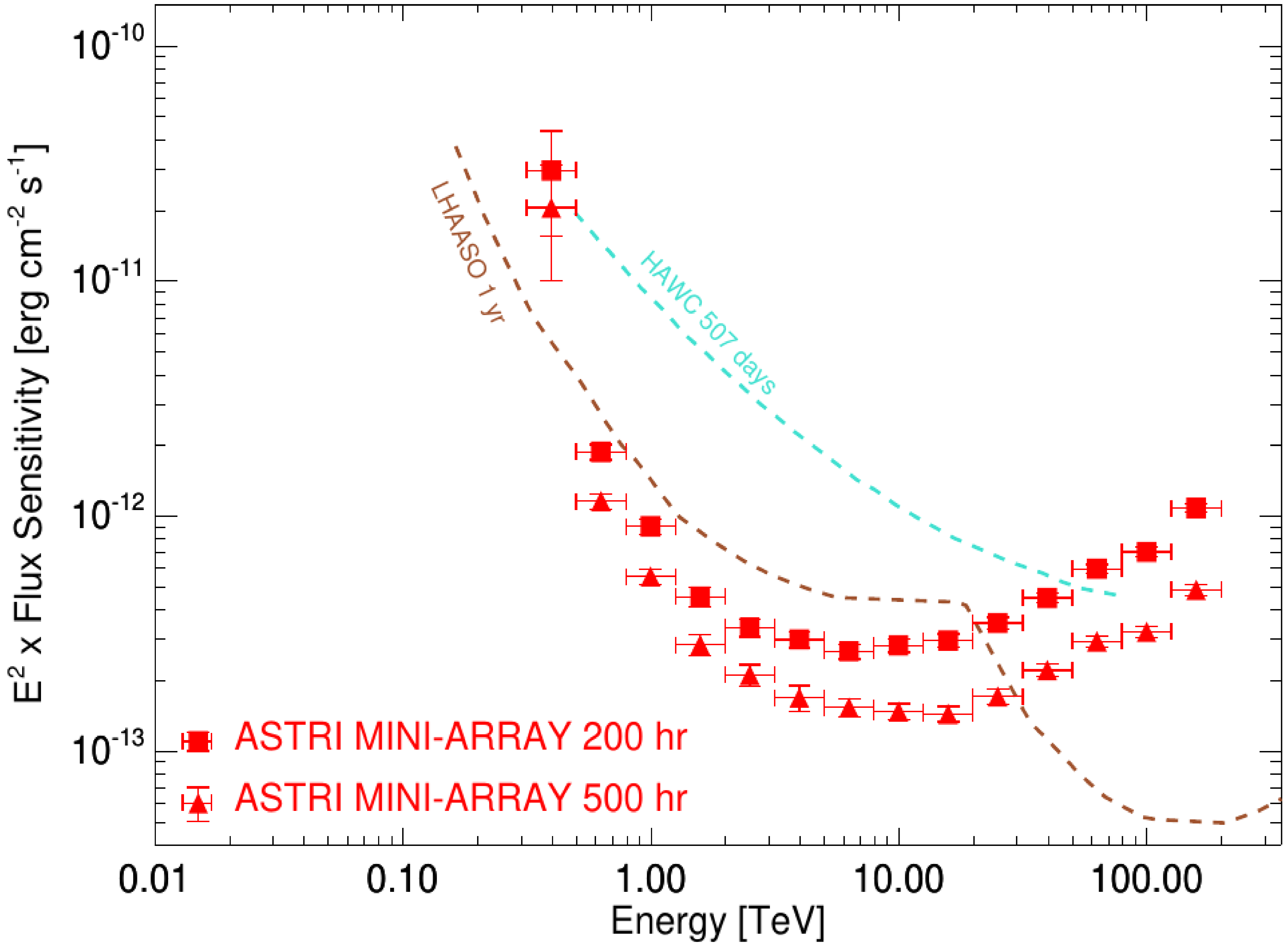
Characterize extended sources morphology

Wide FoV (≥ 10°), with almost homogeneous off-axis acceptance

Multi-target fields and extended sources

Enhanced chance for serendipity discoveries

ASTRI Performance - Flux sensitivity with integration with hundreds of hours on the same source

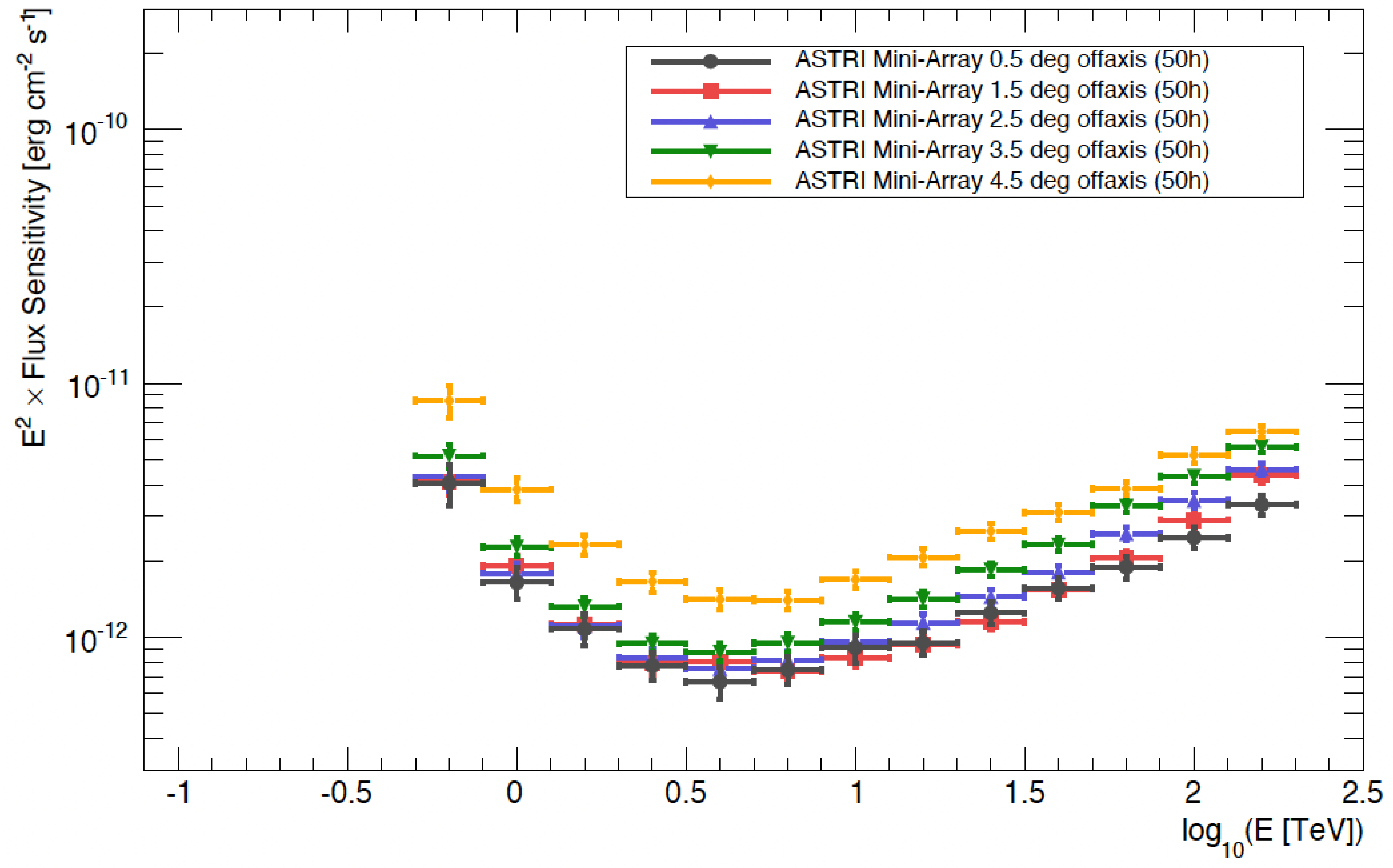


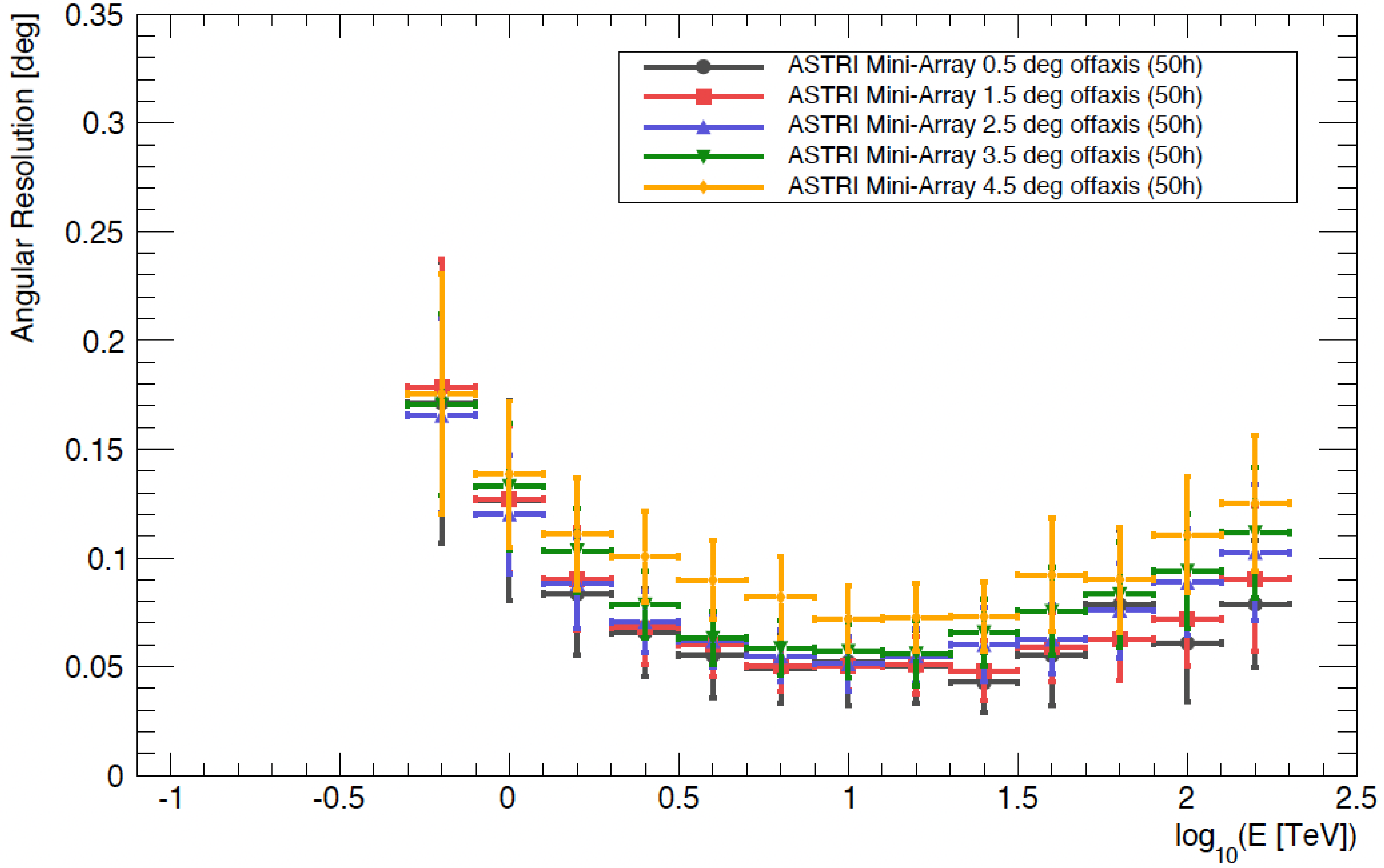
Expected performance

Sensitivity: better than that of current IACTs (E > a few TeV)

- Extend the spectra of already detected sources and/or measure cut-offs .
- Much better angular resolution

Off – Axis Behavior





The ASTRI Mini-Array – Synop

PRELIMINARY

	ASTRI Mini-Array	MAGIC	VERITAS	H.E.S.S.	HAWC	LHAASO
Location	28° 18′ 04″ N	28° 45′ 22″ N	31° 40′ 30″ N	23° 16′ 18″ S	18° 59′ 41″ N	29° 21′ 31″ N
	16° 30′ 38″ W	17° 53′ 30″ W	110° 57′ 7.8″ W	16° 30′ 00″ E	97° 18′ 27″ W	100° 08′ 15″ E
Altitude [m]	2,390	2,396	1,268	1,800	4,100	4,410
FoV	~ 10°	~ 3.5°	~ 3.5°	~ 5°	2 sr	2 sr
Angular Res.	0.05° (30 TeV)	0.07° (1 TeV)	0.07° (1 TeV)	0.06° (1 TeV)	0.15°[a] (10 TeV)	(0.24–0.32)°[b] (100 TeV)
Energy Res.	12% (10 TeV)	16% (1 TeV)	17% (1 TeV)	15% (1 TeV)	30% (10 TeV)	(13–36)% (100 TeV)[b]
Energy Range	(0.3-200) TeV	(0.05-20) TeV	(0.08-30) TeV	(0.02-30) TeV[c]	(0.1-100) TeV	(0.1-1,000) TeV

Observing Strategy

ASTRI will study gamma-ray sources at E >> 1 TeV

LOW FLUX!

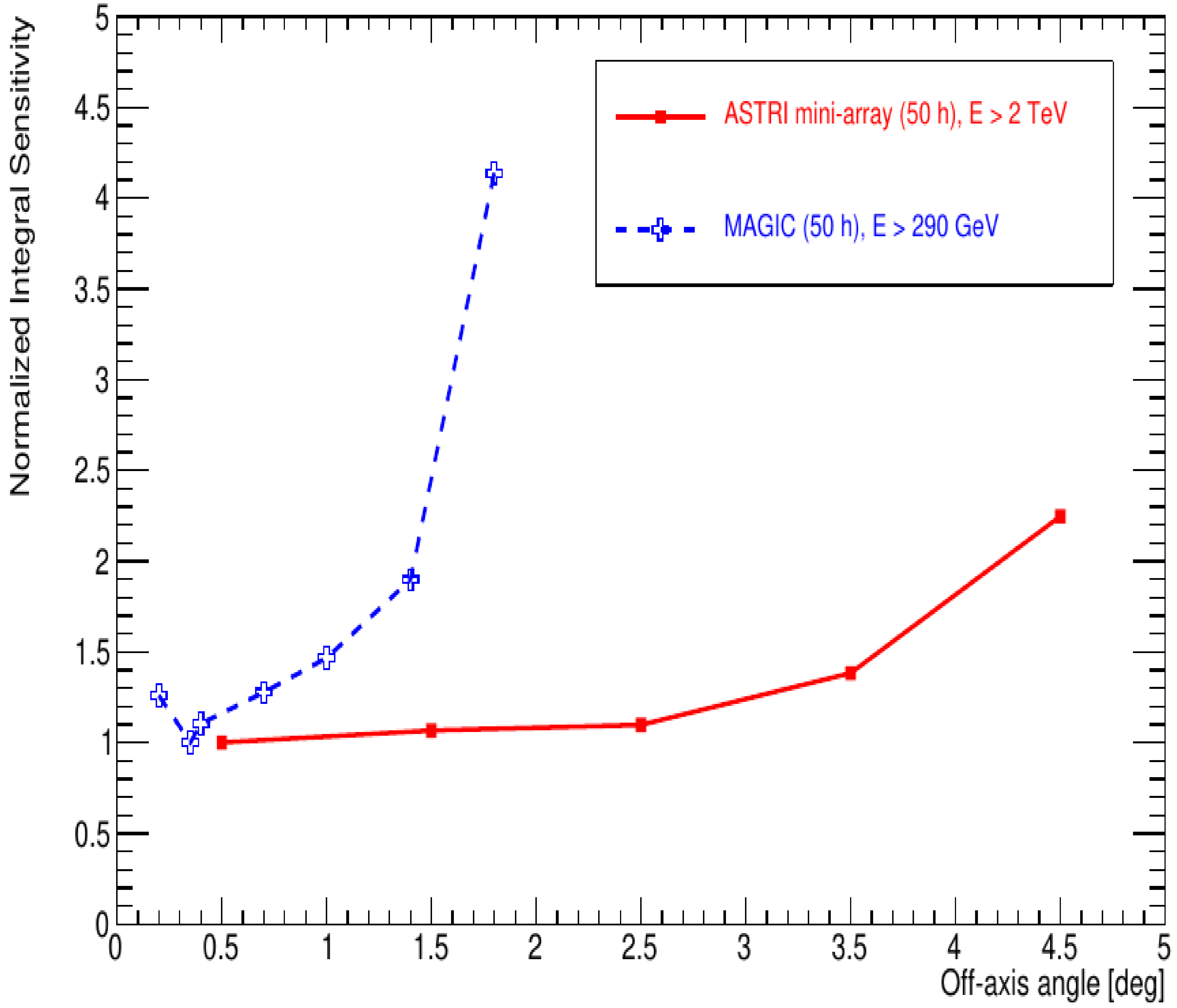
➔ Need for deep exposures

Strategy:

Focus on a few sky fields with long integration time

But with features acing-up our sleeve :

- Large FoV
  - → Several sources in the FOV
- Observations with moonlight
  - → Increases avail. time ~50-80%
- Large Z.A.
  - → Increase Aeff @ high energies



ASTRI VS LACT / LHAASO: A HIGH COMPLEMENTARITY!

