





The ASTRI Mini Array of Cherenkov telescopes

Patrizia Caraveo & ASTRI coll.













Why ASTRI?



ASTRI - Astrofisica con Specchi a Tecnologia Replicante Italiana

Astrophysics with Mirrors via Italian Replication Technology (No mirrors, no party!)



Name given by Nanni Bignami:

www.iasf-milano.inaf.it/nanniday/

23-09-2022



PROGRAM

NANNIs-day-final Download

MEETING RECORDING

ASTRI HORN



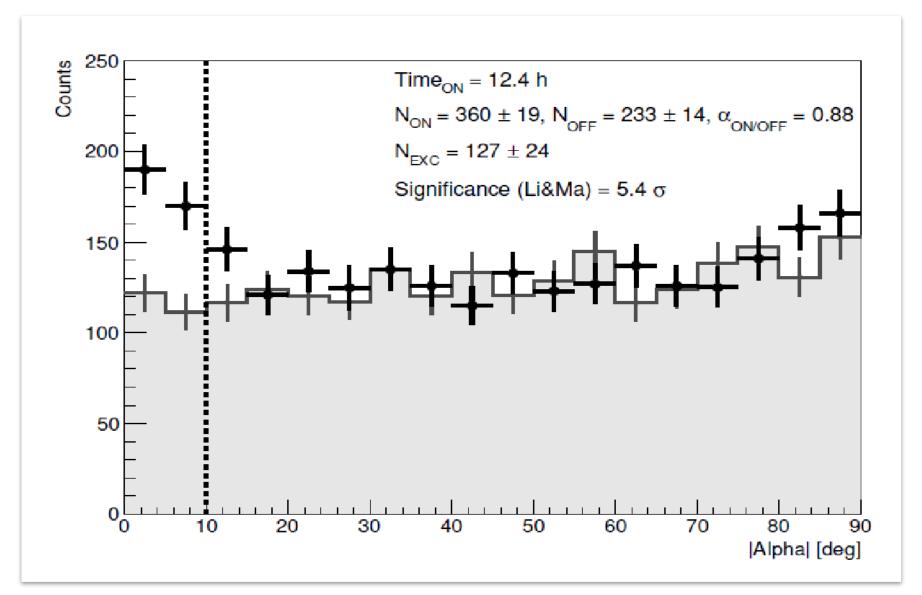
ASTRI

was born as "Progetto Bandiera" funded by MIUR with the initial aim to design and realize an innovative end-to-end prototype of the 4 meters class telescopes in the framework of the CTA observatory



ASTRI-Horn.

ASTRI
prototype at
OACT in Serra
La Nave, Etna
Volcano



First detection of a gamma-ray source (Crab Nebula) above 50 with a dualmirror, Schwarzschild-Couder Chrenkov telescope (Lombardi et al., 2020)

The ASTRI Mini-Array Project



The ASTRI Mini-Array is a project whose purpose is to construct, deploy and operate an array of 9 Cherenkov telescopes of the 4 meters class at the Observatorio del Teide in Tenerife (Spain) in collaboration with IAC.

More than 150 researchers belonging to

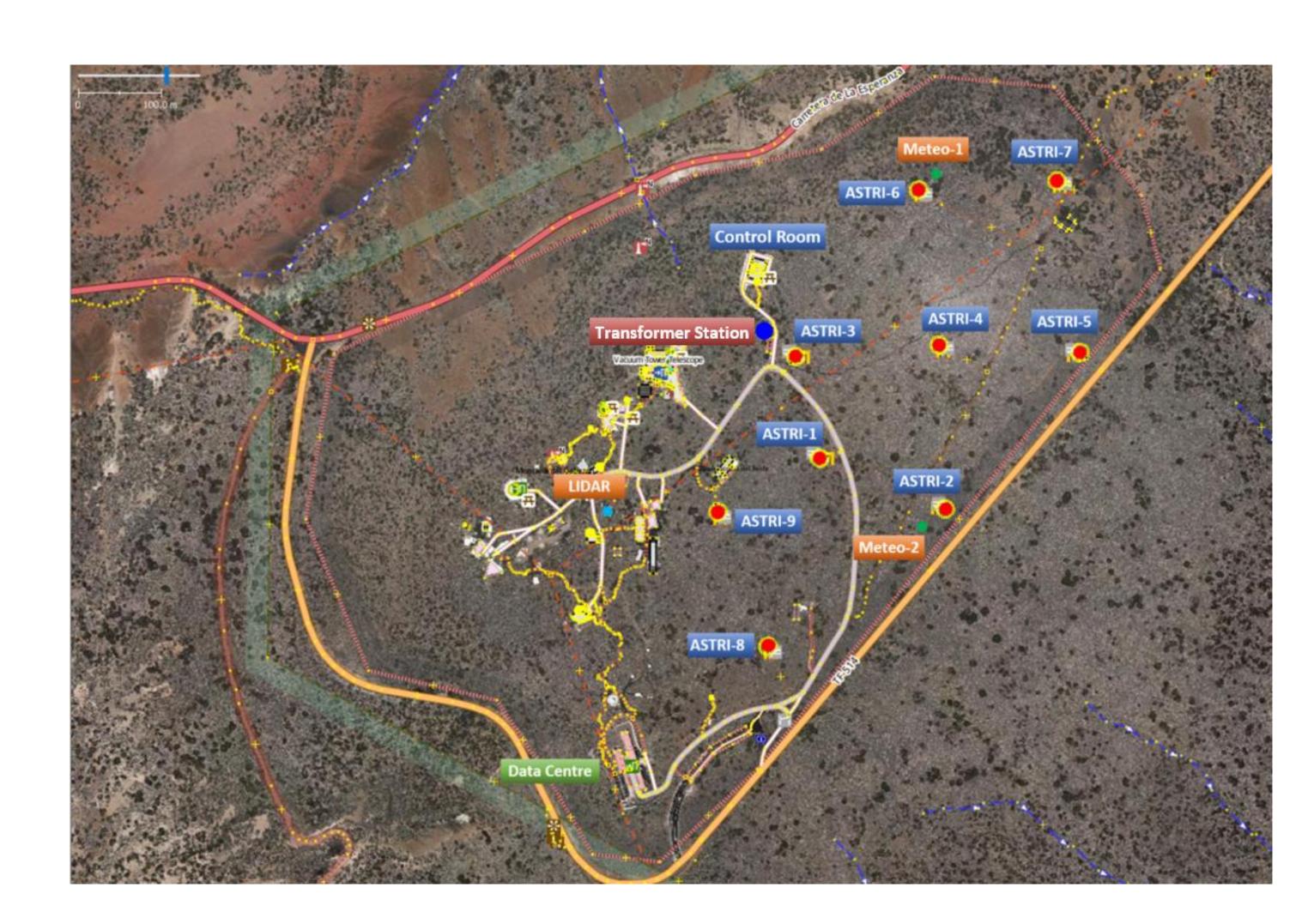
- INAF institutes (IASF-MI, IASF-PA, OAS, OACT, OAB, OAPD, OAR)
- Italian Universities (Uni-PG, Uni-PD, Uni-CT, Uni-GE, PoliMi) & INFN
- Fundacion Galileo Galilei
- International institutions (IAC Spain, University of Sao Paulo Brazil, North-West University - South Africa, Université / Observatoire de Geneve CH).

Italian and foreign industrial companies are and will be involved in the ASTRI Mini-Array project with important industrial return.