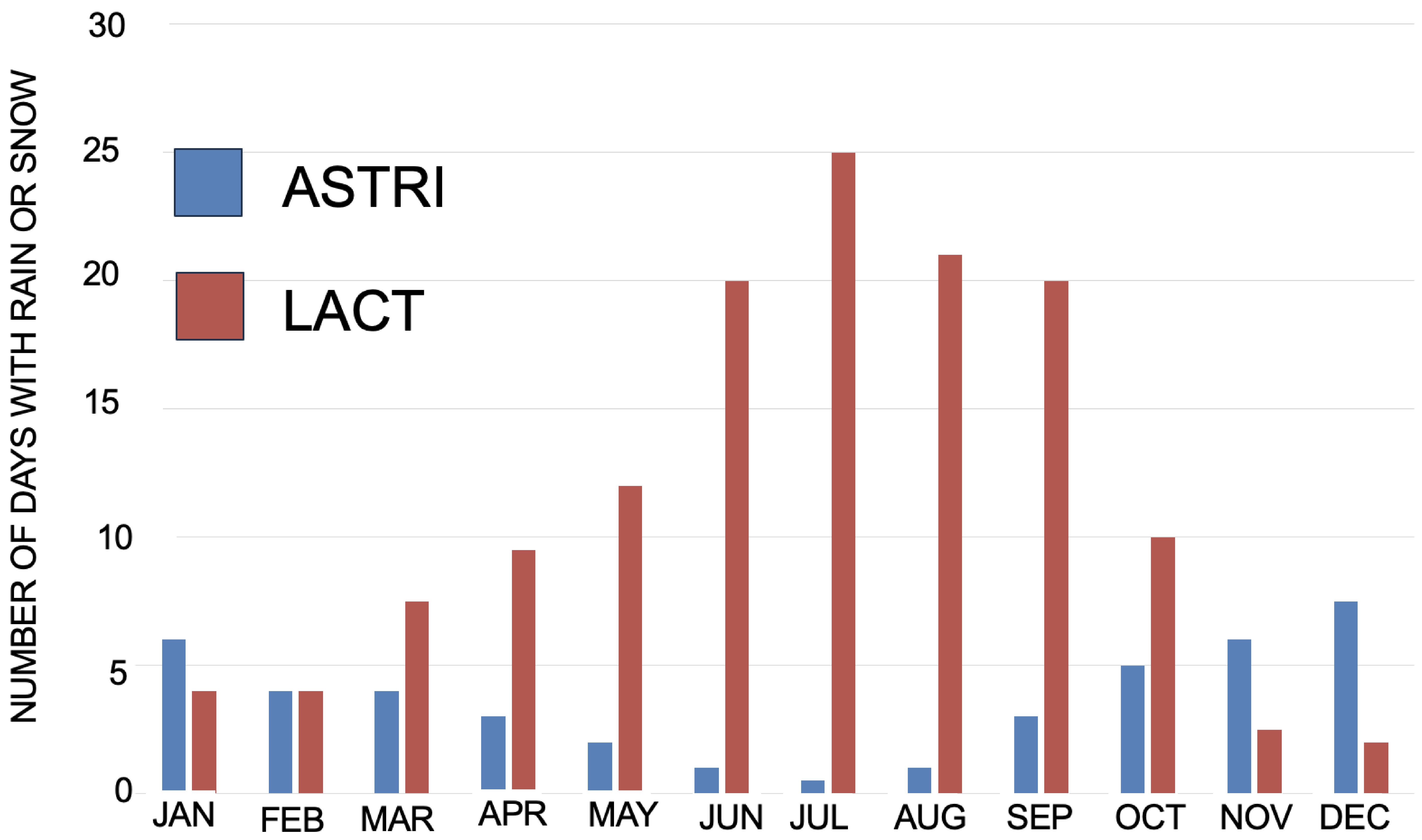
Parameter	ASTRI	LACT
Location	28º 17' 60" N 16º 30' 21" W	29° 21` 27.6`` N 100° 08' 19'6`` W
Altitude	2400 m	4400 m
Monsoon	NO	YES
Number of Telescopes	9	8 x 4 = 32
Field of View & Pixel Size & Number of pixels	10.5° - 0.2°	8° - 0.2°
Muon anticoincidence	NO	YES
Angular resolution @30 TeV	3 arcmin (constant across the FOV)	6 - 8 arcmin
Energy Resolution	10 -15 %	10-20 %
Flux Sensitivity extended sources (Crab spectrum)	9 E-11 cgs (9 telescopes)	E-12 cgs (8 telescopes)
Monsoon	NO	YES

DAYS OF PRECIPITATIONS

SOURCES:

https://www.sichuantravelguide.com/

http://www.izana.org/index.php?option=com_content&view=article&id=23&Itemid=23&lang=en

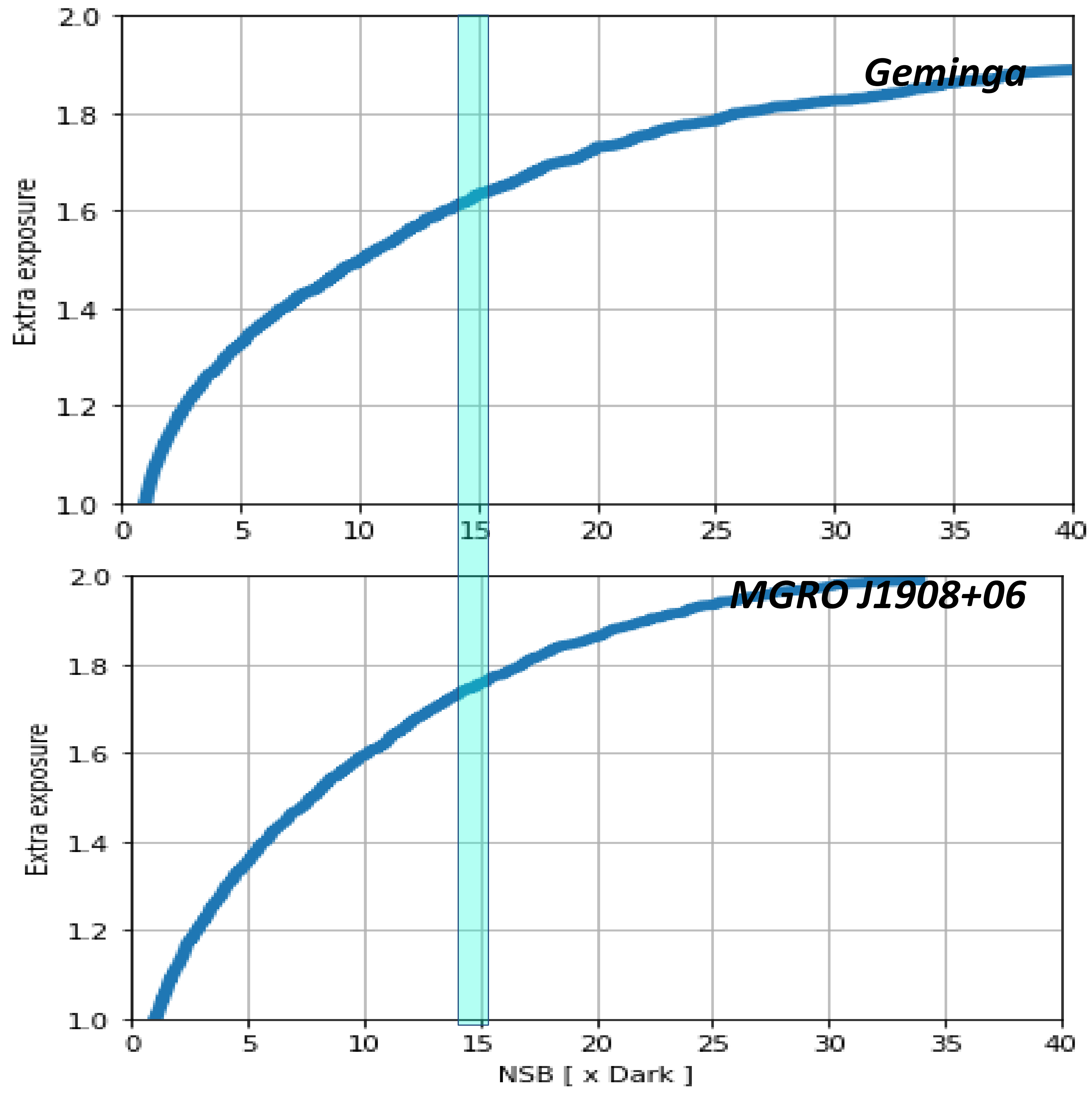


Observation duty-cycle

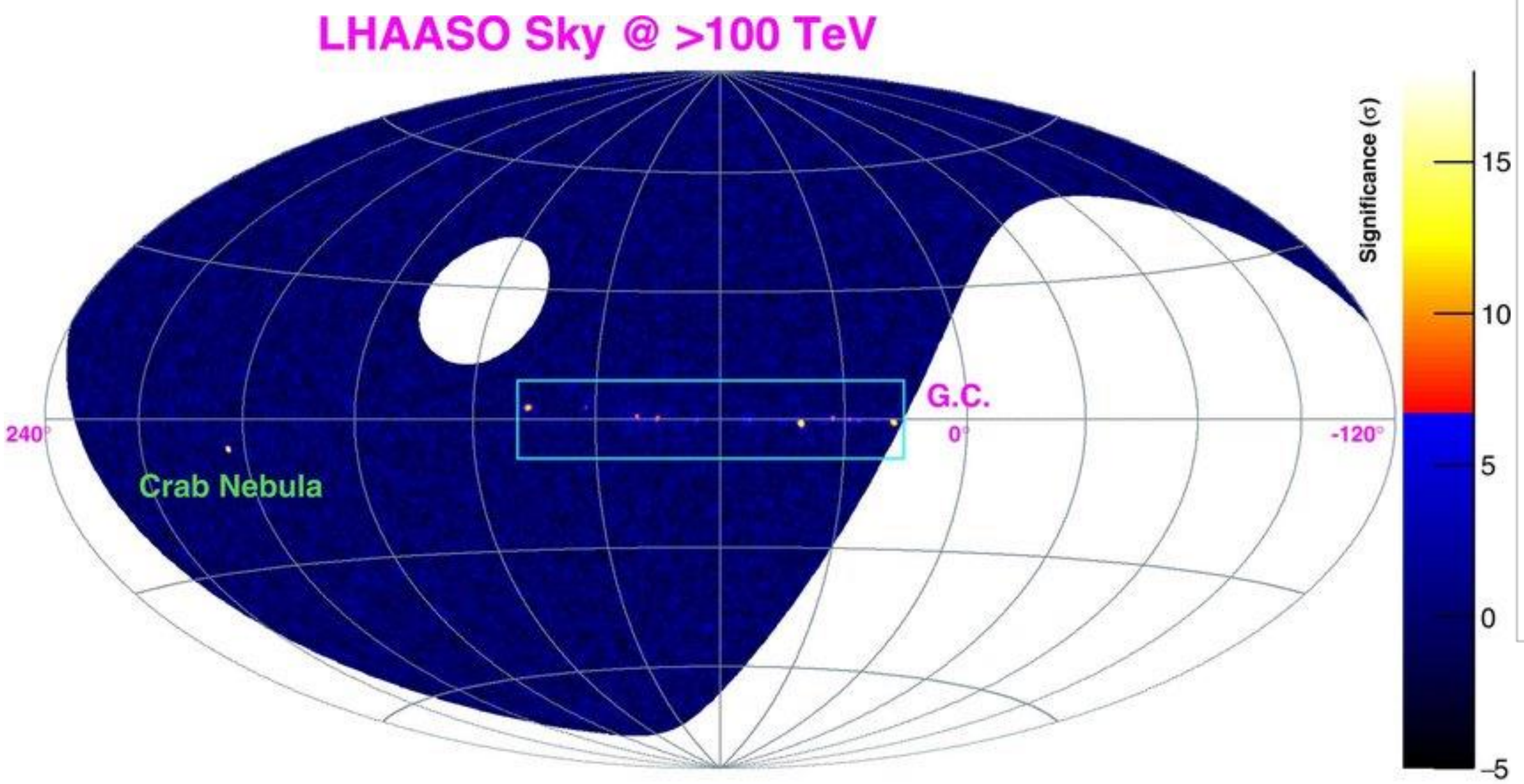
Moonless Night Hours	1565 h
Fraction of clear nights (cloud coverage <20%)	0.79
Fractional loss due to bad weather	0.04
Fractional loss due to "Calima"	0.07
Average Annual Observation Time	1104 h

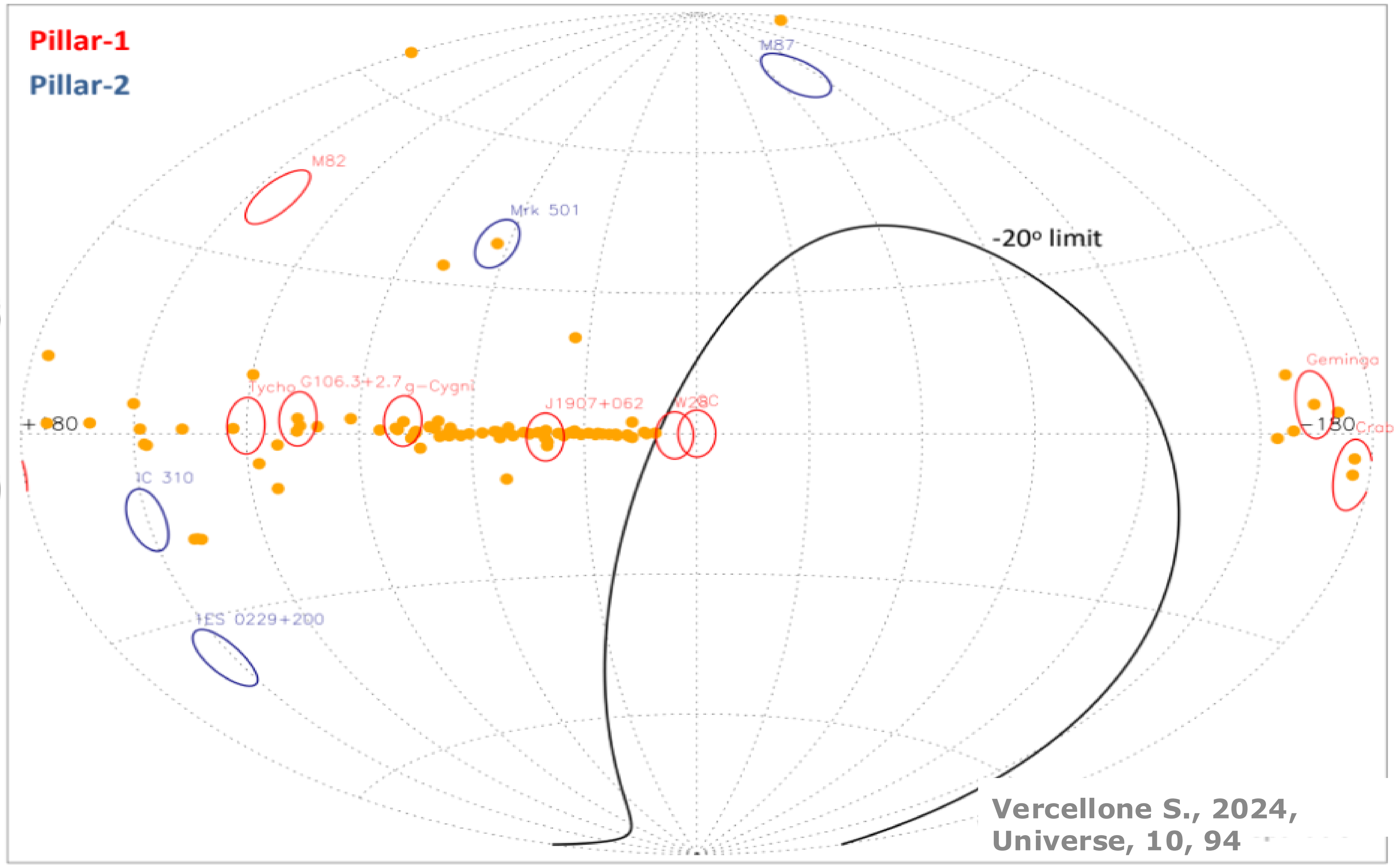
Setting 15 NSB as limit → AAOT ~ 2000 h

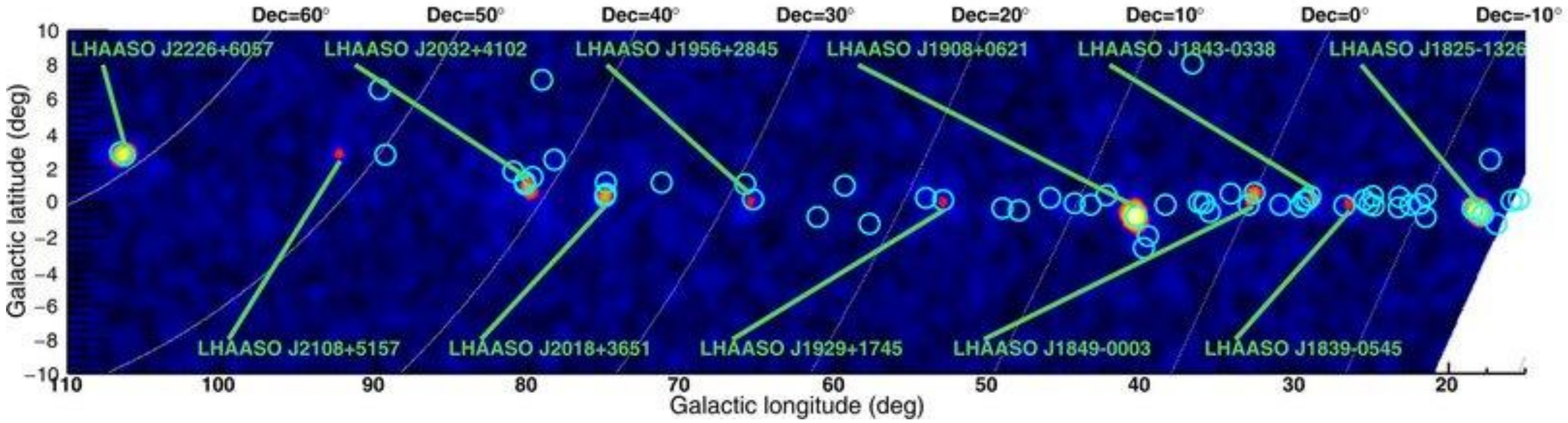
Gain Factor with Moon-light



ASTRI follow up of LHAASO Sources







- **Many of the LHAASO sources are still unidentified**
  - PWNe and Halos up to PeV energies?
  - Few SNRs and YSO?
- **Source confusion?**

ASTRI Science

Example of possible soures

Pillar 1: The origin of CRs

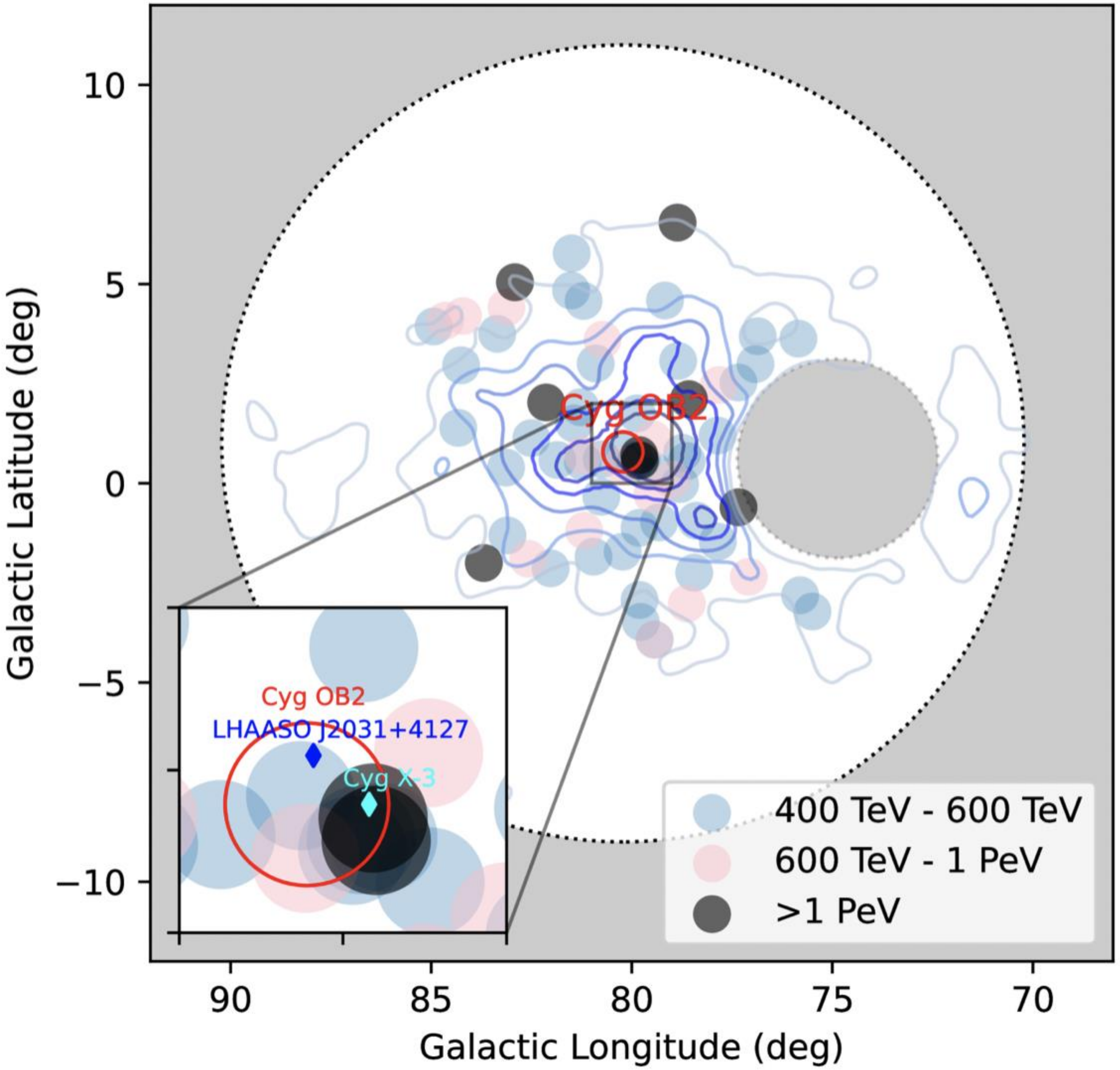
- **PeVatrons**
- **CRs Propagation**
- **Pulsar Wind Nebulae**

Pillar 2 : Cosmology and Fundamental Physics

Name	Type	Req. Exposure (Hrs)
Tycho Snr	SNR	400
Gal. Center	Diffuse	260
VER J1907	[illegible]	500
G106.3+2.7	[illegible]	200
γ-Cygni	[illegible]	500
W28	[illegible]	500
M82	[illegible]	400
Crab	[illegible]	300
Geminga	[illegible]	500
IC 310	Radio gal	10-500
M87	Radio gal	10-500
Mkn 501	Blazar	5-500
1ES 0229+200	Blazar	200-250

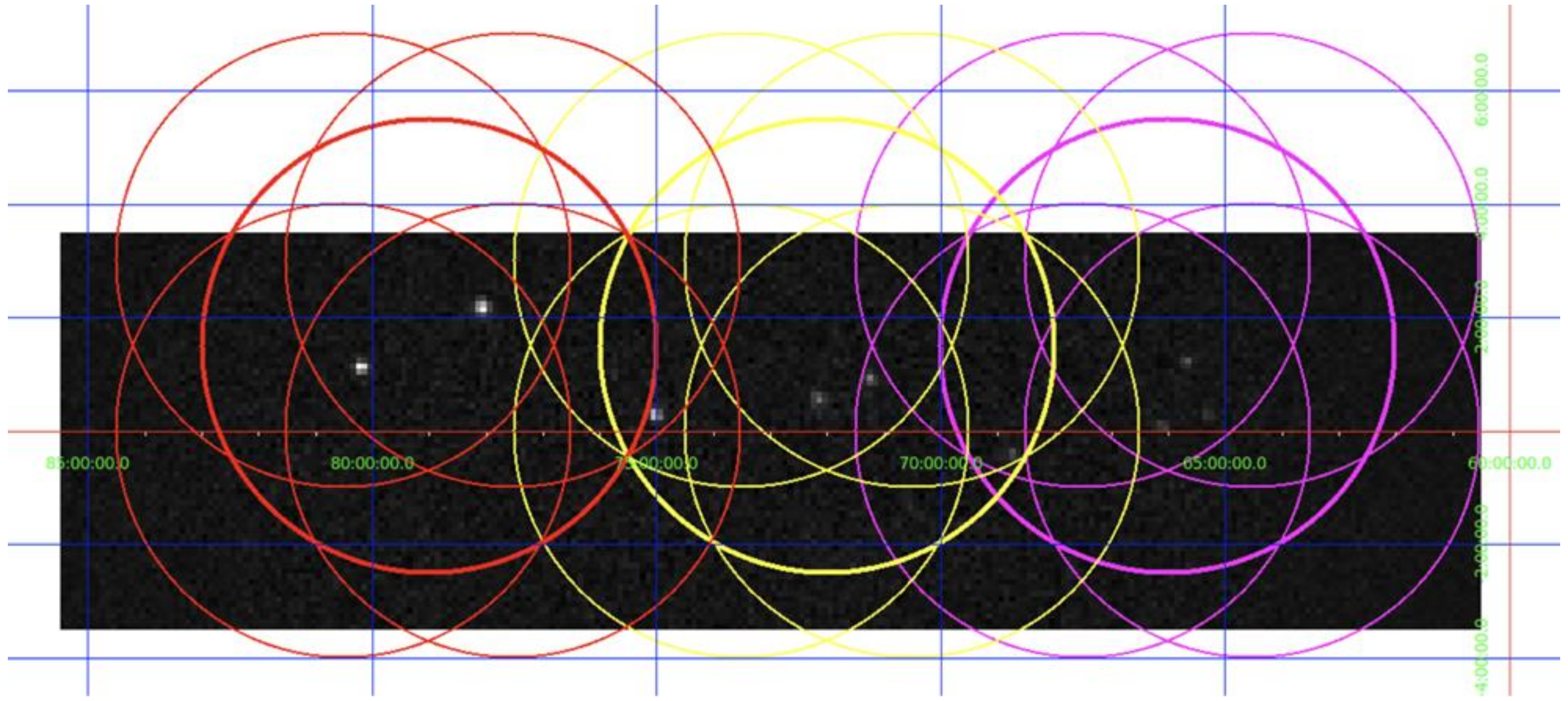
Large exposure time is required

Cygnus OB2 region after LHAASO



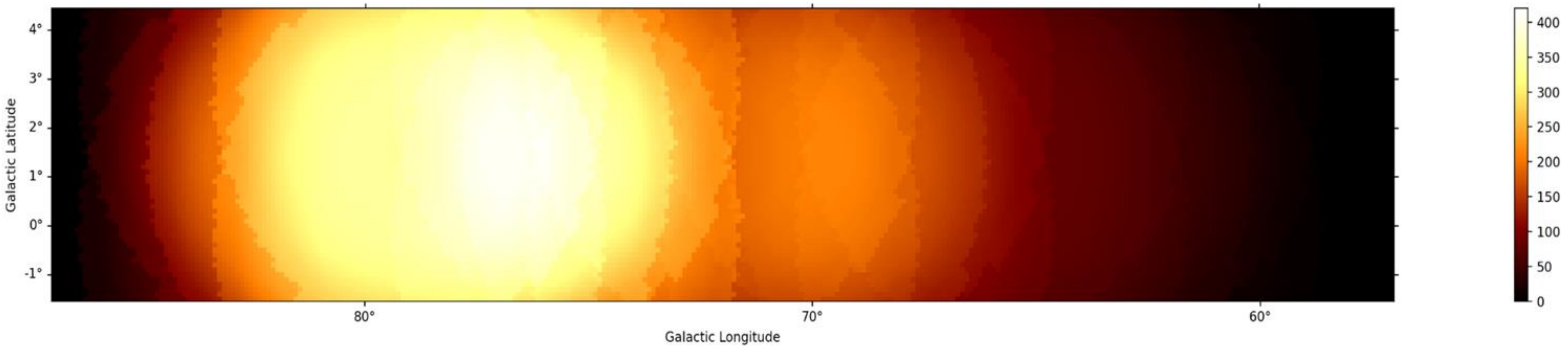
A Messy situation…

The data challenge of the Cygnus region

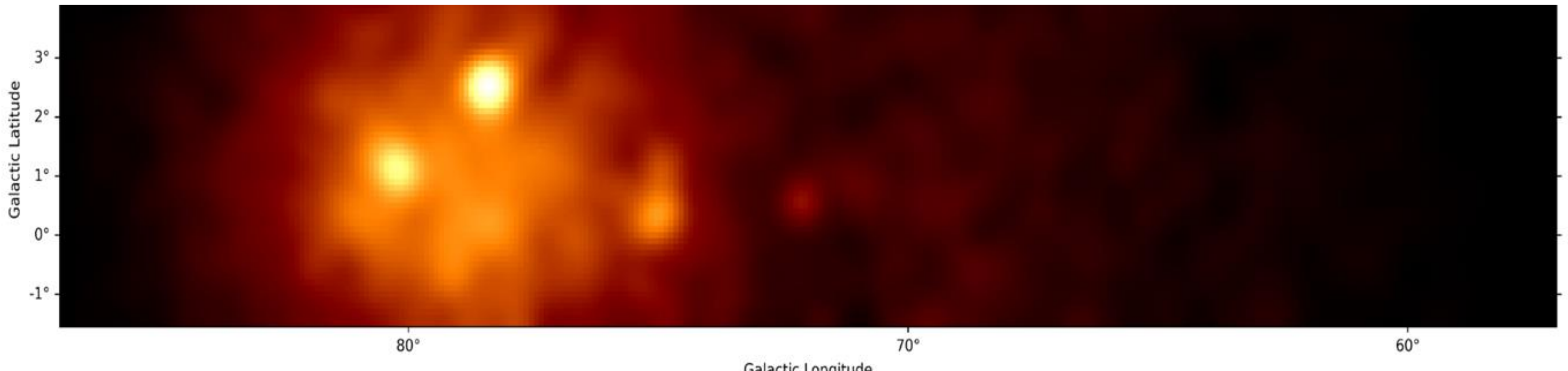


We simulated a survey of the Cygnus region, adopting 15 pointing positions along the Galactic longitude in the [60-85 deg] range.

All the known sources (eg from 3rd HAWC catalogue + LHAASO) and the Galactic diffuse component (from Gaggiero et al.) were simulated.

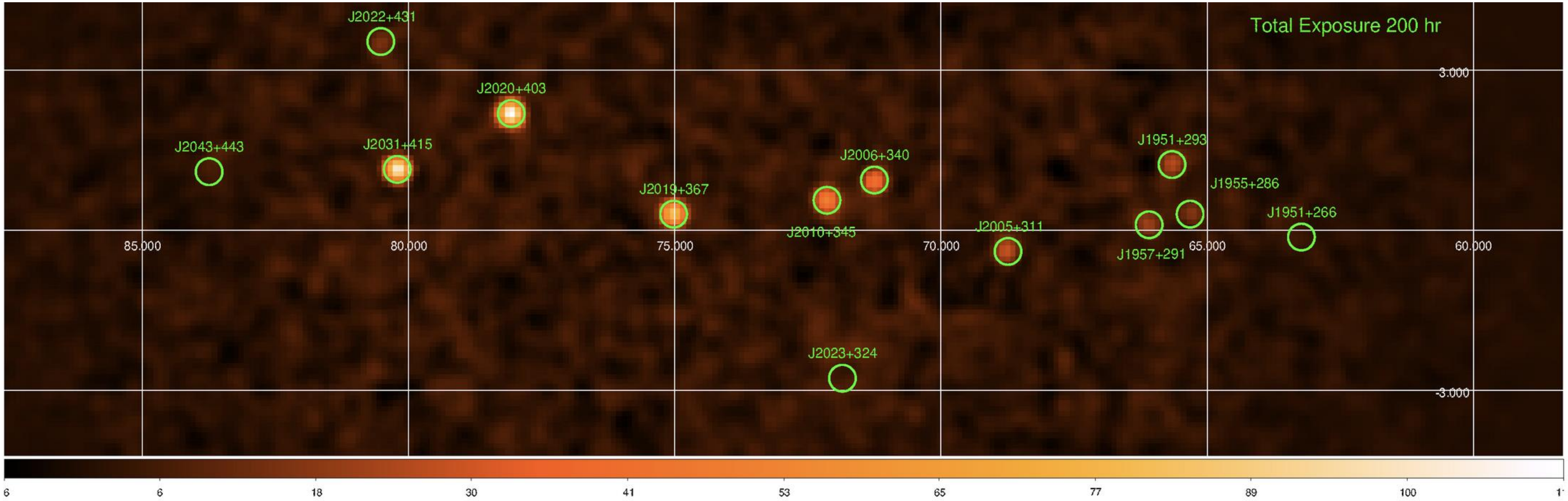


Background map of the region, brightness indicates regions of higher ***exposure***



Excess map of the region, brighter points indicate ***source or diffuse emission***

Cygnus OB2 region after LHAASO



ASTRI Mini-Array simulations of the Cygnus region mini-survey. Sky map units are counts/pixels. The simulations combined 50 different pointings, at the same Galactic latitude and spaced by 0.4° in Galactic longitude, from (l, b) = (64, 0) to (l, b) = (84, 0), and lasting 4 h hours each, respectively.

Third HAWC Catalog of very high-energy γ-ray sources. Thirteen of them fall inside the area considered and were simulated according to their published spectral parameters.

Ten of these very high-energy sources are always significantly detected by the ASTRI Mini-Array, even at the shortest (50 h) exposure time. The ASTRI Mini-Array wide FoV (~10◦ in diameter) and the stable off-axis performance will allow us to investigate this region with a single pointing and prolonged exposure, performing a more accurate morphological measurement on the core region of the bubble discovered by LHAASO.

The Galactic Center – a challenge in a challenge

Mini-Array

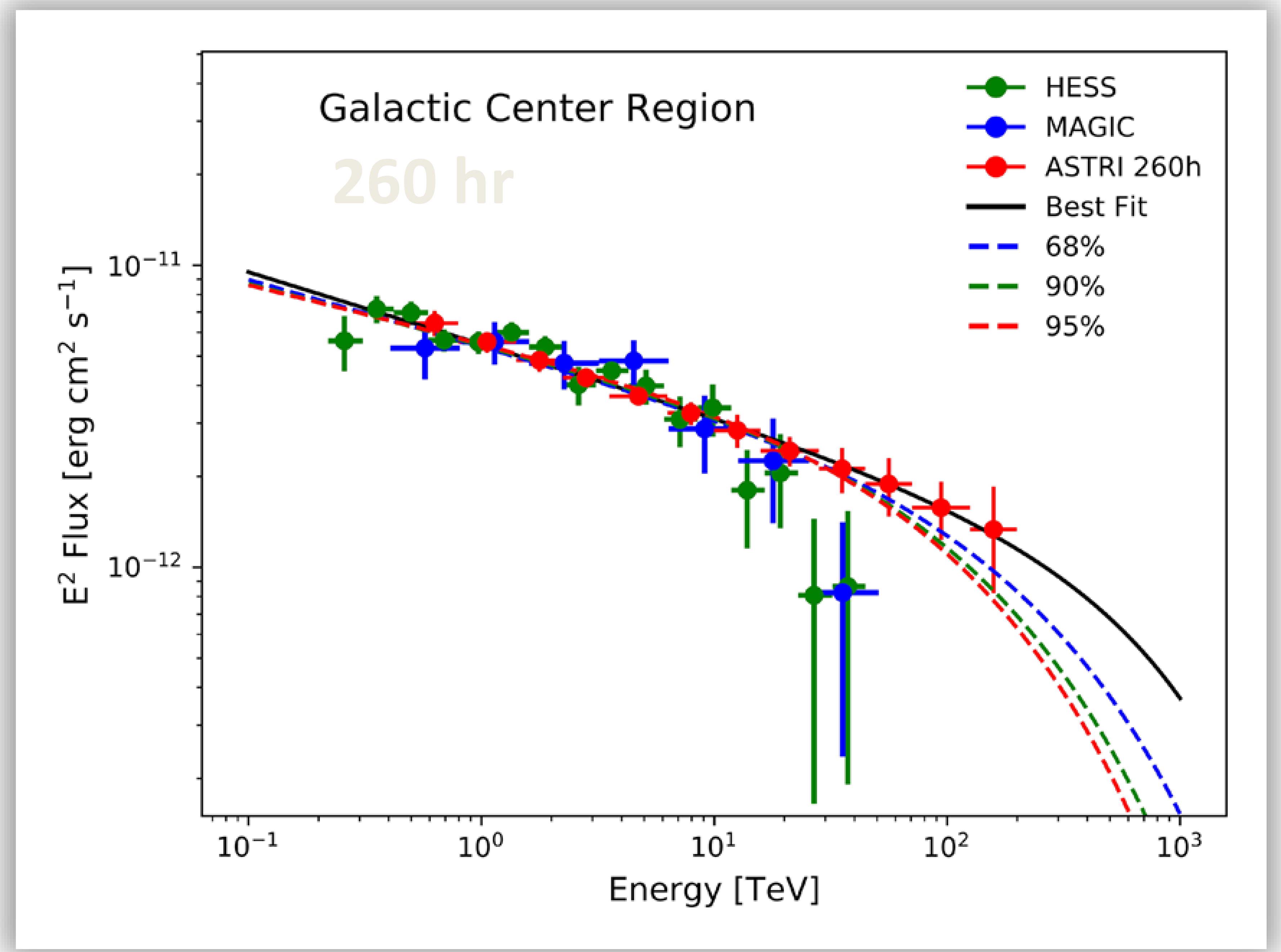
It is a complex region harbouring several potential sources of particle acceleration

It can be observed by the ASTRI Mini-Array also at high zenith angles

Current IACTs detected **non-variable emission with no significant cut-off up to a few tens of TeV**

ASTRI Mini-Array assets

- **the large FoV** will allow us to map the **whole GC region in a single observation**
- **the excellent angular resolution** could help us to **identify any HE source** among several candidates



Spatial and spectral characterization of the inner Galactic Ridge emission (HESS Collab., 2018)

HESS, MAGIC and ASTRI spectra fitted with a proton population with a cut-off power-law with E_{cut} = 120 PeV

Exclude a cut-off in proton pop. below 3.5 PeV, 2.0 PeV, and 1.7 PeV at 68%, 90%, and 95% C.L.

The mini-array @Teide: the adventure starting!