ASTRI Mini-Array @ Teide Observatory



- Under construction at the Observatorio del Teide (Tenerife), in collaboration with IAC
- Being developed in all its aspects, from design/implementation of all HW/SW components to dissemination of final scientific products
- Unprecedented performance and wide FoV for observations at TeV/multi-TeV energy scale
- Core Science Program in the first 3 years
- Important synergies with other Northern ground-based gamma-ray facilities (LHAASO, HAWC, MAGIC, VERITAS, CTAO-N)



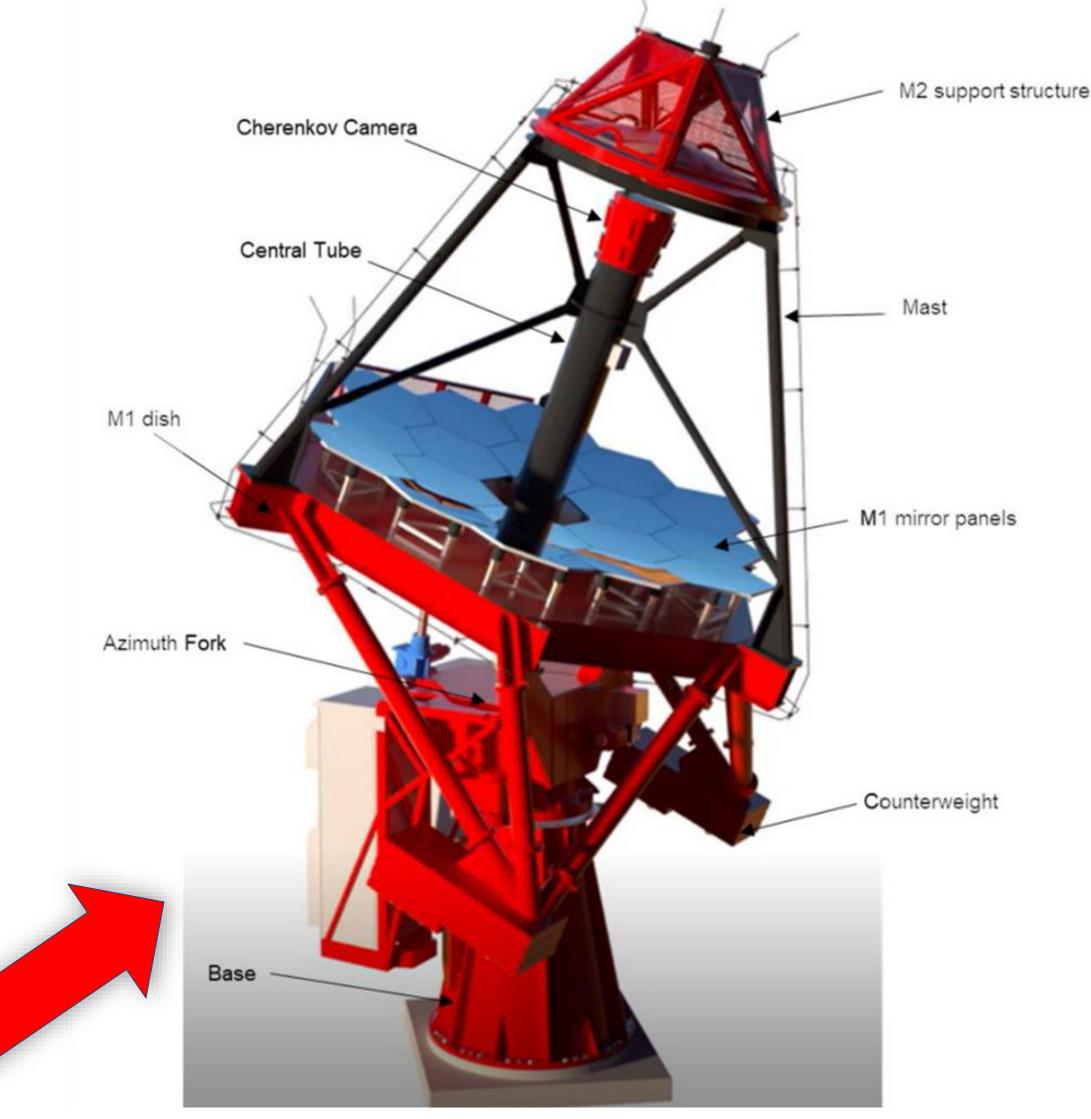
Telescope



 The current design of the ASTRI electromechanical structure is an evolution of the ASTRI-Horn prototype telescope.

• Electro-mechanical structure has been optimized in terms of mass, functionality and maintainability (mass has been reduced by

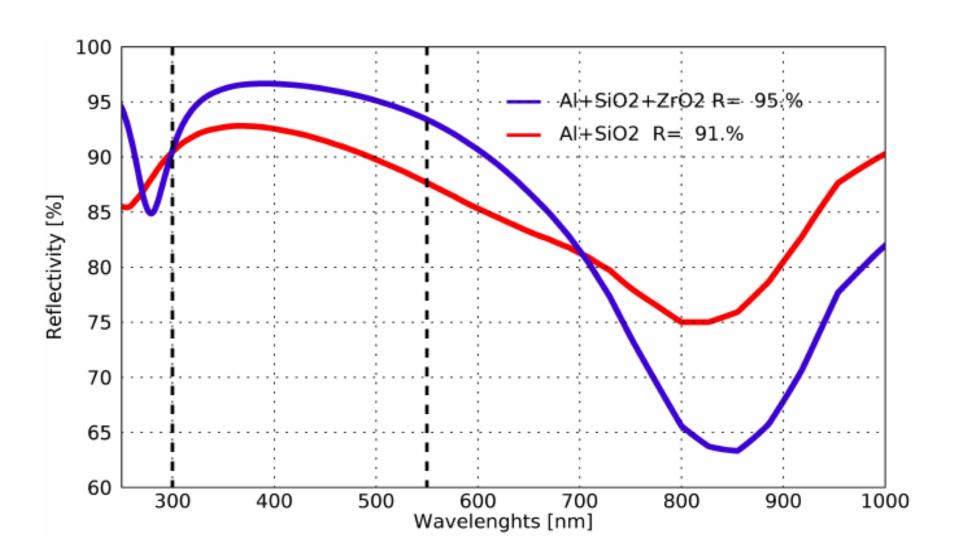
30%).

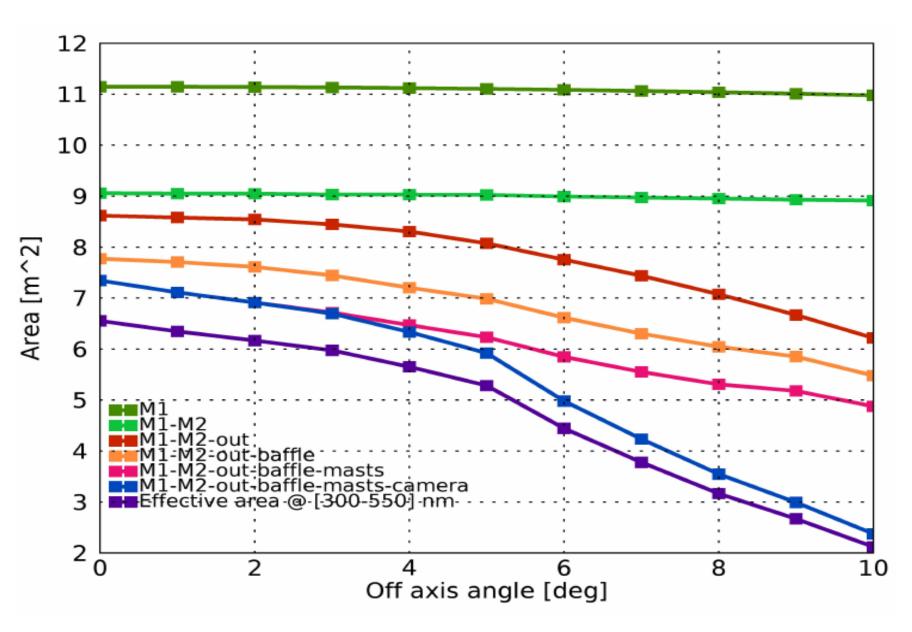


Optics



- The optical design is based on a modified (Vassiliev et al. (2007), see also Sironi (2017) Schwarzschild-Couder configuration.
- This configuration allows better correction of aberrations at large incident angles even for small focal ratios and hence facilitates the construction of compact telescopes.
- This optical system enables good angular resolution across the entire field of view and allows reducing the focal length and therefore the physical pixel and overall camera size.