ASTRI: a new pathfinder of the arrays of Cherenkov telescopes

On June 12nd 2019, in La Laguna (Tenerife, Spain) Prof. Nichi D'Amico, President of the Italian National Institute for Astrophysics (INAF), and Prof. Rafael Rebolo Lopez, Director of the Instituto de Astrofisica de Canaries, signed a Record of Understanding to enter a detailed negotiation on a technical and programmatic basis aimed to install and operate the ASTRI Mini-Array at the Observatorio del Teide

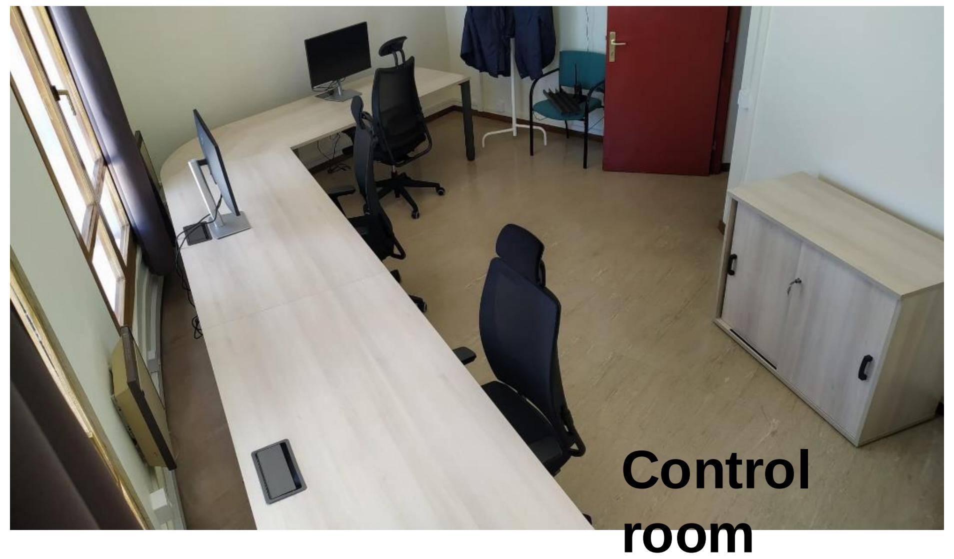
12 June 2019

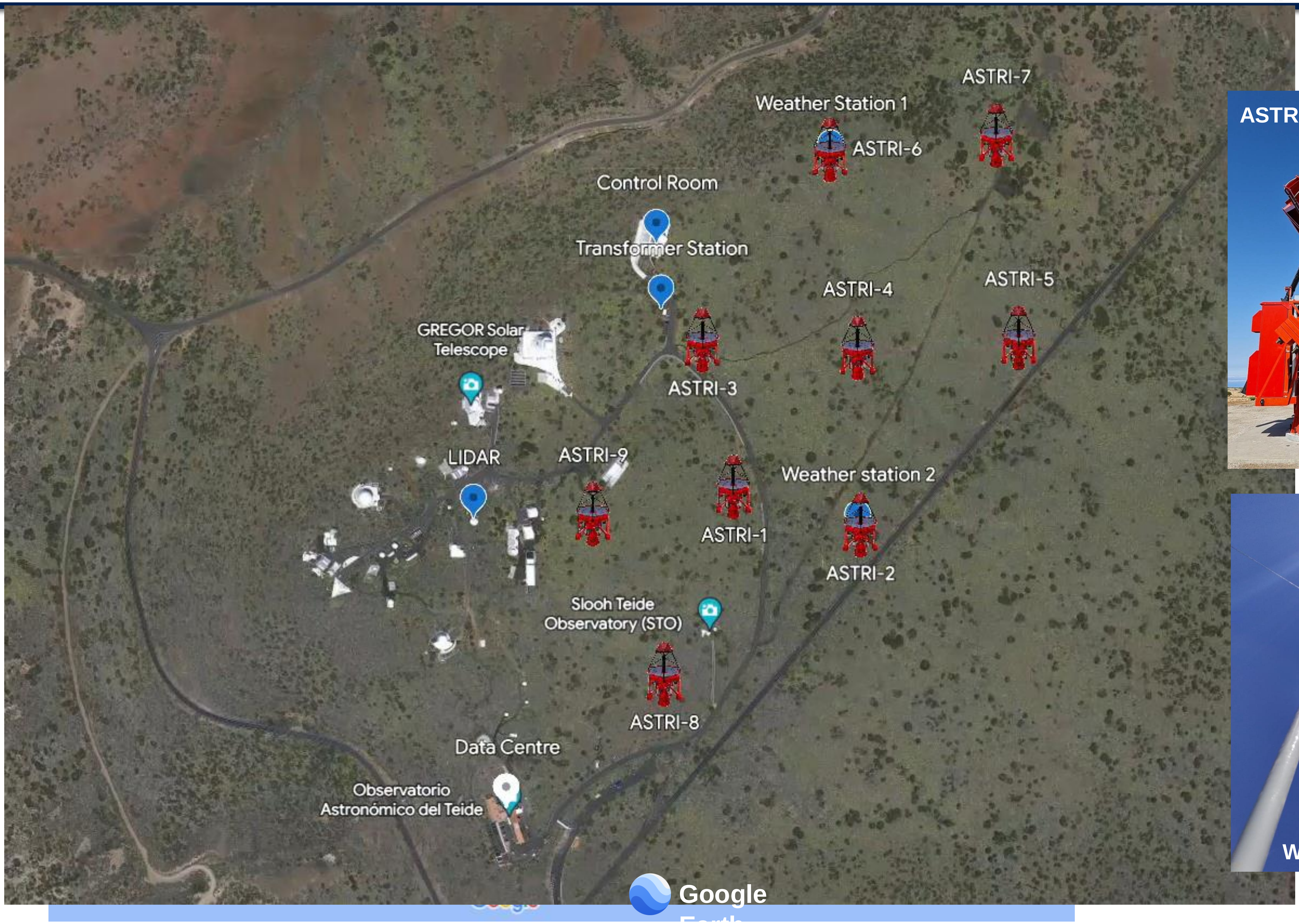
INAF and IAC Representatives on the Teide Observatory site