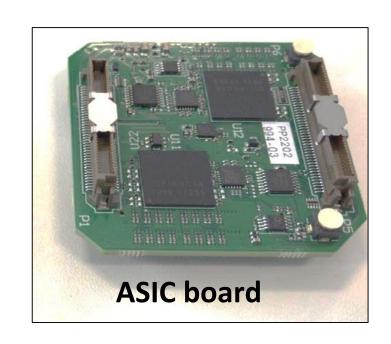


ASTRI Camera





SiPM matrices



- The SiPM produced by Hamamatsu photonics (7x7 mm²) grouped in matrices of 8x8 pixels
- 37 matrices are arranged to adapt to the curved focal plane of the telescope.
- innovative electronics for peak detection(CITIROC ASICS, WEEROC-INAF) ⇒ smalls mount of data
- Interferential filter as front window (Romeo et al. (2018) and Catalano et al. (2018)) that allows to reduce the contribution from the night sky background at wavelengths greater than 550 nm where the sensitivity of SiPM detector is still high.





The ASTRI Mini-Array locations

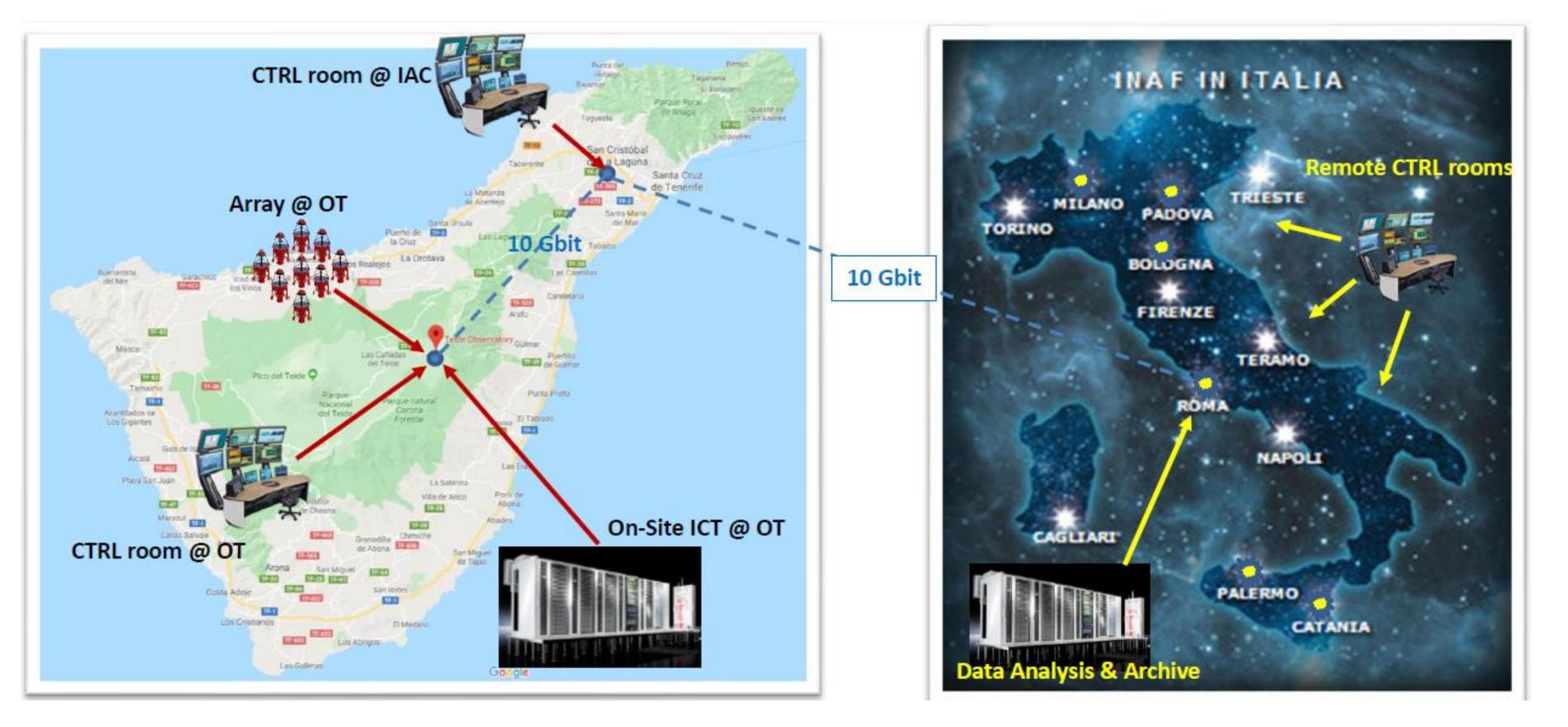


The ASTRI Mini-Array in Tenerife

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

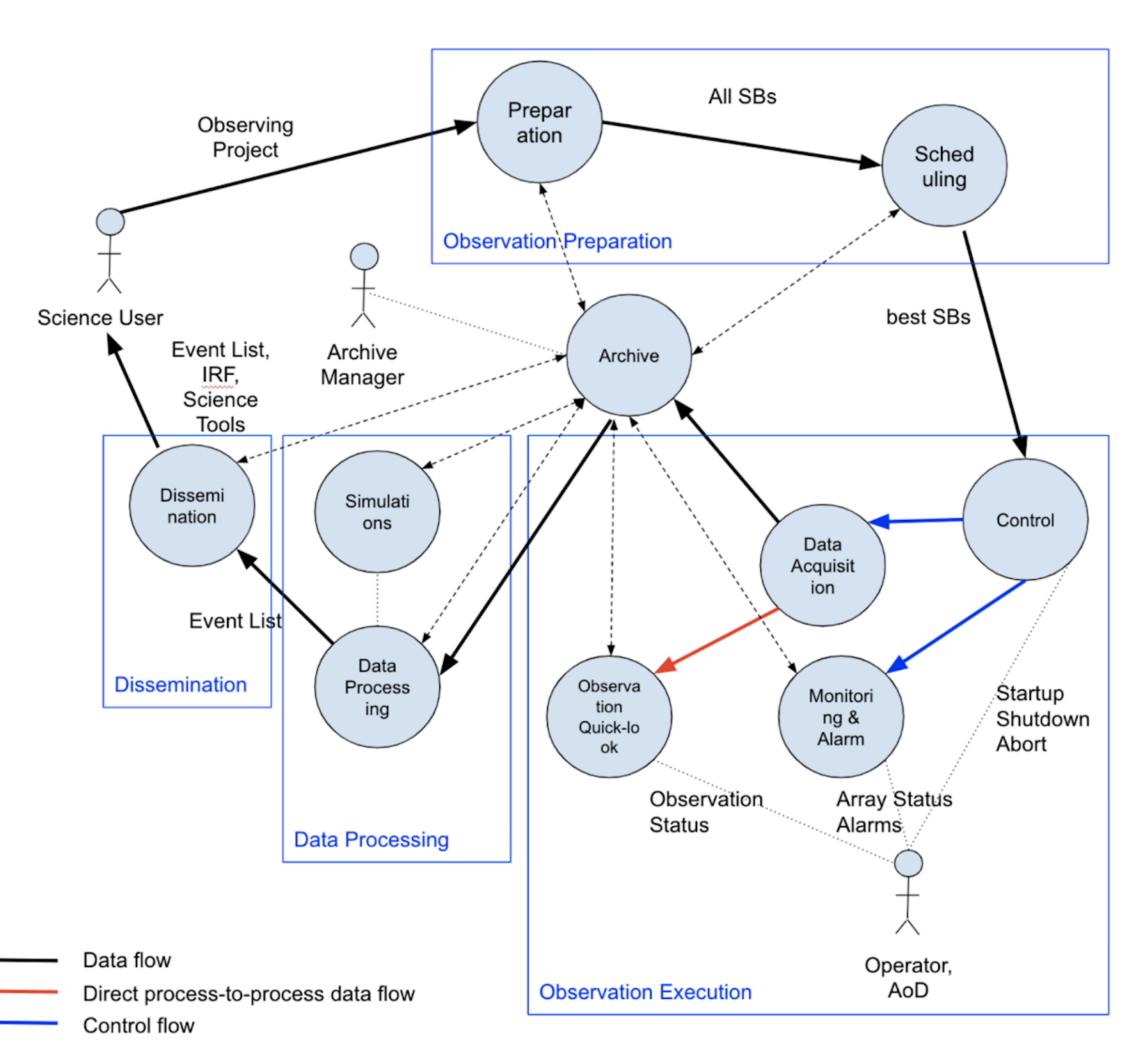
The ASTRI Mini-Array in Italy

- Data Centre in Rome
- Remote Array operation centers



Software: data & information flow





To archive

Interaction with actors

The ASTRI Mini-Array software is envisioned to handle an observing cycle, i.e. the end-to-end control and data flow system. The observing cycle can be divided into the following main phases:

- 1. Observation preparation
- 2. Observation execution
- 3. Data Processing
- 4. Dissemination

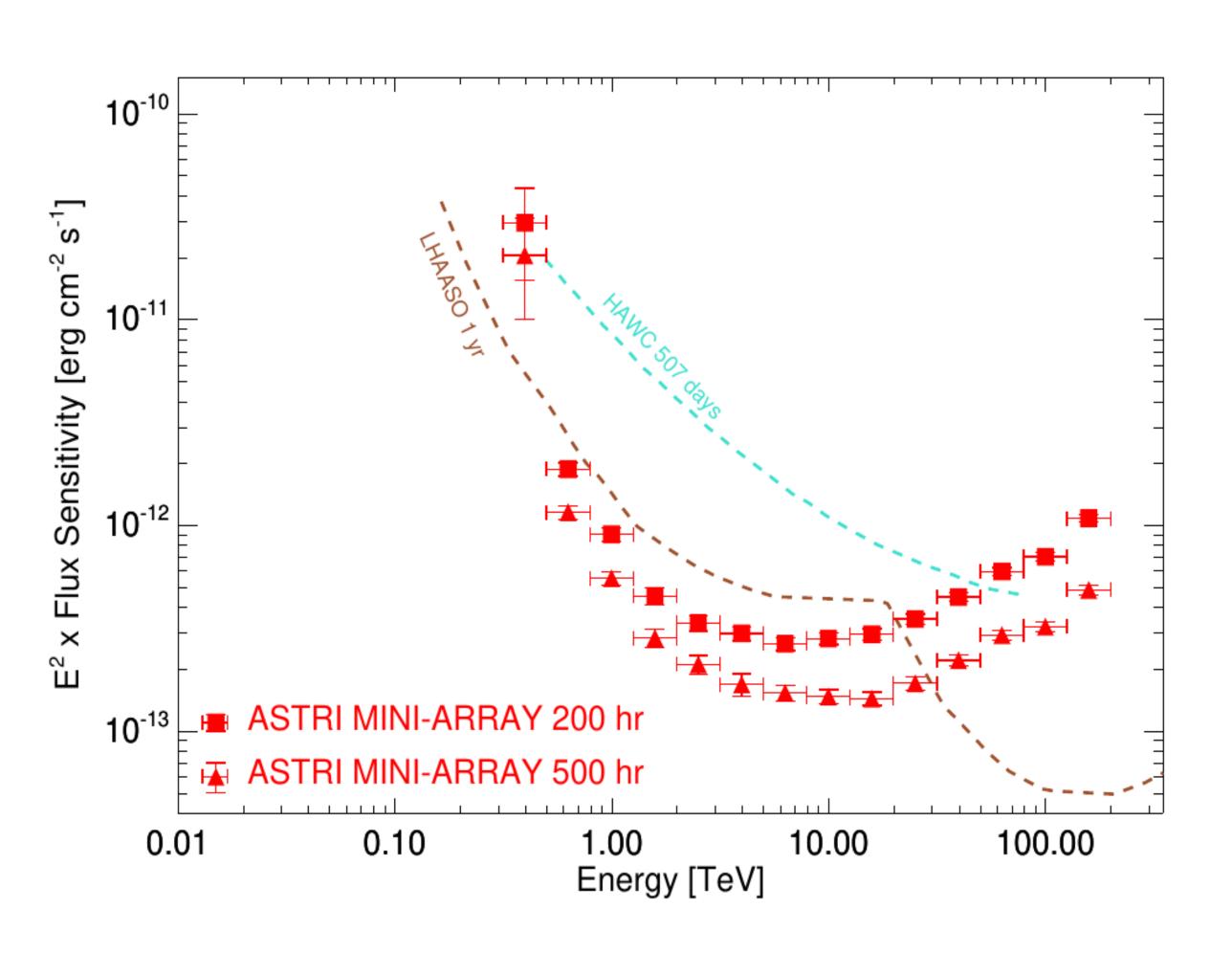
Software development mainly by INAF

Support by external companies/research institutions on specific aspects as for example:

- Central Control System by Universidad Tecnica Federico Santa Maria (SCADA)
- Operator Human Machine Interface by University of Geneve (SCADA)