Infrstructure, lets start: October 2021

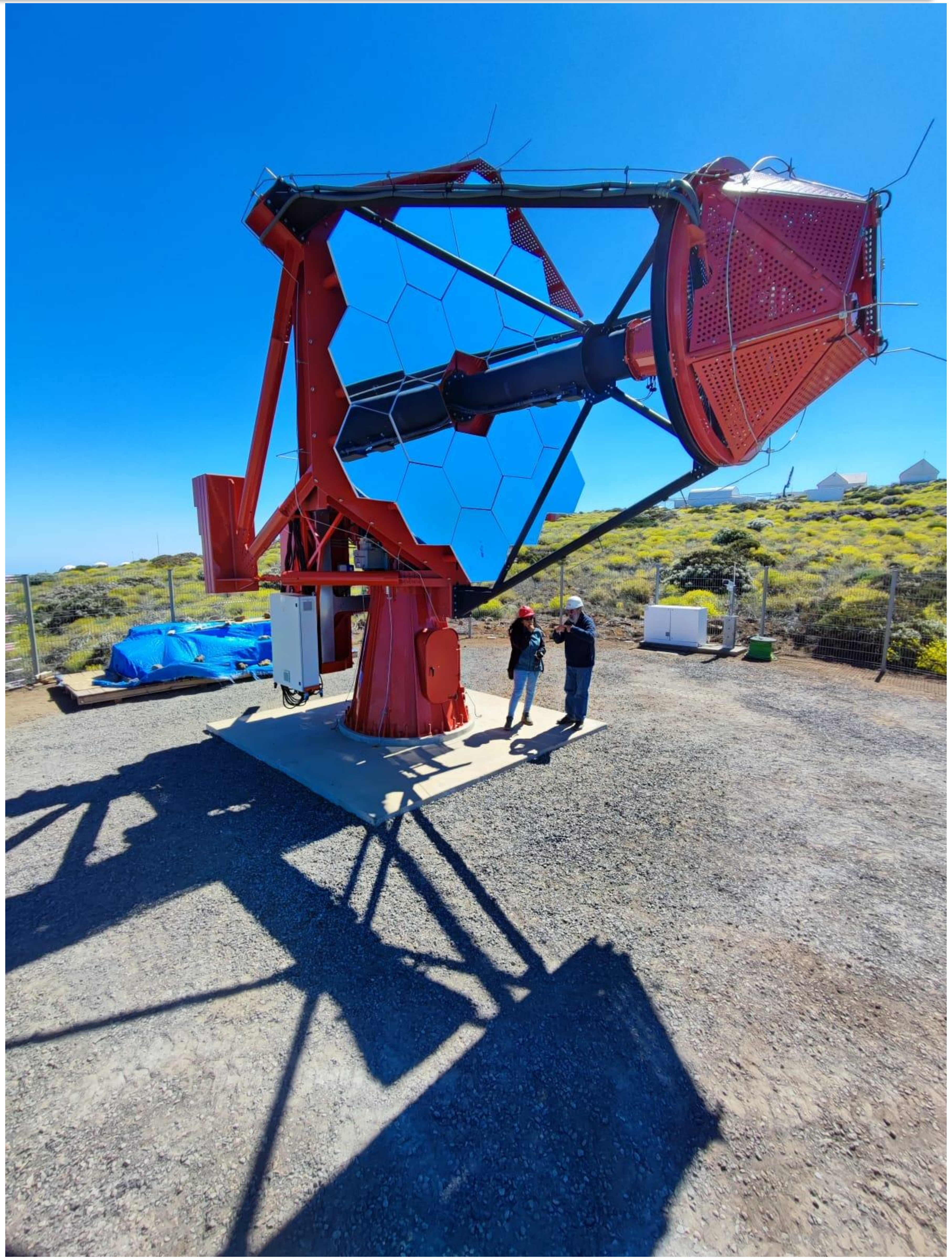
ASTRI Mini-Array

The ASTRI Mini-Array @ the Teide observatory



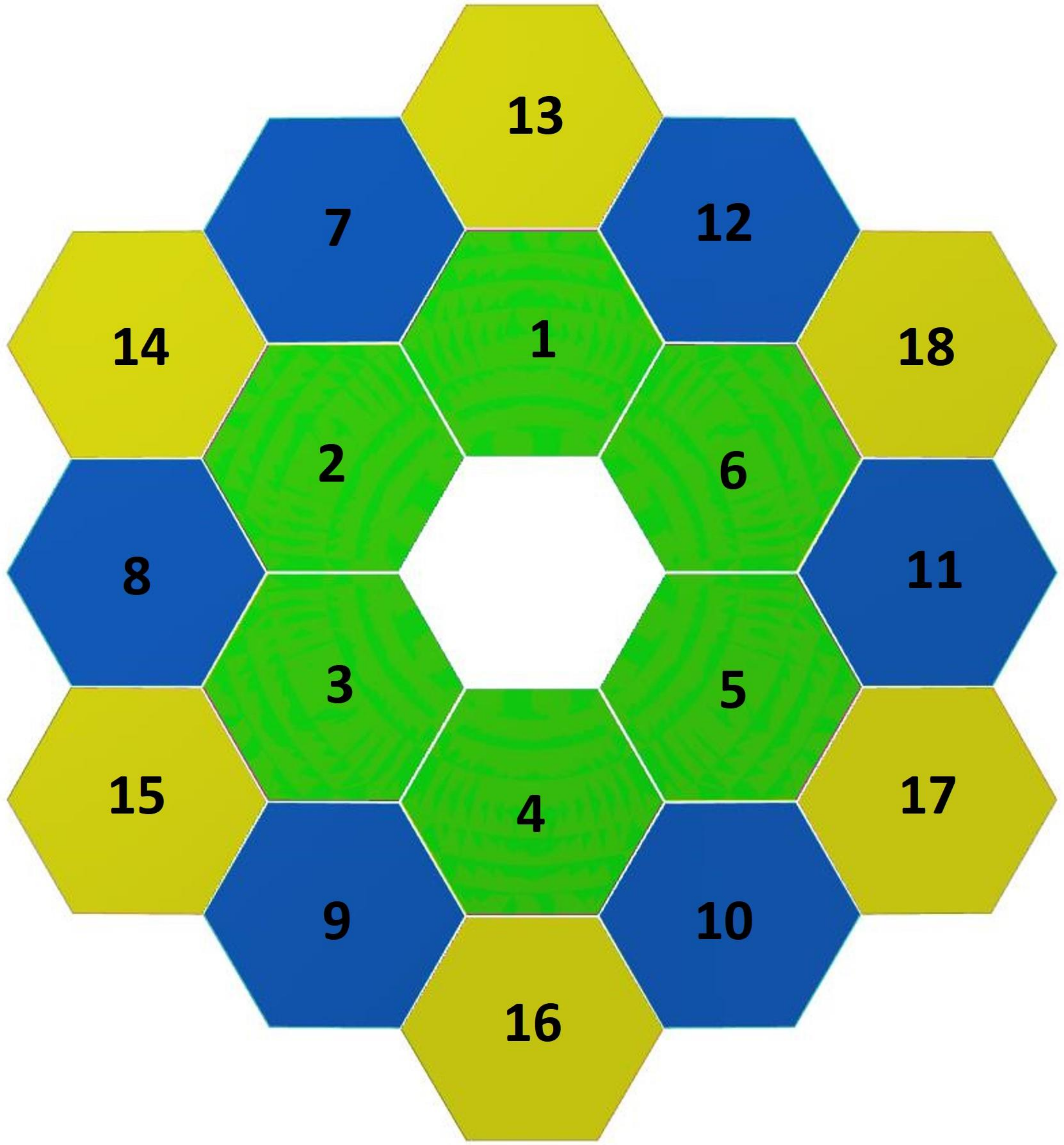


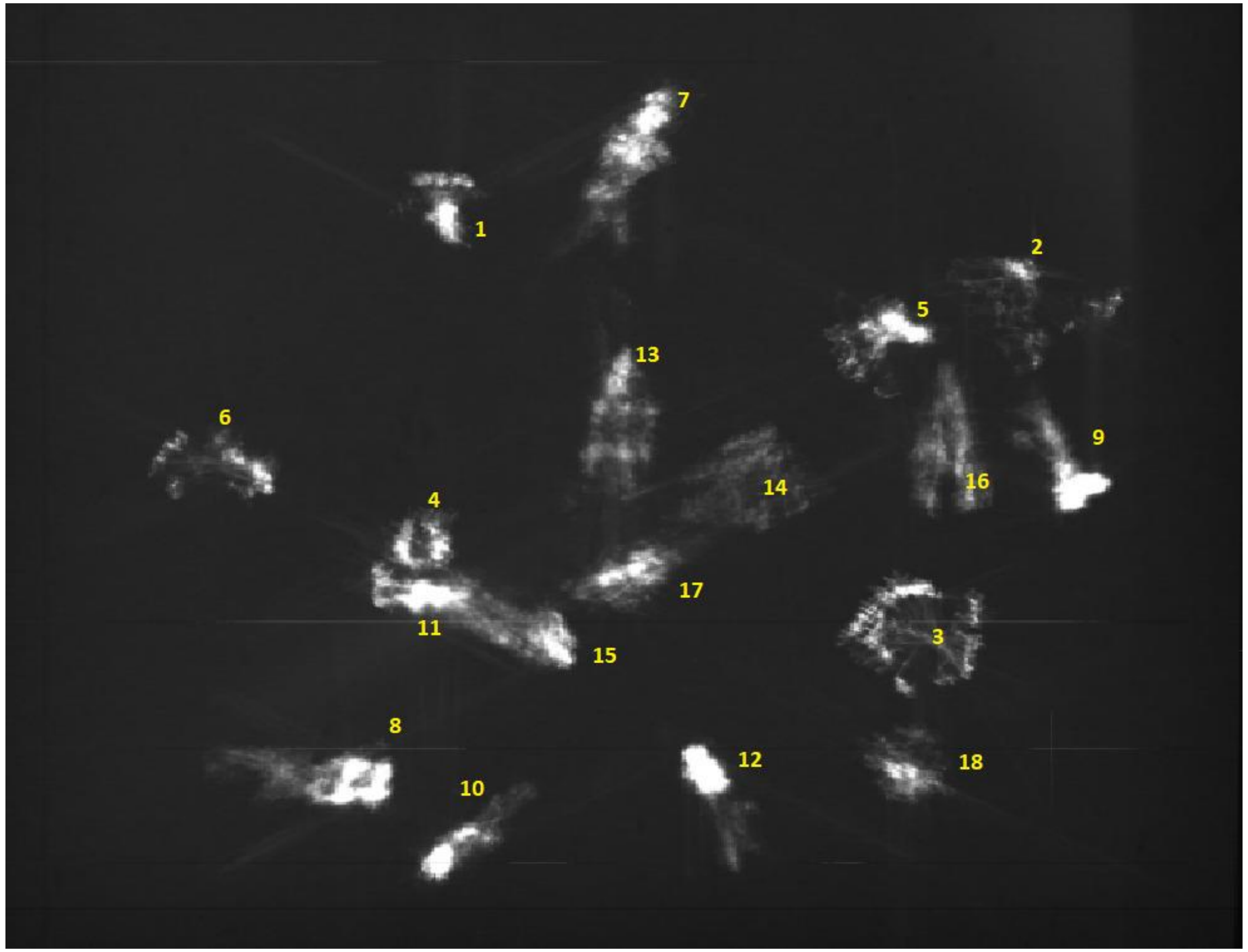
ASTRI-1



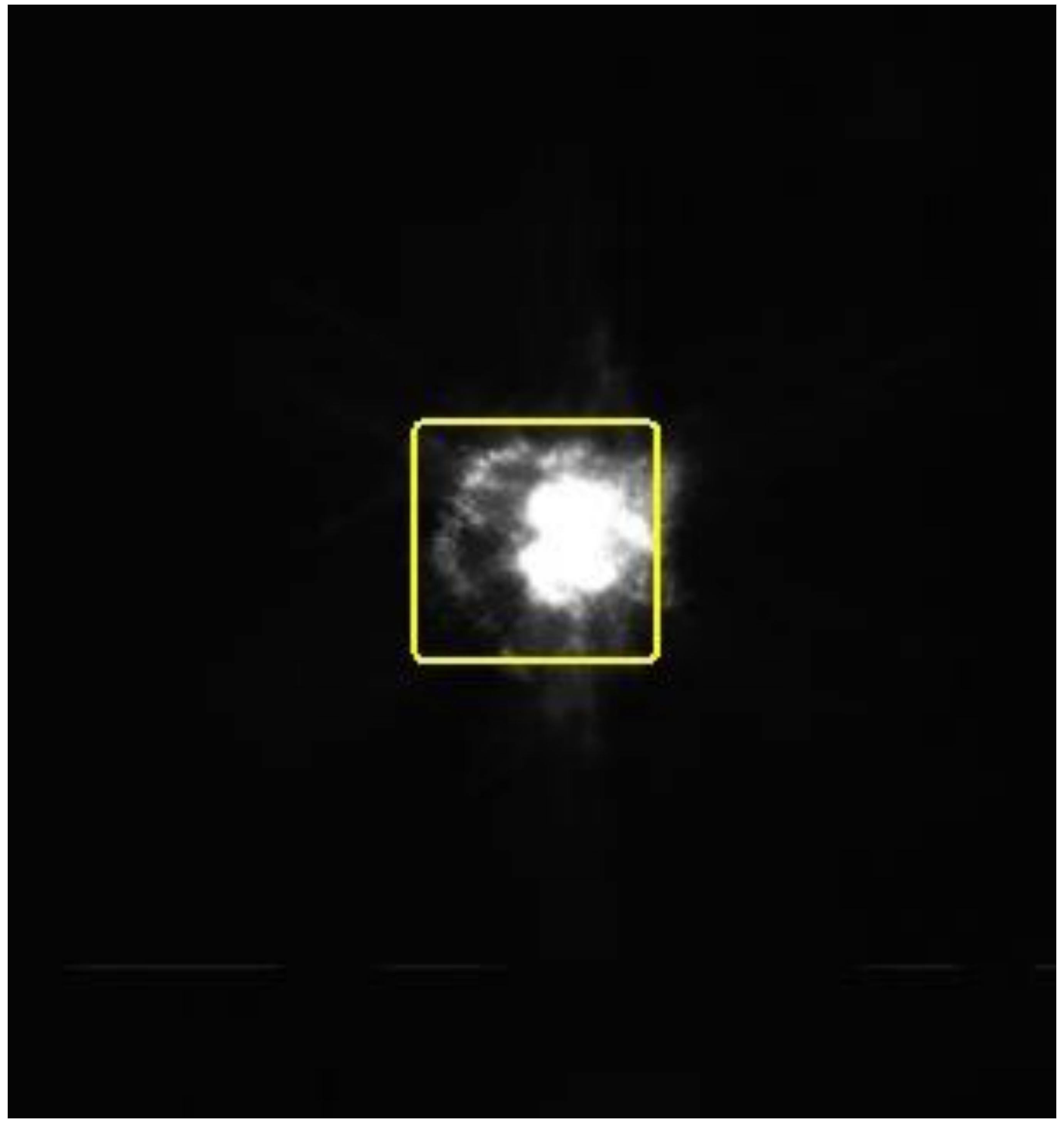
in collaboration with EIE GROUP srl

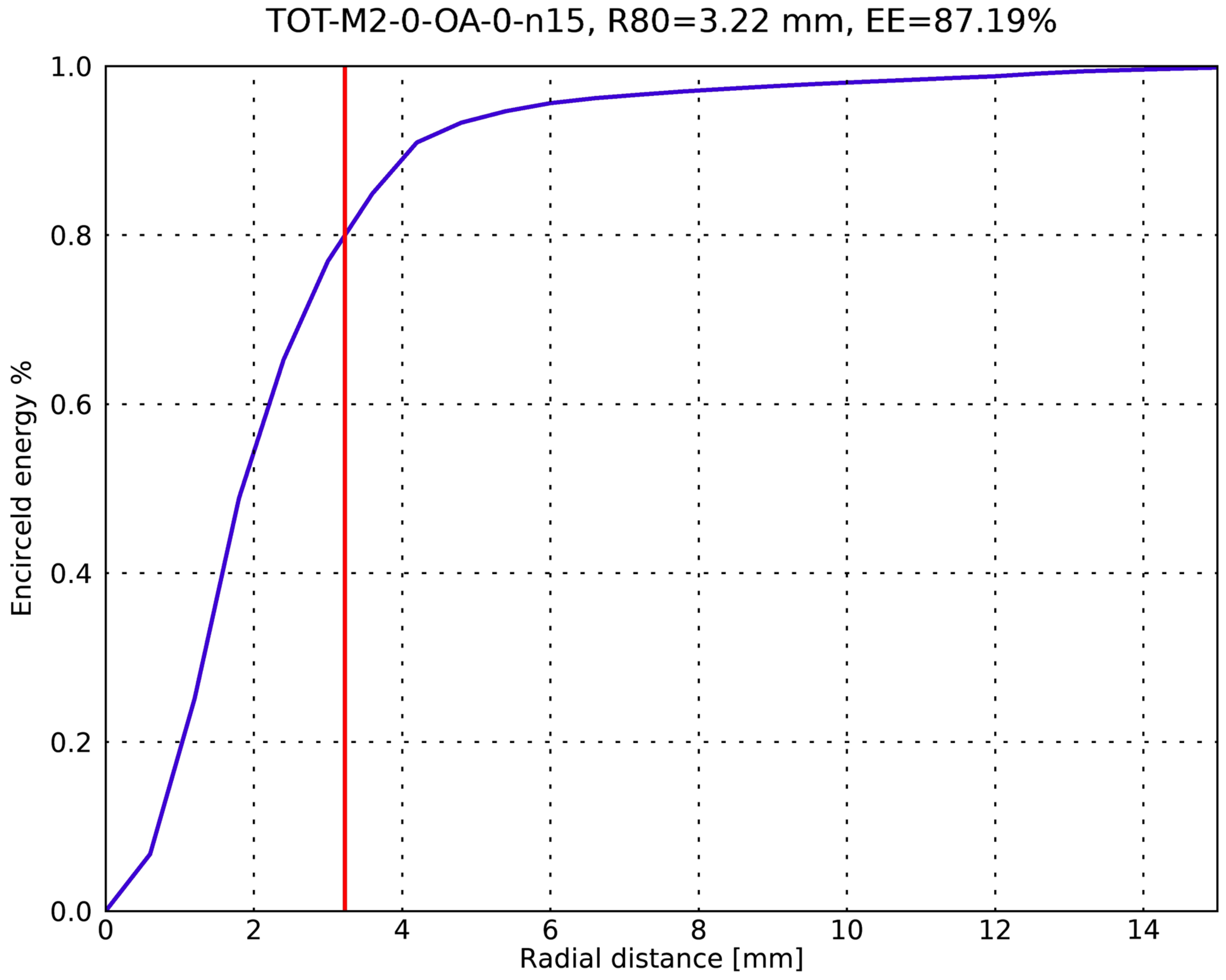
Mirrors alignment: identification



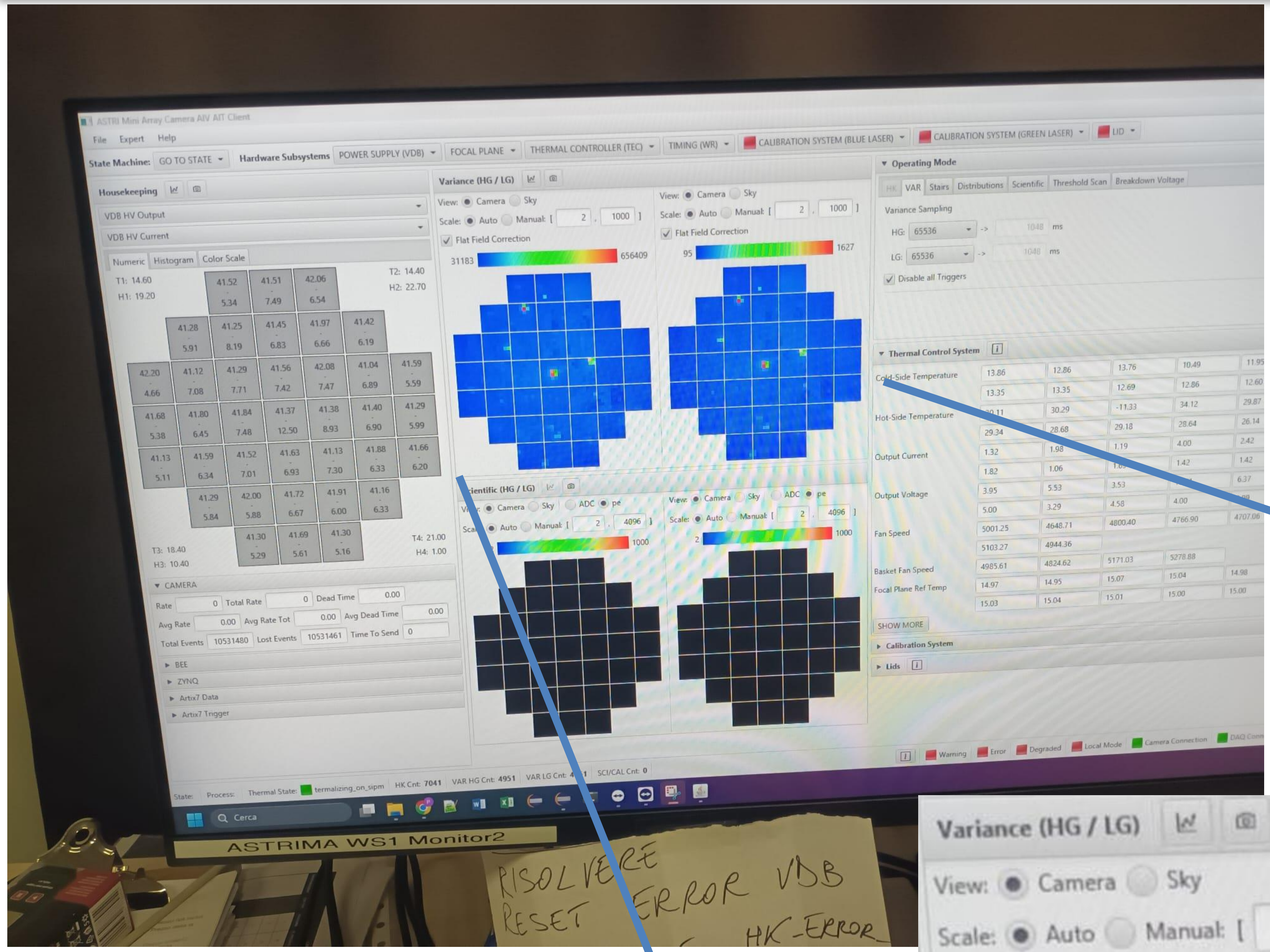


Mirrors alignment: preliminary results



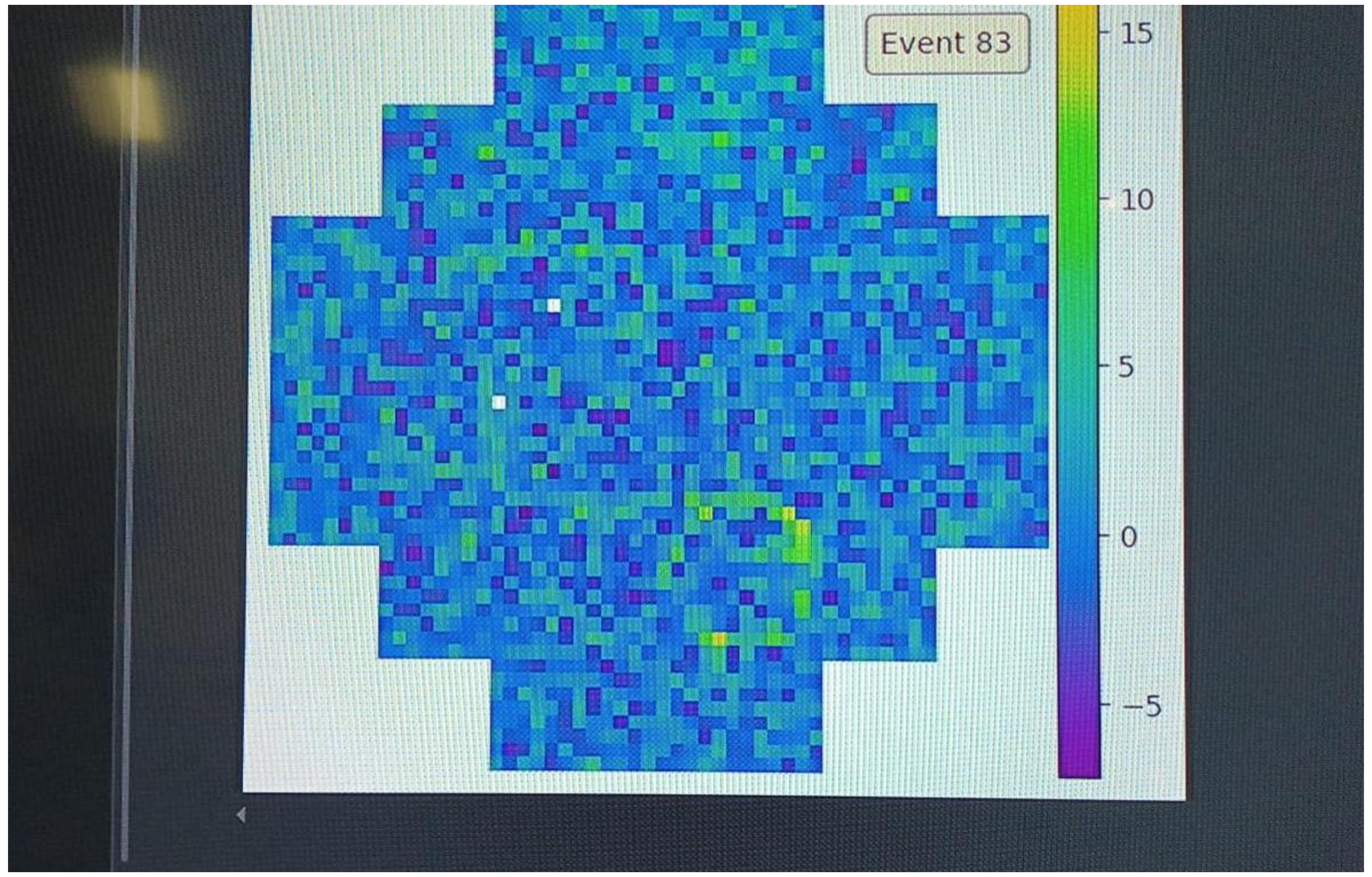


ASTRI latest achievements

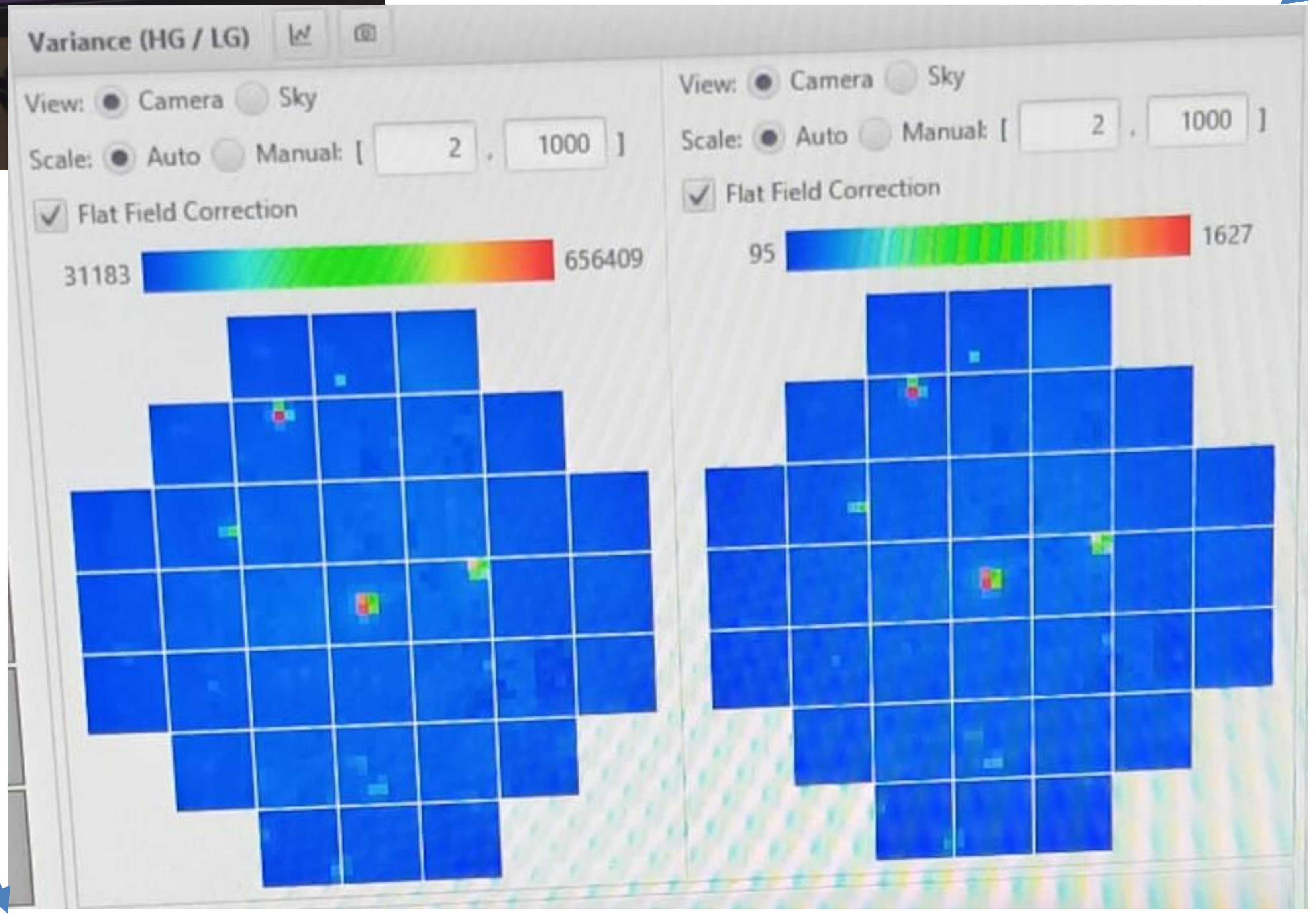


ASTRI-1 first light !

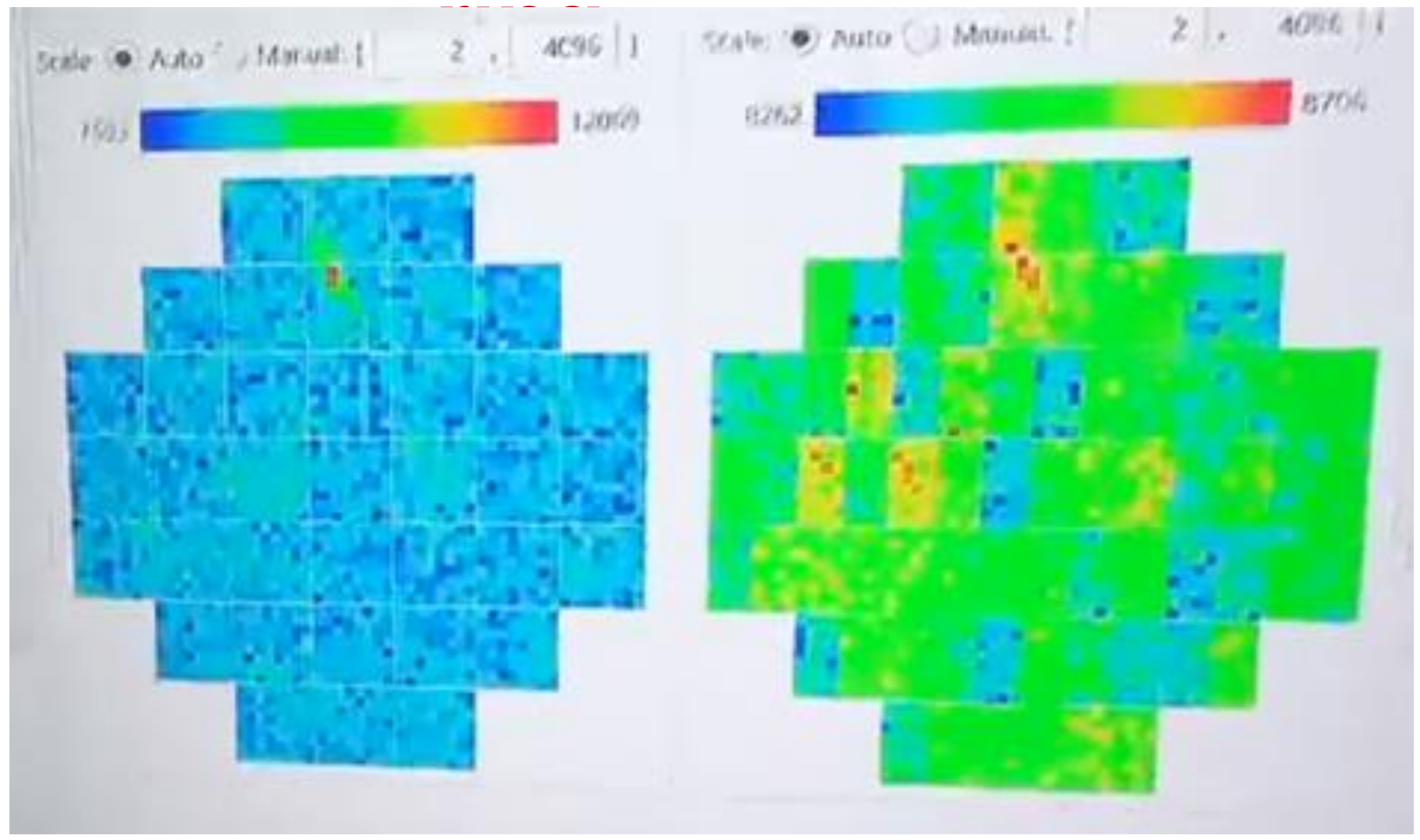
Sep 2nd, 2024



First muon

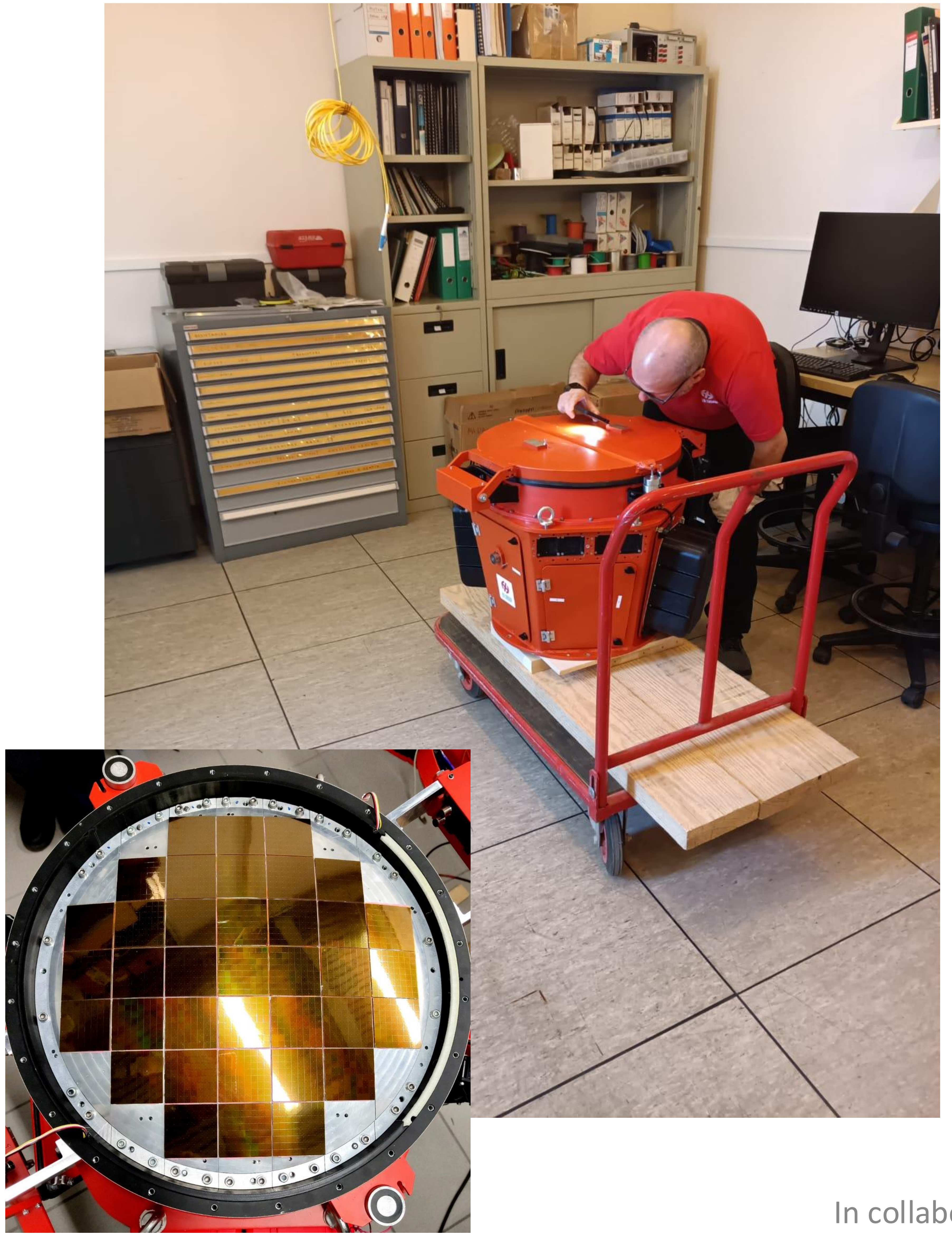


Some stars clearly visible in the variance monitor, both in the High and Low Gain channels



First cosmic-ray event

The ASTRI Camera



- SiPM: 7×7 mm^2 , 50% PDE, bias voltage down to 30V Hamamtsu
- CITIROC ASIC by Weeroc/INAF - Peak detection technique → store the signal proportional to the charge injected in the pixel and time of arrival
- Variance technique → signal proportional to photon flux → NSB measurements & camera astrometric calibration
- Data produced by a telescope 50 GByte/hour → all data transfer to offsite data centre in 15 min
- → No need for onsite pre-processing, data storage and array stereo trigger → simplified onsite ICT and operational software

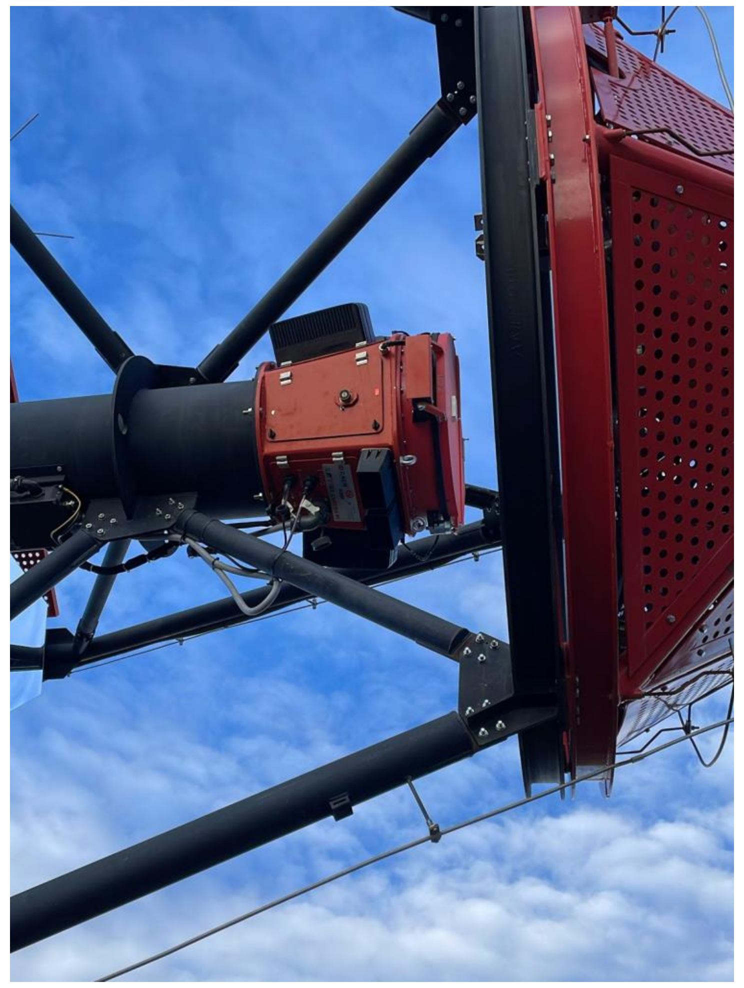
In collaboration with CAEN spa + EIE GROUP srl + Nuclear Instruments srl

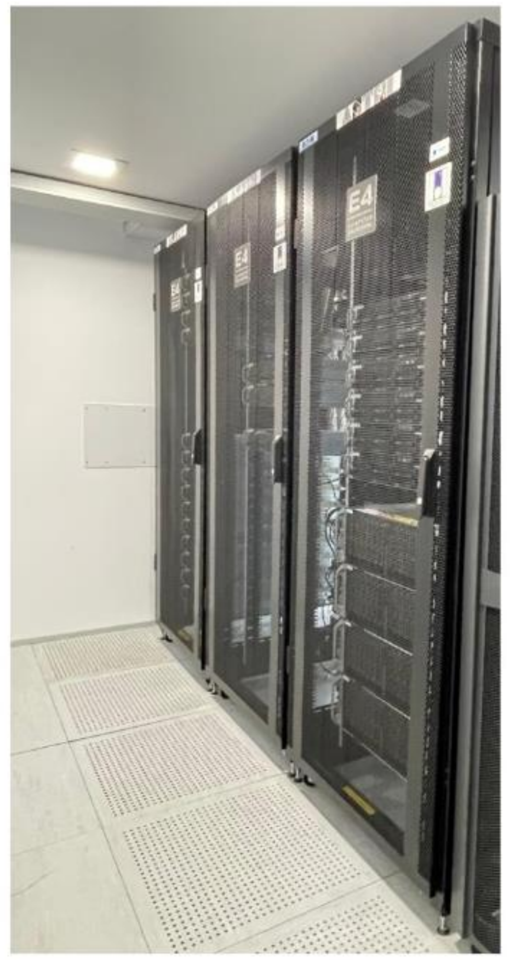
The other 8 telescope structures are under completion

ASTRI Mini-Array

CREDITS: Dal Ben spa and EIE GROUP srl

ASTRI Mini-Array: Status





Two telescopes (ASTRI-1 and 3) at the site

ASTRI-1 complete with Camera

Onsite ICT at the site

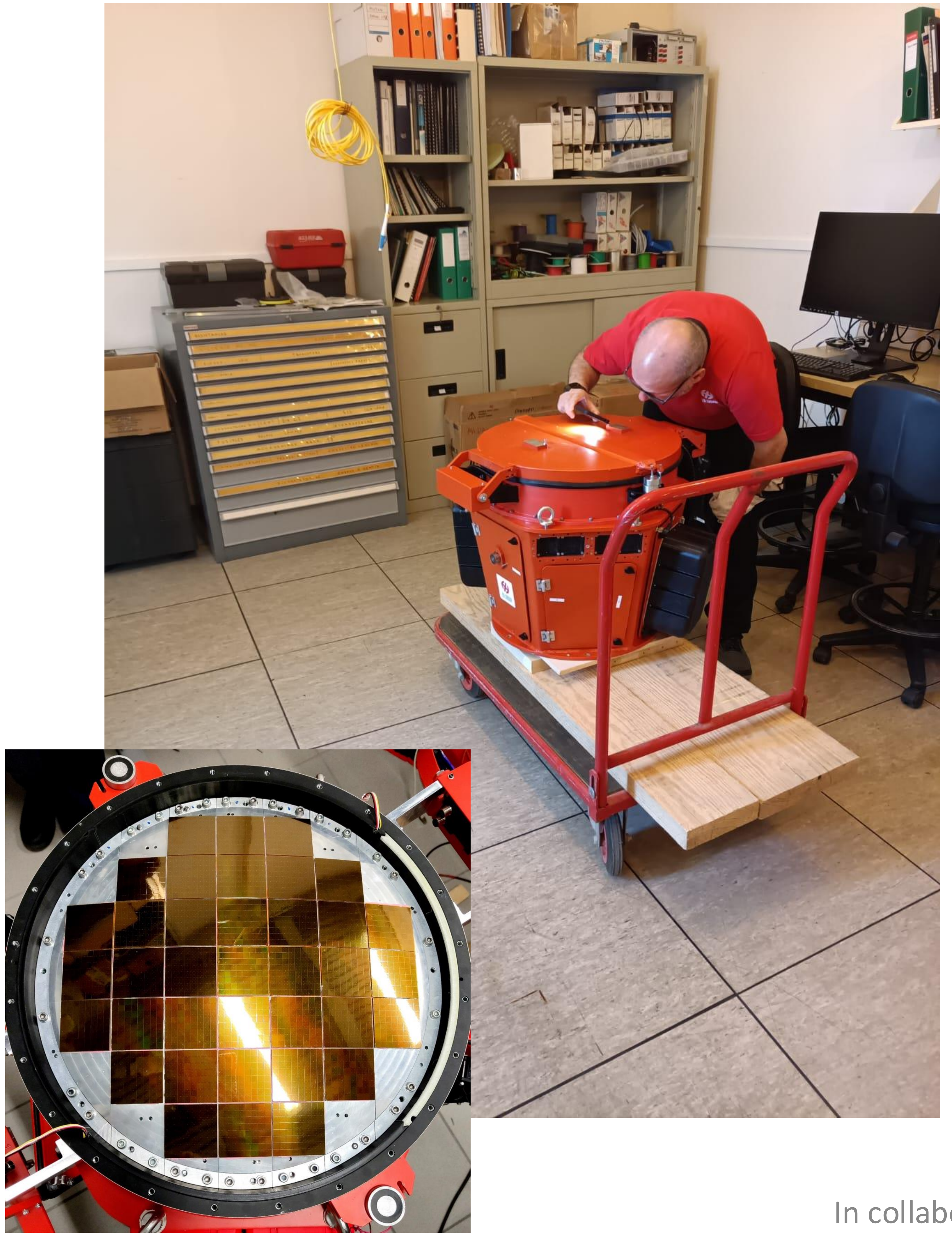
Three cameras in production

Further telescopes shipped or to be shipped soon

The other 8 telescope structures are under completion

CREDITS: Dal Ben spa and EIE GROUP srl

The ASTRI Camera



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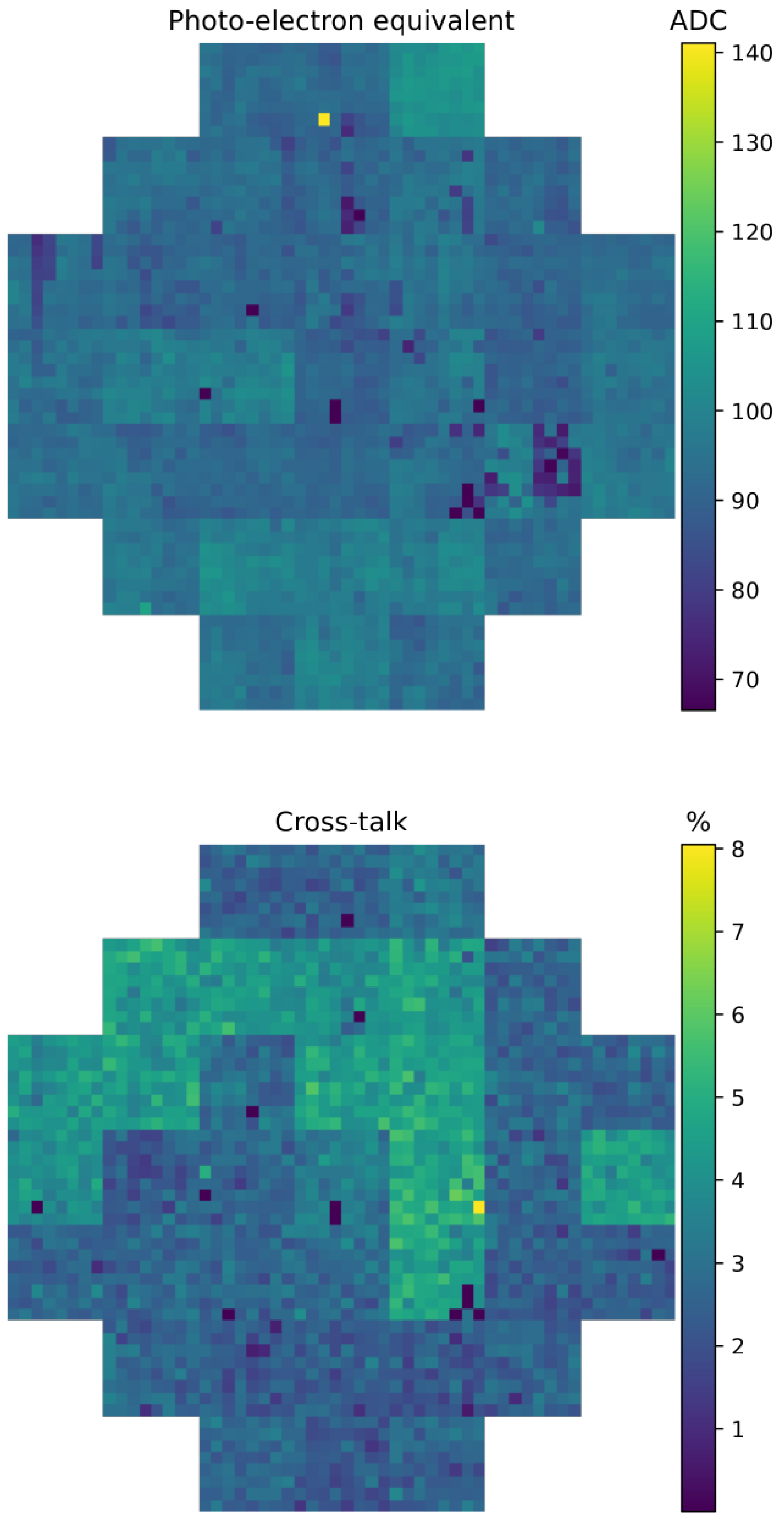
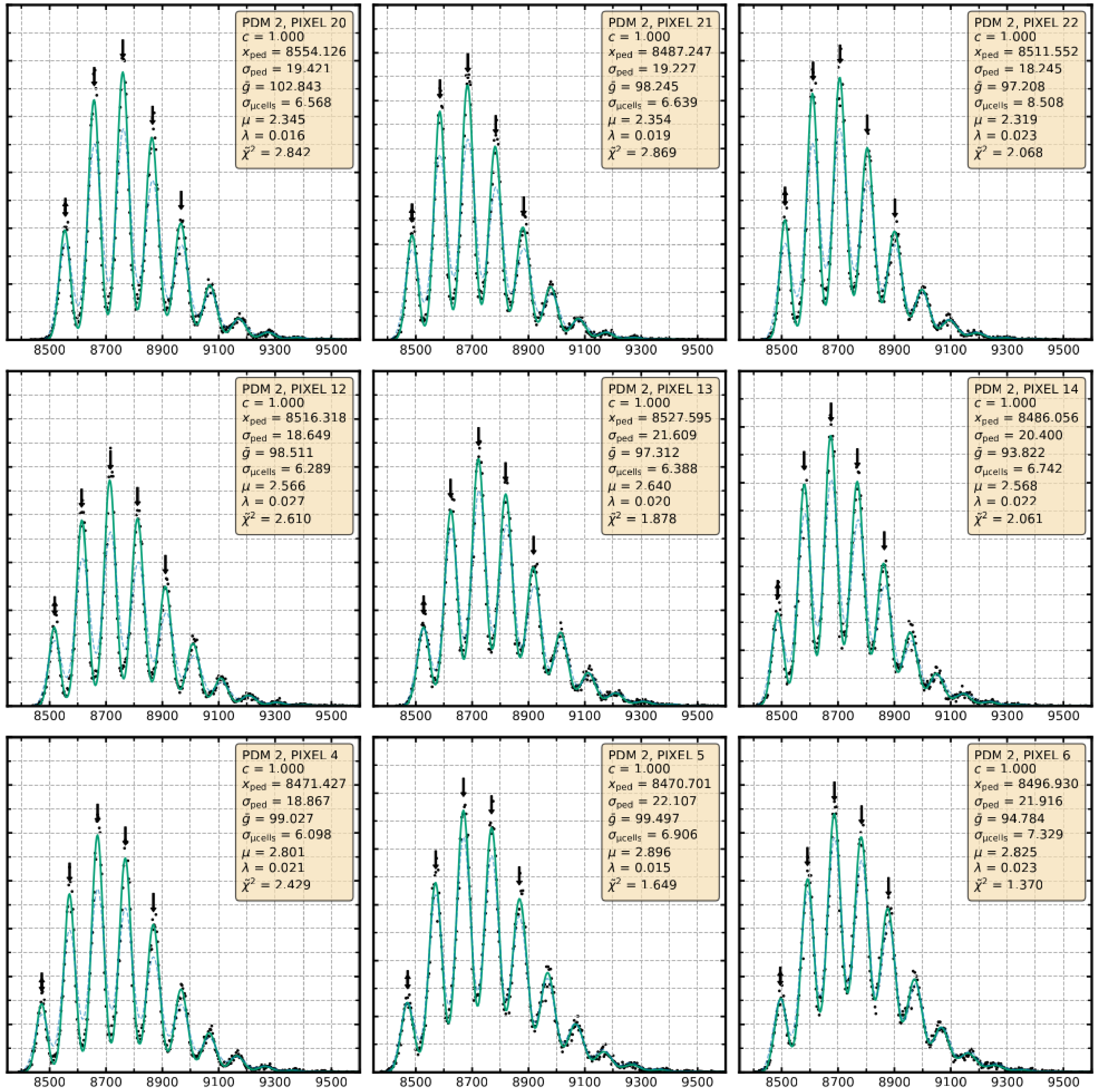
In collaboration with CAEN spa + EIE GROUP srl + Nuclear Instruments srl