ASTRI Performances





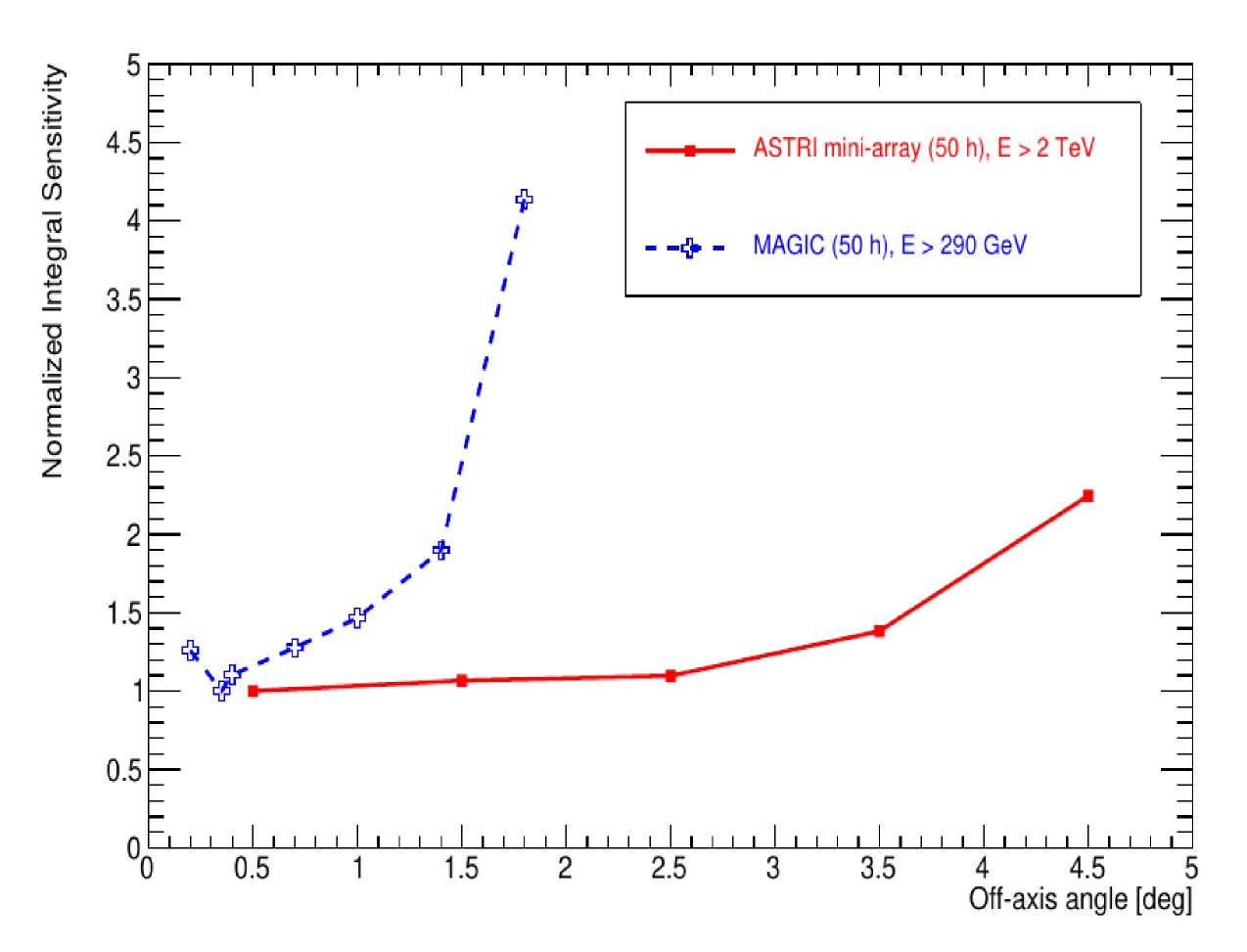
Expected performance

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

 Extend the spectra of already detected sources and/or measure cut-offs

ASTRI Performances





Expected performance

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 Extend the spectra of already detected sources and/or measure cut-offs

Energy/Angular resolution: ~ 10% / ~ 3' (E > a few TeV)

Characterize the morphology of extended sources at the highest VHE

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

- Optimal for multi-target fields, surveys, and extended sources
- Enhanced chance for serendipity discoveries

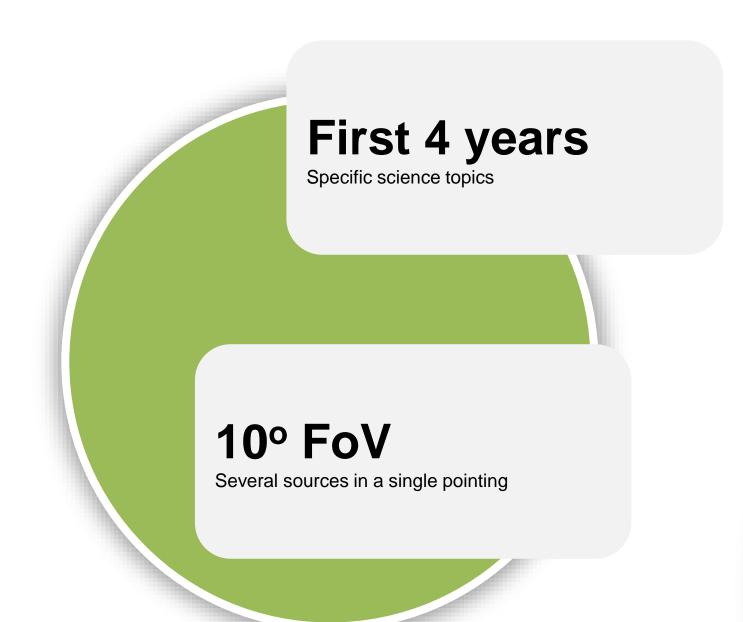
The ASTRI Mini-Array operations

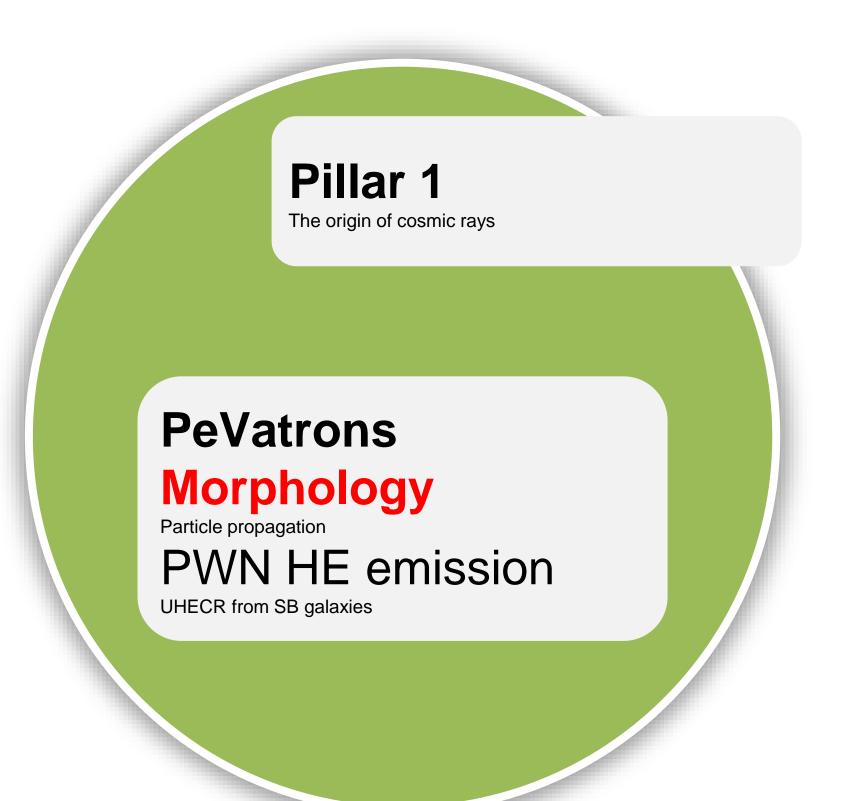


- Hosting agreement foresees 4 + 4 years of operations for the ASTRI Mini-Array starting from beginning of operations
- During the first 3 years of operations the array will be run as an experiment
- The ASTRI Science team will develop a strategy to concentrate the observational time on a limited number of programs with clearly identified objectives
- After this initial period **the project will gradually move towards an observatory model** in which a fraction of the time will be assigned to scientific proposals through a Time Allocation Committee procedure