- Based on a Gaussian smeared generalized Poisson distribution model

- Provides the calibration coefficients needed for the Cherenkov image analysis
- (e.g.: cross-talk and equivalent photo-electron)



ect



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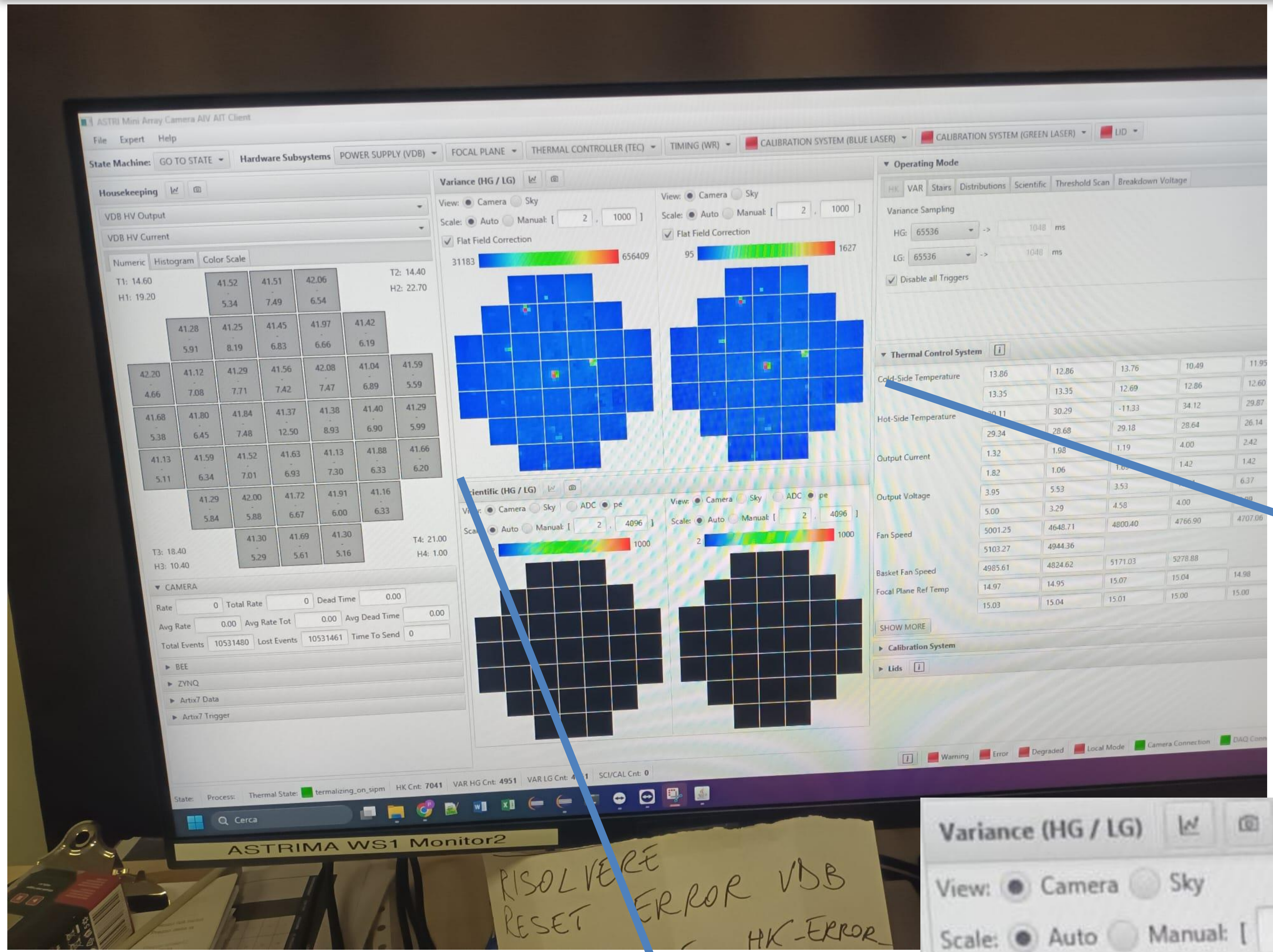
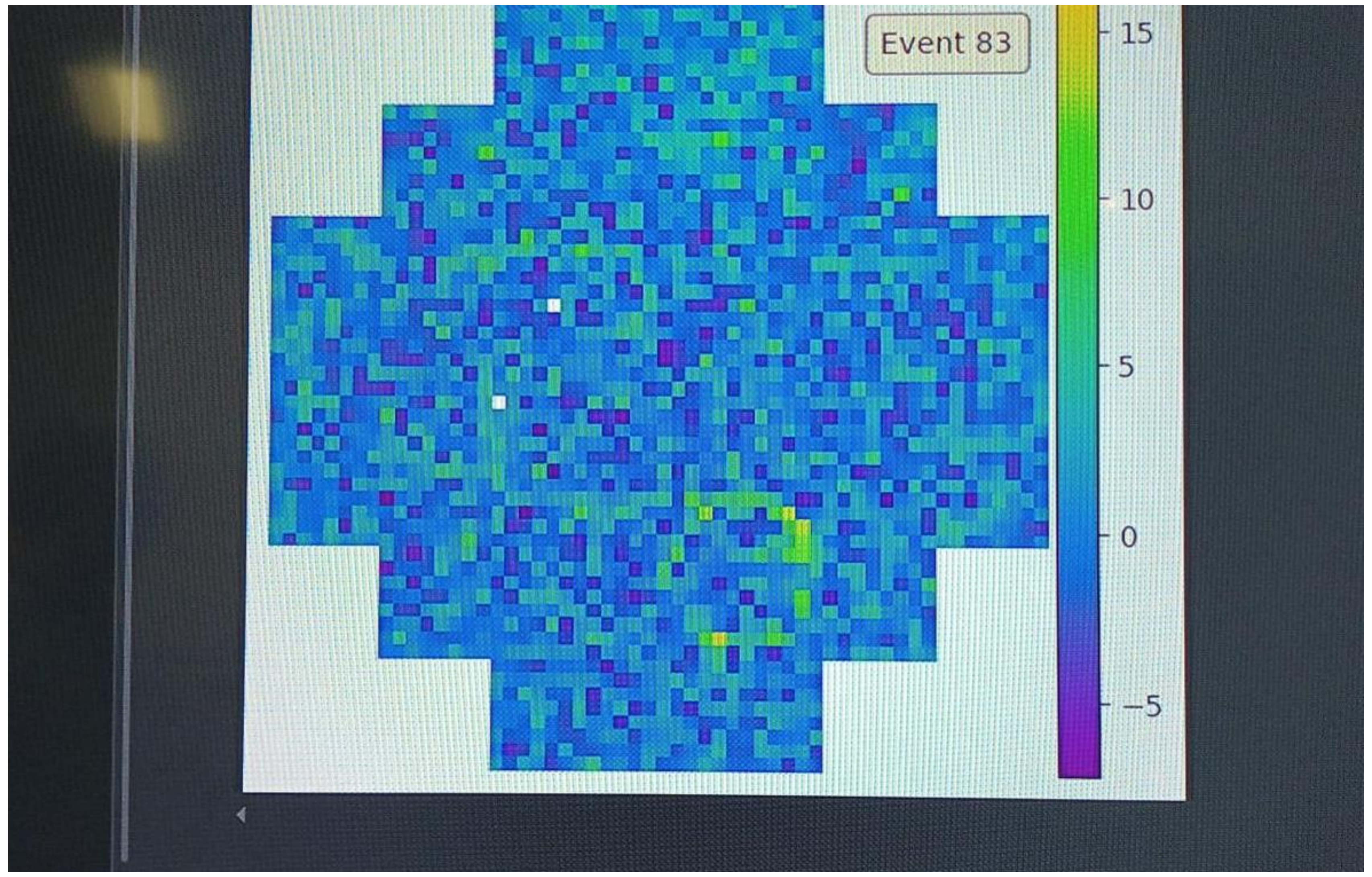
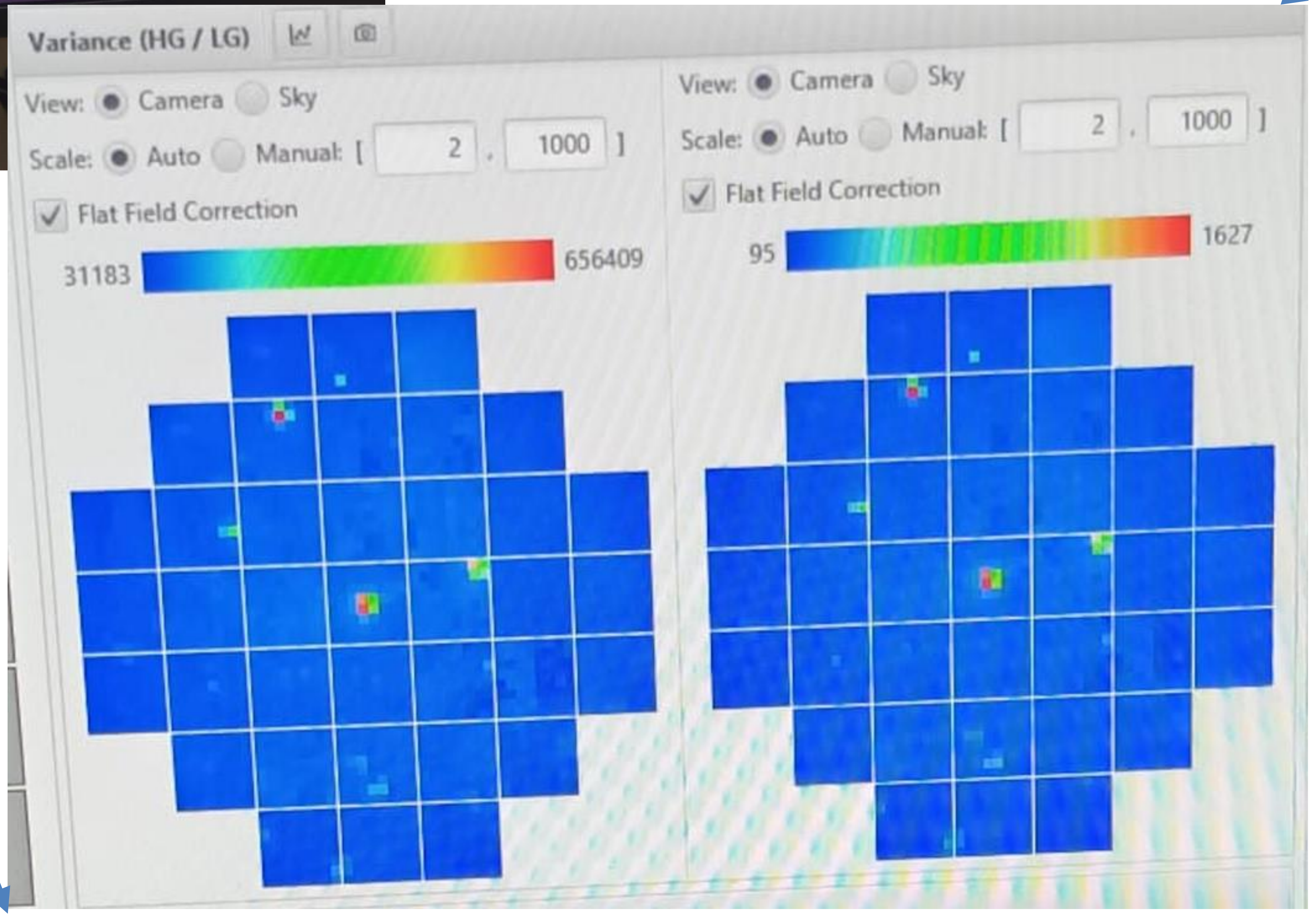


ASTRI-1 first light !

Sep 2^{nd}, 2024



First muon



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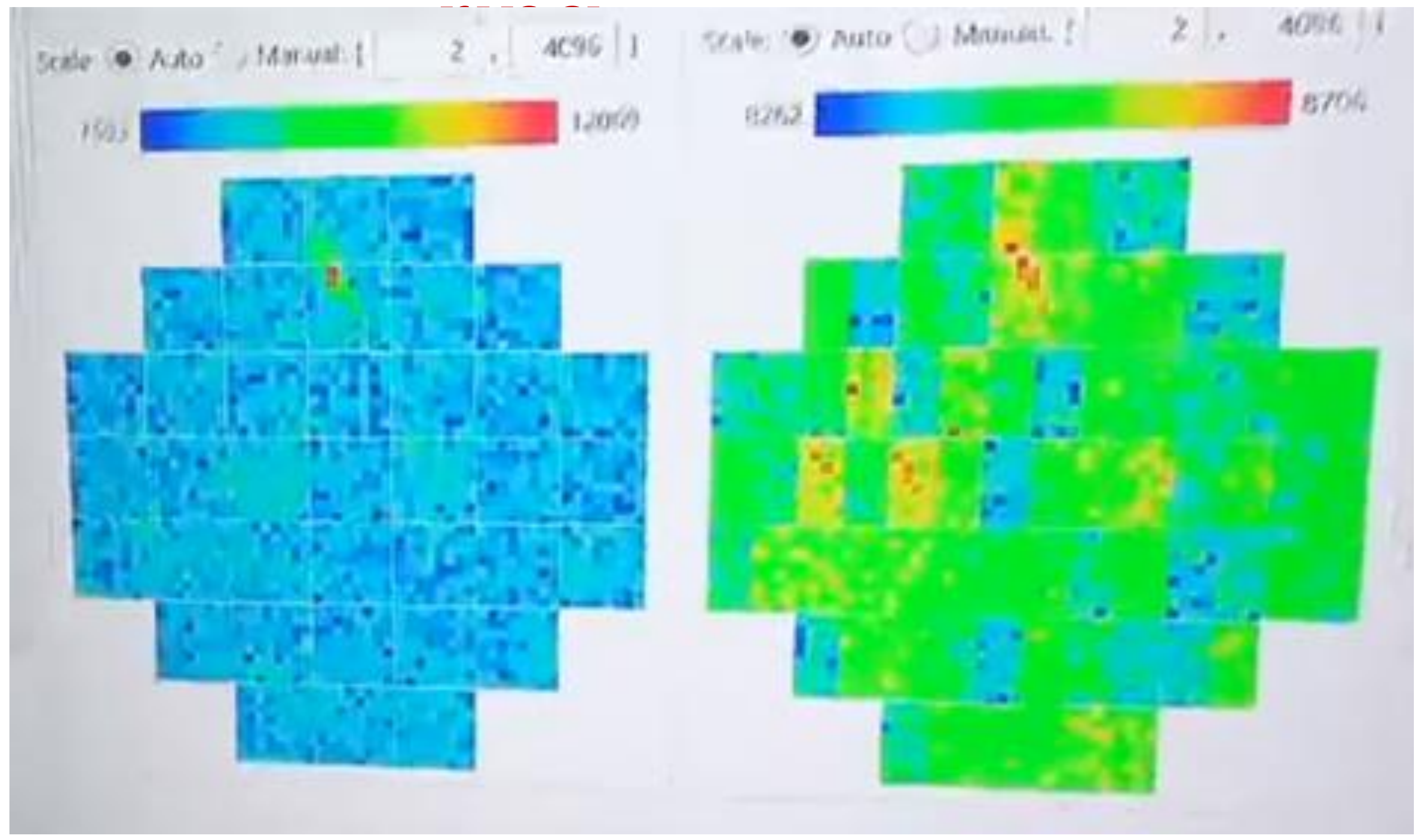

First cosmic-ray event

C.Bigongiari, ɣ-2024, Sep 6^{th} 2024

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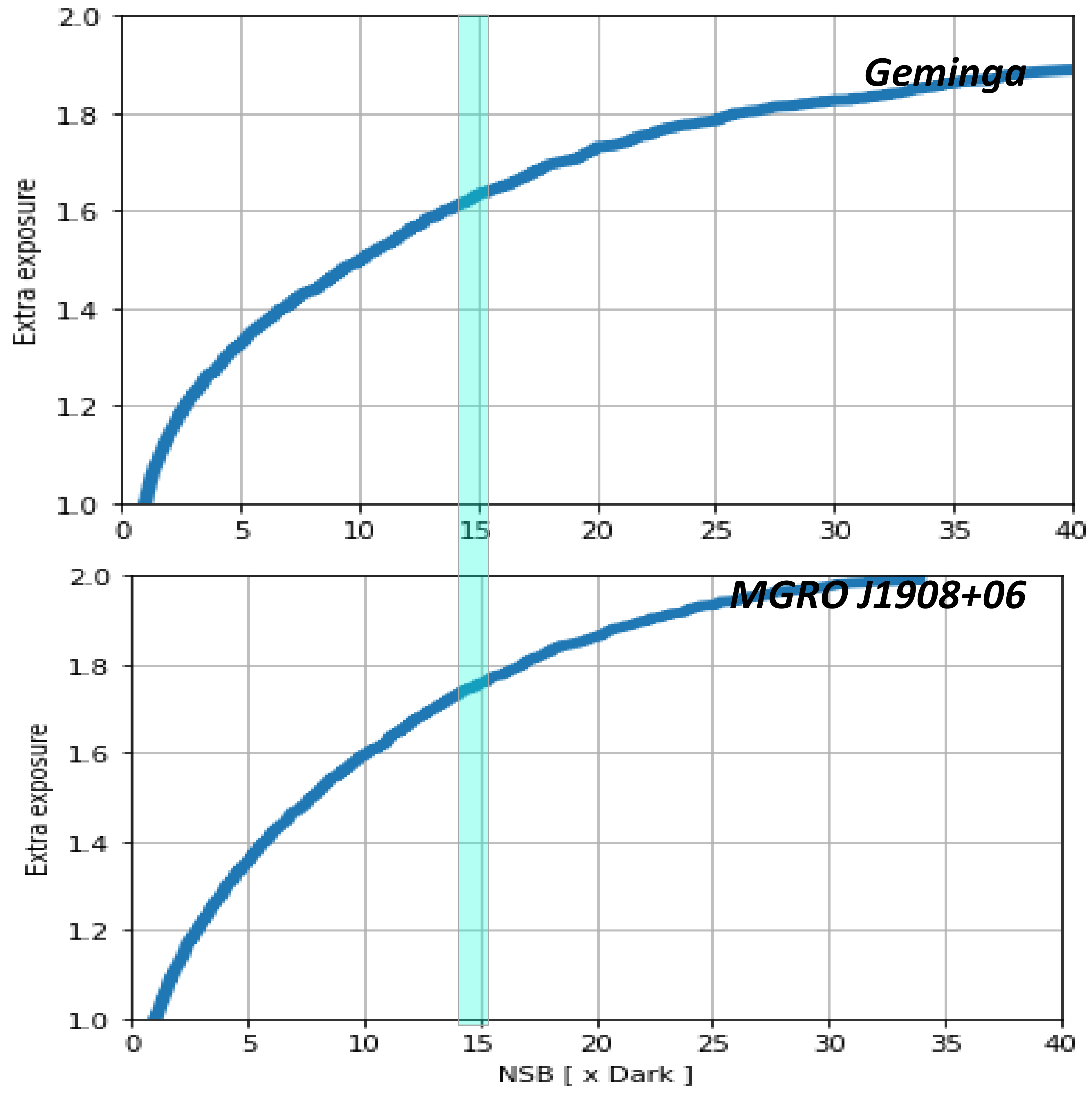