• The Pillars' concepts



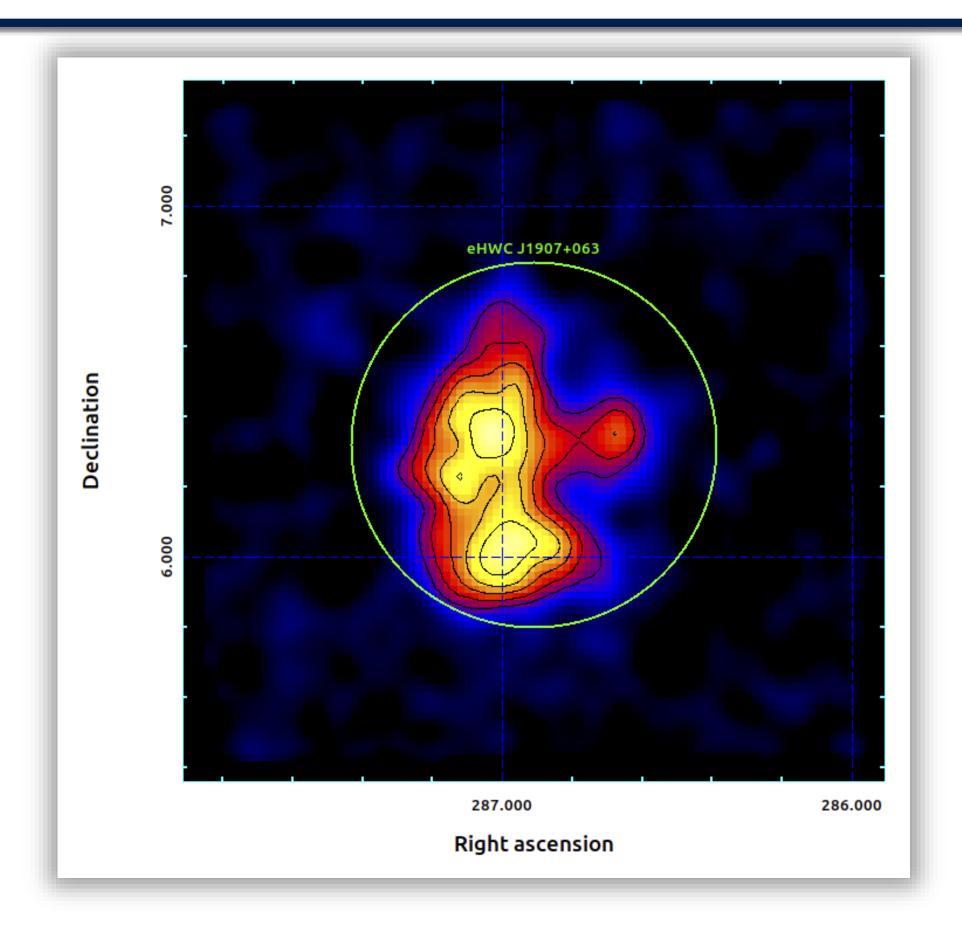


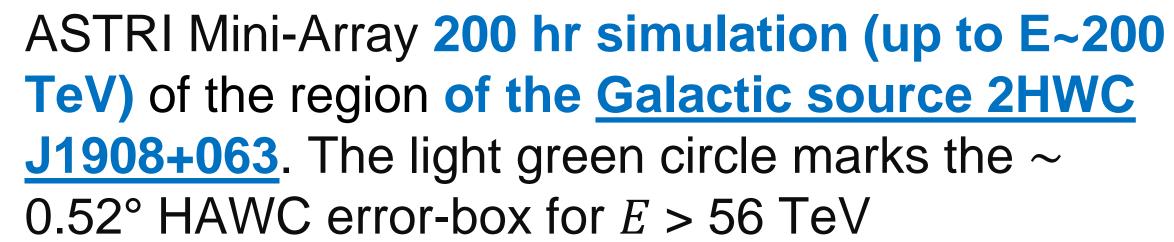


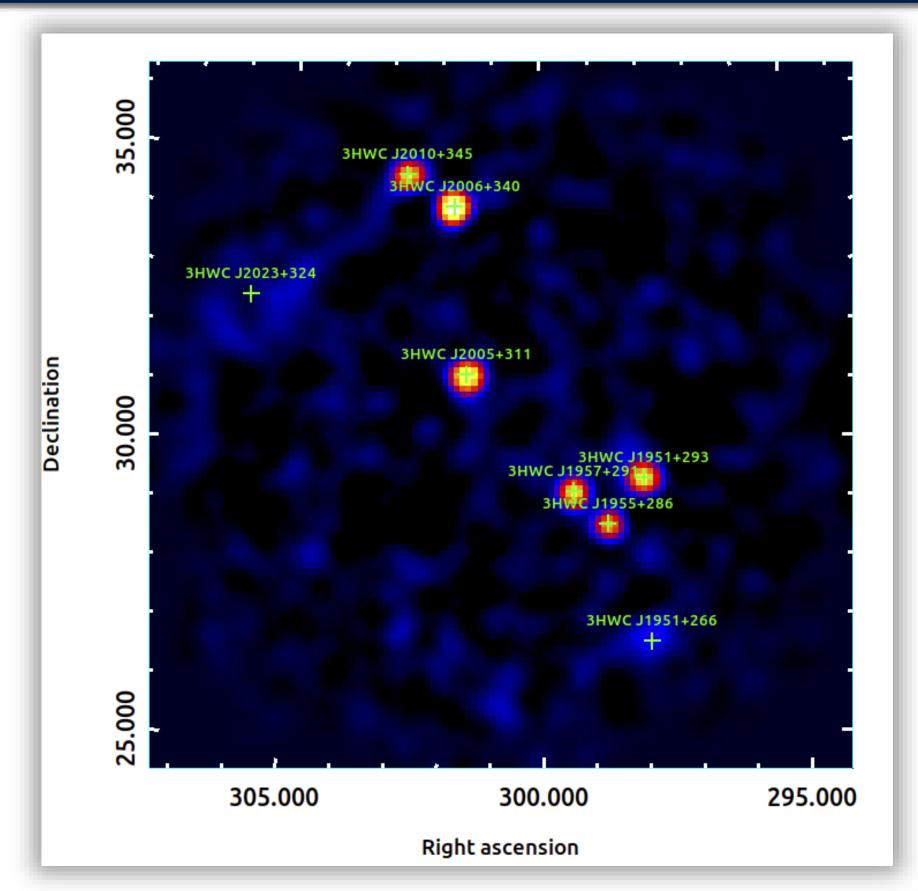


Angular resolution and large field of view









ASTRI Mini-Array 200 hr simulation of the Cygnus Region. Green crosses mark the positions of the 3HWC sources in a 10° × 10° field of view

ASTRI Science

Pillar 1: Origin of CRs	Name	Type	Req. Exposure (Hrs)
- PeVatrons - CRs Propagation - Pulsar Wind Nebulae	Tycho Snr Gal. Center VER J1907 G106.3+2.7 γ-Cygni W28 M82	SNR Diffuse SNR+PWN SNR SNR SNR SNR/MC Starburst	400 260 500 200 500 500 400
	Crab	PWN	300
	Geminga	PWN	500
Pillar 2: Cosmology and Fundamental Physics	IC 310	Radio gal	10-500
	M87	Radio gal	10-500
	Mkn 501	Blazar	5-500
	1ES 0229+200	Blazar	200-250

Observing Plan

Issue: Long exposures are required

Strategy:

Focus on few sky fields → Long exposures

3 aces up the sleeve:

- Large FoV \rightarrow Several sources in the FOV

- Large Z.A. \rightarrow Increase Aeff @ high energies

- Observations with moonlight \rightarrow ASTRI Camera can deal with high NSB

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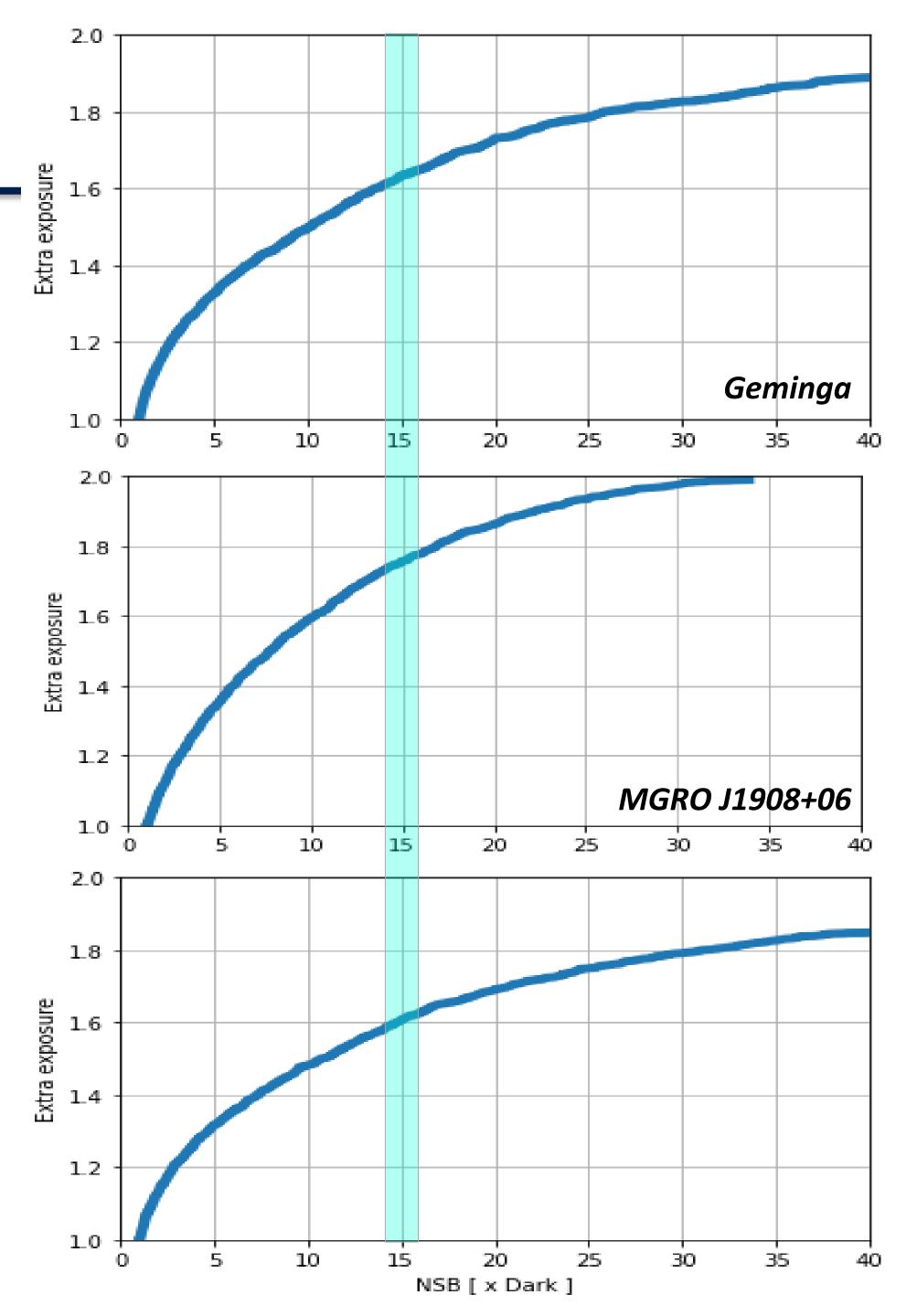
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Observations with moonlight \rightarrow ASTRI Camera can deal with high NSB