ASTRI-1: November-March Crab Campaign II

350 hrs of Data

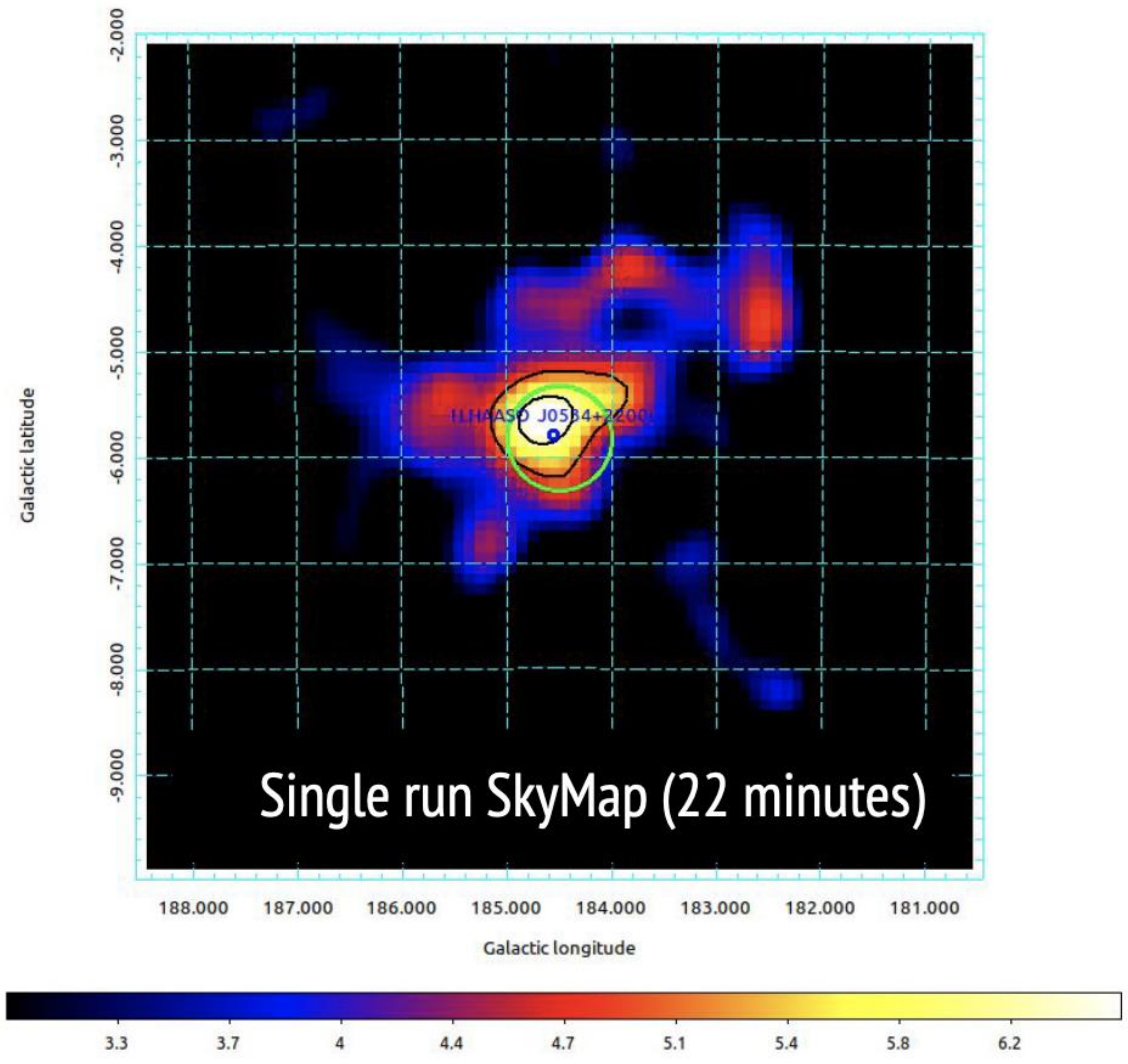
220 hrs ➔ Crab Data
- Wobble angles = 0.5, 1.5, 2.5, 3.5, 4.5
- ZA = 5 - 60
- Dark Sky and Moonlight (phase = 0 - 0.6)

130 hrs ➔ OFF pointings data
- ZA = 1
- ZA = 20 AZ = 0, 180 degrees
- ZA = 40 AZ = 0, 90, 180, 270 degrees
- ZA = 60 AZ = 0, 90, 180, 270 Degrees

Variance and Sky Quality Monitor

Calibration data

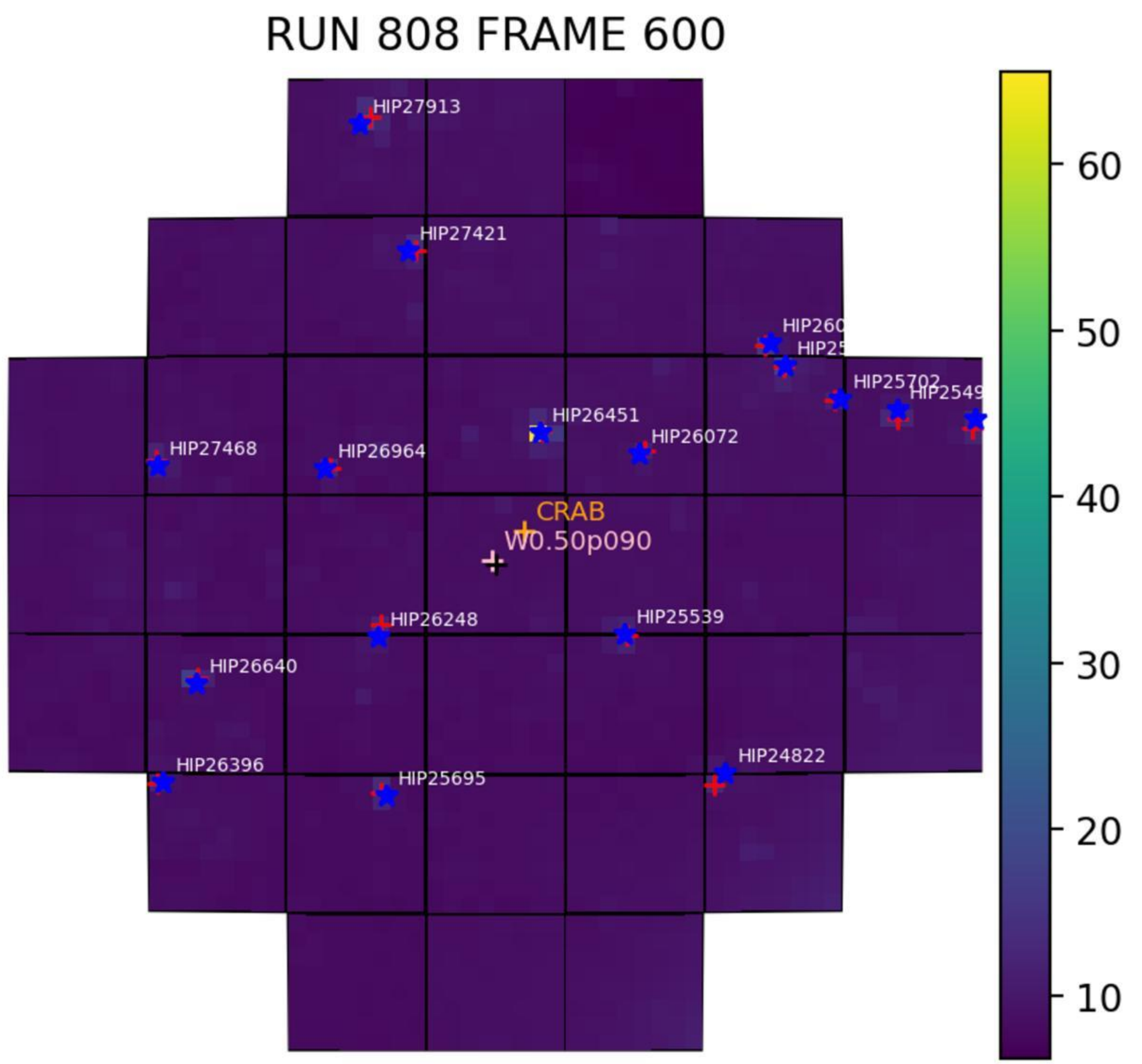
- single run SkyMap (22 minutes



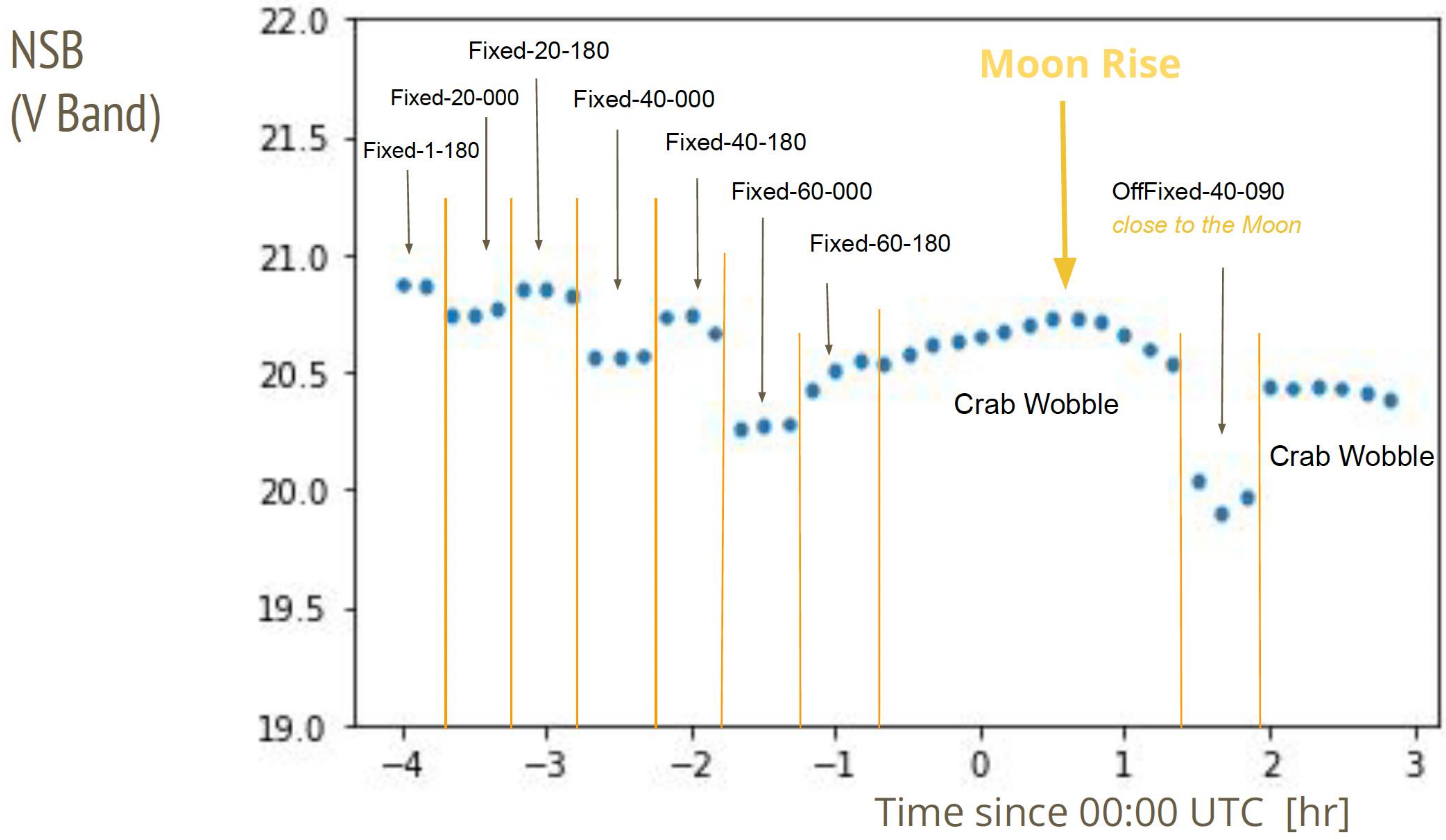
Direct monitoring of the sky

Thanks to the variance channel, the sky is simultaneously monitored using the **variance channel**.

Magnitude Limit : ~ 8
with integration of 1 second



Direct measurement of the night-sky background



Crab Events (very rough analysis)

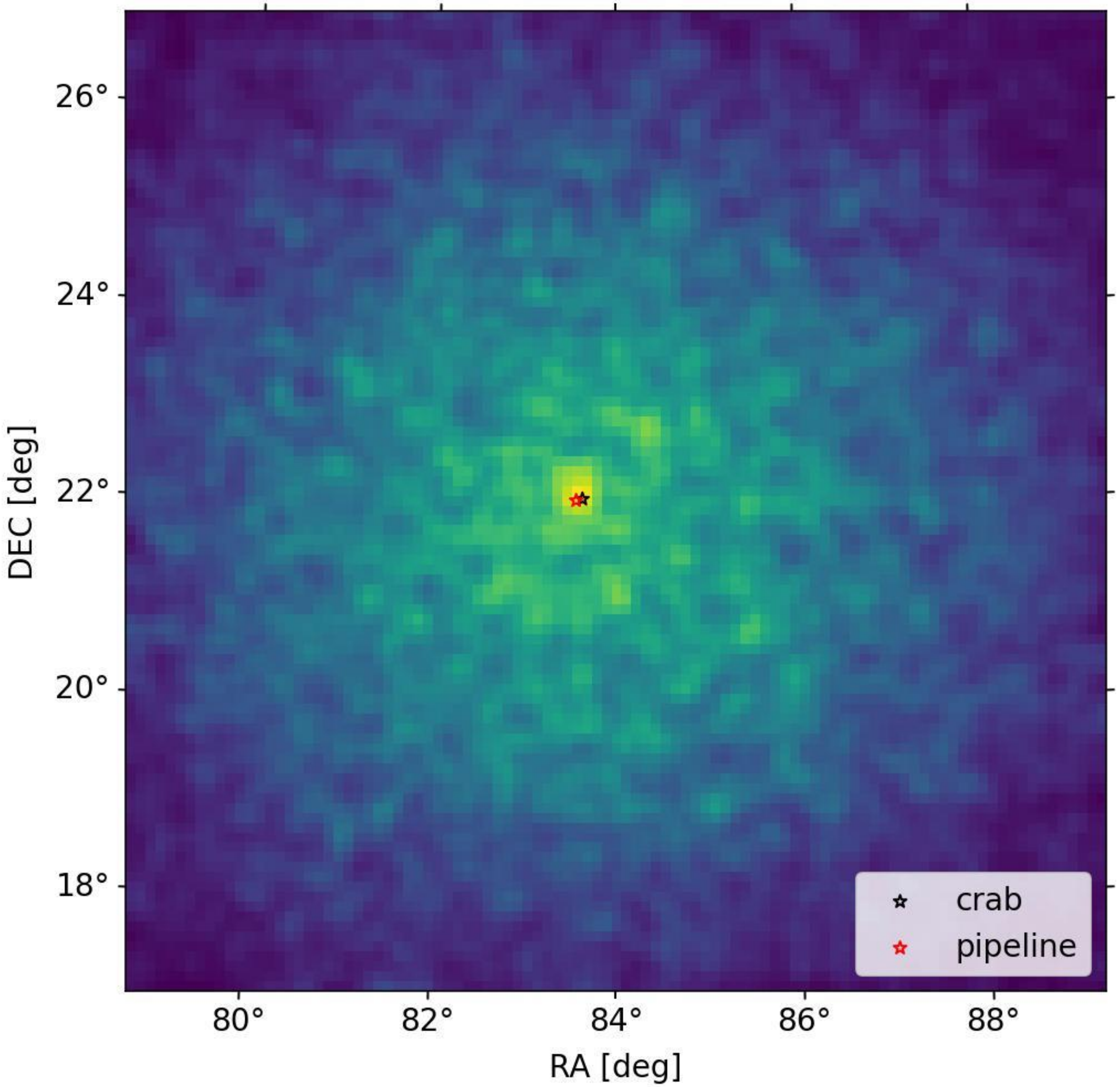
Exposure 77 hr

Excesses 1124.8

Rate 14.543 hr-1

Rate tot ~21 hr-1
Li&Ma 19.647 sigma

(gammaness >0.85)

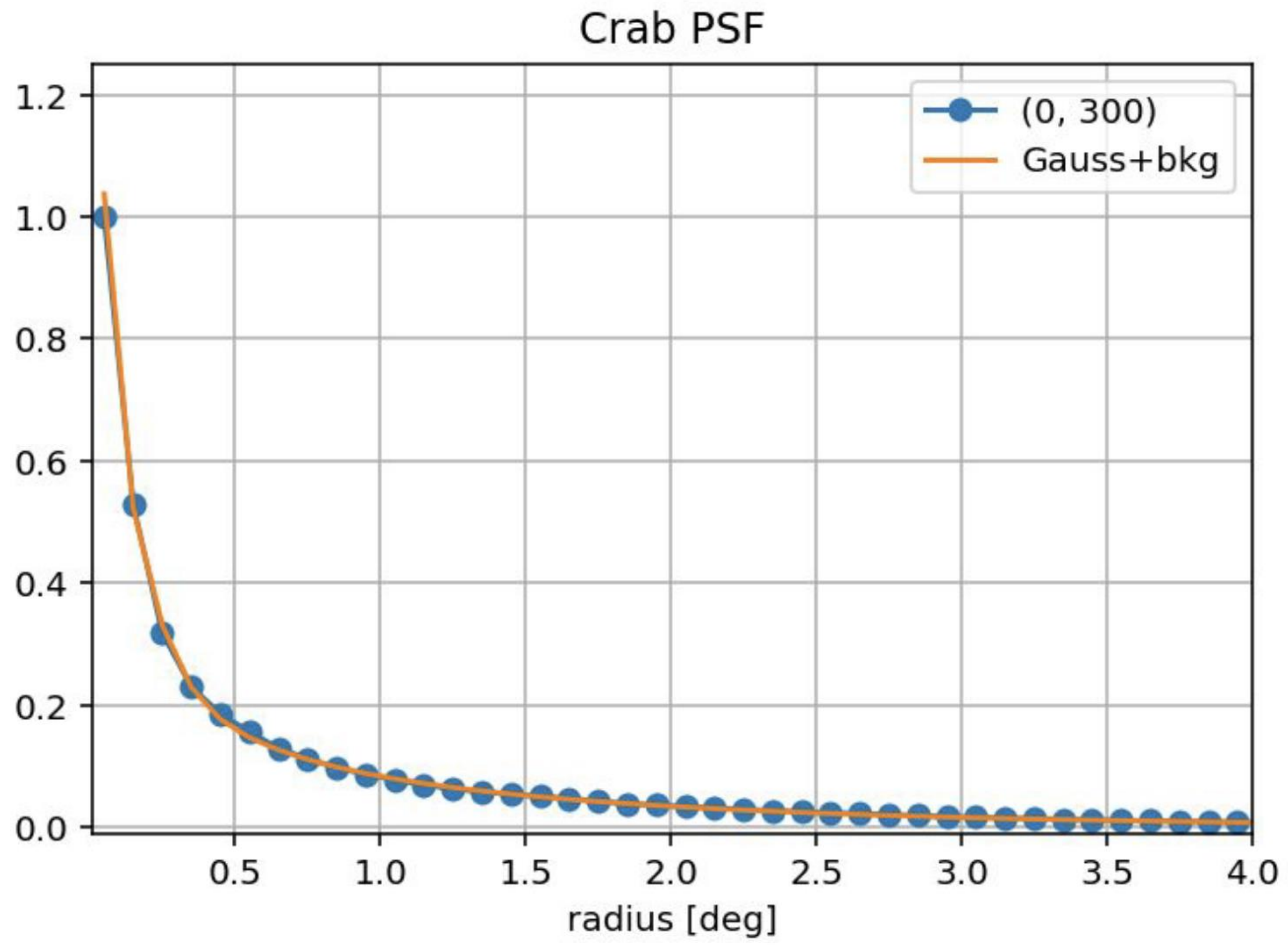


ASTRI-1 Gamma-ray PSF

Gaussian + Background

sigma = 0.16 deg

68% Cont. Radius = 0.24 deg



ASTRI Mini-Array: Timeline

- Site infrastructure completed
- First telescope ASTRI-1 accepted October 2023
- First camera on ASTRI-1 delivered at end of July 2024
- Data taking for commissioning of ASTRI-1 completed in February 2025
- On site ICT delivered in October 2024
- Second telescope (ASTRI-3) integrated in January 2025 ➔ ASTRI-3 acceptance tests ongoing

- Three telescopes (ASTRI-2, 4 and 6) will be integrated at site from beginning of May ‘25 (already shipped to Tnerife)
- ASTRI-5 and ASTRI-7 will follow in June ‘25
- Second Cherenkov camera ready to be shipped end of May ‘25
- Two more cameras by fall of 2025
- Scientific operations will start with a partial array in 2025 (4 telescopes by the end of the year)
- Mini-Array completed in 2026

Eager to collaborate with existing and future gamma-ray facilities! (MAGIC, HESS, VERITAS, HAWC, **LHAAZO/LACT**, CTAO, SWGO…)

ASTRI Summer plans