Observation duty-cycle

1565 h
0.79
0.04
0.07
1104 h

Setting 15 NSB as limit → AAOT ~ 1800 h



ASTRI Mini-Array - Schedule



June 2022

Phase 0

- 1 Telescope Structure
- m-ICT

Spring 2023

Phase 1

• 3 Telescope Structures

Late Spring 2023

Phase 2

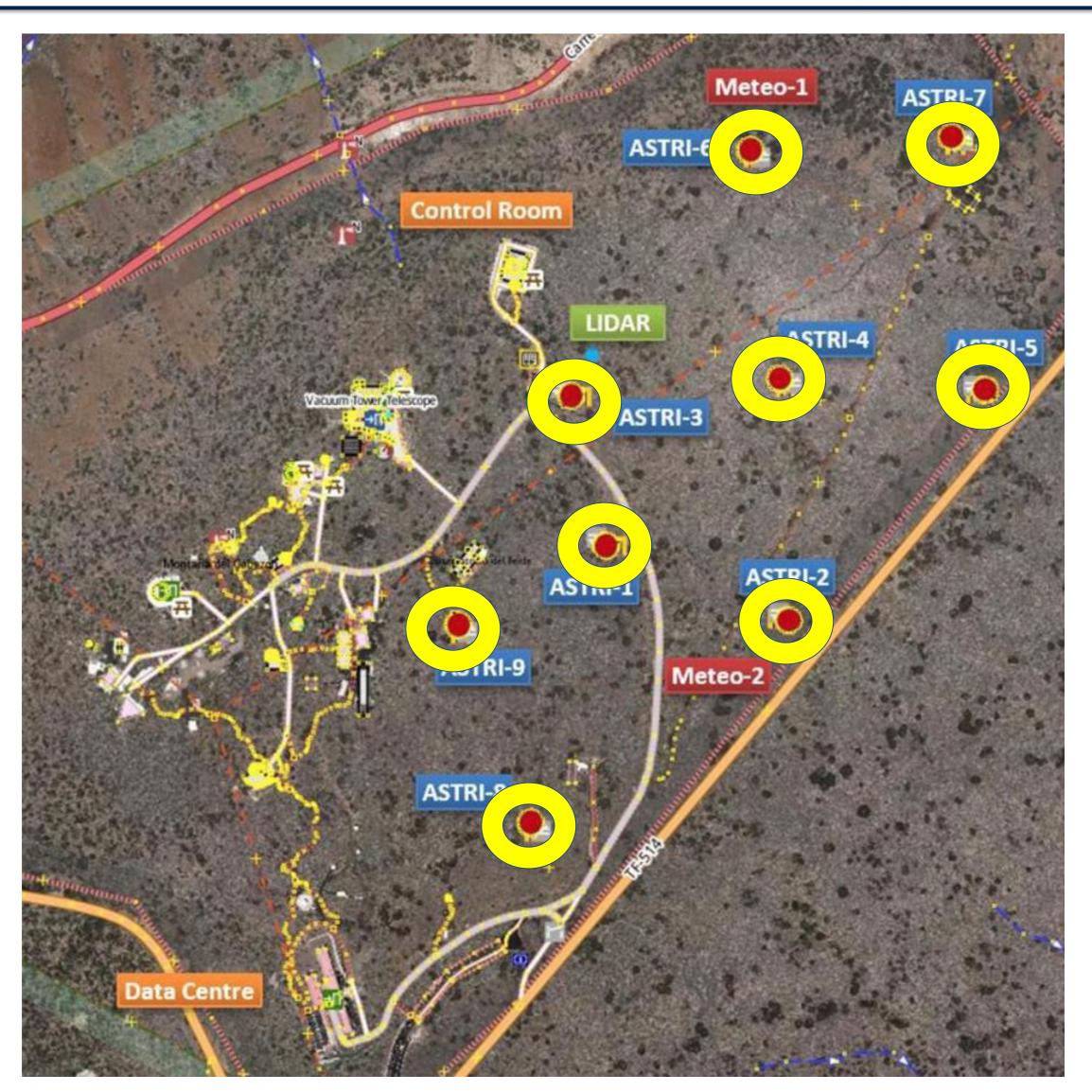
• 3 Telescope Structures + Cameras

Autumn 2023

Phase 3

• Full Array

End of 2024



Status of the infrastructure



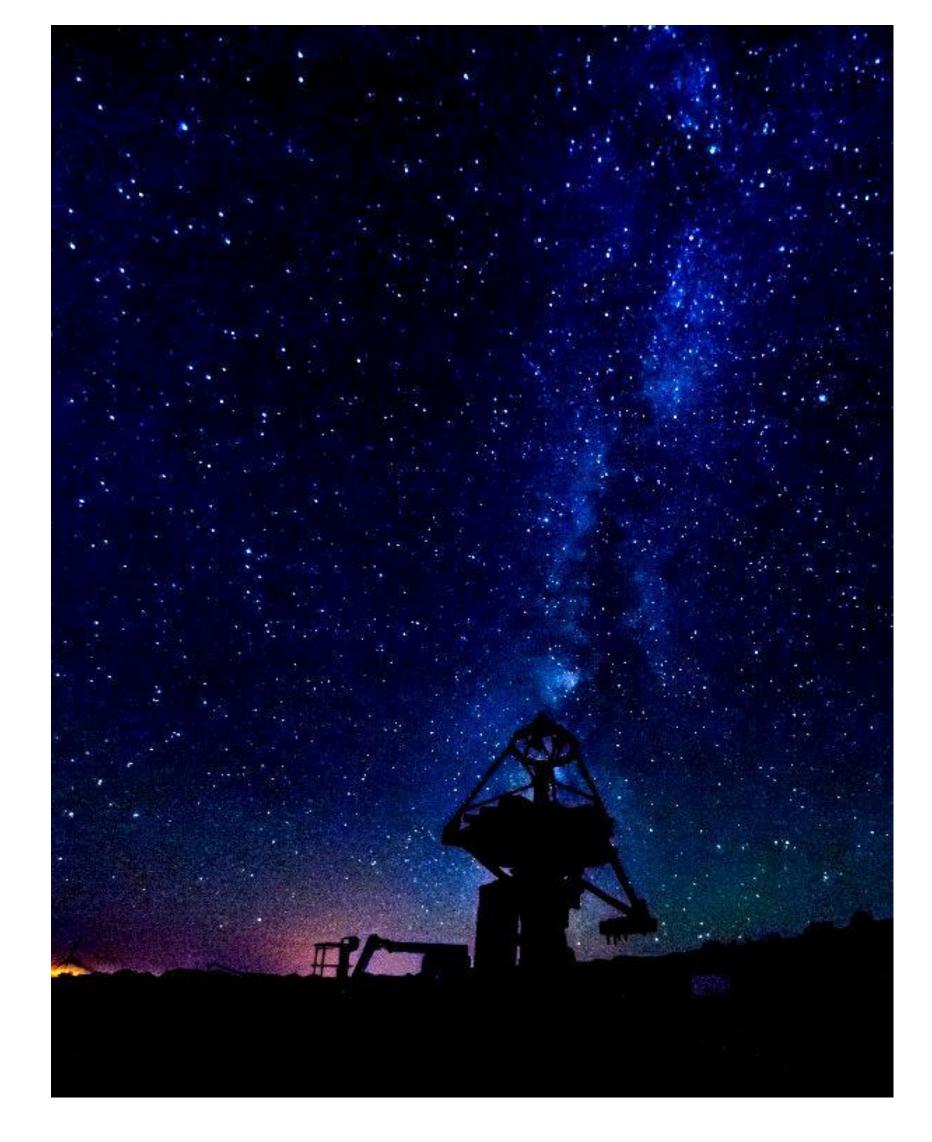
- All telescope foundations completed
- Excavations and tubes for power and data network completed
- Control room @ Themis completed
- Data Centre completed
- Electric cables & optical fibres being laid



ASTRI-1







More at...



Set of 4 papers published on the «Journal of High Energy Astrophysics»

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The ASTRI Mini-Array of Cherenkov Telescopes at the Observatorio
 del Teide
 S. Scuderi<sup>a,*</sup>, A. Giuliani<sup>a</sup>, G. Pareschi<sup>b</sup>, G. Tosti<sup>c</sup>, O. Catalano<sup>f</sup>, E. Amato<sup>p</sup>, L.A. Antonelli<sup>h</sup>,
 J. Becerra Gonzàles<sup>m</sup>, G. Bellassai<sup>d</sup>, C. Bigongiari<sup>h</sup>, B. Biondo<sup>f</sup>, M. Boettcher<sup>n</sup>, G. Bona<sup>r</sup>
 P. Bruno<sup>d</sup>, A. Bulgarelli<sup>e</sup>, R. Canestrari<sup>f</sup>, M. Capalbi<sup>f</sup>, M.Cardillo<sup>k</sup>, V. Conforti<sup>e</sup>, G
 M. Corpora<sup>f</sup>, A. Costa<sup>d</sup>, G. Cusumano<sup>f</sup>, A. D'Aì<sup>f</sup>, E. de Gouveia Dal Pino<sup>l</sup>, R. D'
 E. Escribano Rodriguez<sup>o</sup>, D. Falceta-Gonçalves<sup>s</sup>, C. Fermino<sup>l</sup>, M. Fiori^{j,g}, V
 S. Gallozzi<sup>h</sup>, C. Gargano<sup>f</sup>, S. Garozzo<sup>d</sup>, S. Germani<sup>c</sup>, A. Ghedina<sup>o</sup>, F. C
 R. Gimenes<sup>f,l</sup>, V. Giordano<sup>d</sup>, A. Grillo<sup>d</sup>, C. Grivel Gelly<sup>o</sup>, D. Impic
 S. Incorvaia<sup>a</sup>, S. Iovenitti<sup>b</sup>, A. La Barbera<sup>f</sup>, N. La Palombara<sup>a</sup>.
L. Lessio<sup>g</sup>, G. Leto<sup>d</sup>, F. Lo Gerfo<sup>f</sup>, M. Lodi<sup>o</sup>, S. Lombard<sup>;<sup>t</sup></sup>
M.C. Maccarone<sup>f</sup>, D. Marano<sup>d</sup>, E. Martinetti<sup>d</sup>, S. Me<sup>r</sup>
G. Morlino<sup>q</sup>, A. Morselli<sup>t</sup>, G. Naletto<sup>t,g</sup>, G. Nicotra

J. Lucarelli<sup>h</sup>,

Acciché<sup>d</sup>, R. Millul<sup>b</sup>, T. Mineo<sup>f</sup>,

J. N. Parmiggiani<sup>e</sup>, G. Piano<sup>k</sup>,
 F. Pintore<sup>f</sup>, E. Poretti<sup>o</sup>, B. Olmi<sup>q</sup>, G. Rodeghiero<sup>e</sup>, G.
                                                                                                        guez Fernandez^i, P. Romano<sup>b</sup>,
 G. Romeo<sup>d</sup>, F. Russo<sup>e</sup>, P. Sangiorgi<sup>f</sup>, F.G. Saturni<sup>h</sup>, J.L. Schwarz<sup>b</sup>, E. Sciacca<sup>d</sup>, G. Sironi<sup>b</sup>,
 G. Sottile<sup>f</sup>, A. Stamerra<sup>h</sup>, G. Tagliaferri<sup>b</sup>, V. Testa<sup>h</sup>, G. Umana<sup>d</sup>, M. Uslenghi<sup>a</sup>, S. Vercellone<sup>b</sup>,
 L. Zampieri<sup>g</sup> and R. Zanmar Sanchez<sup>d</sup>
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Galactic Observatory Science with the ASTRI Mini-Array at the Observatorio del Teide

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A. D'Aìa,*, E. Amatob, A. Burtovoib, A. A. Compagninoa, M. Fioric, A. Giulianid
Palombarad, A. Paizisd, G. Pianoe, F. G. Saturnif, A. Tutonea, A. Belfiored,
S. Crestand, G. Cusumanoa, M. Della Valleij, M. Del Santoa, A. La Barbe, arolaa,
S. Lombardif, S. Mereghettid, G. Morlinob, F. Pintorea, P. Romanok, A. Antonellif,
C. Arcarol, C. Bigongiarif, M. Böettcher, P. Brunon, A. Bulgare, arotio, A. Costan, E. de
Gouveia Dal Pinop, V. Fiorettio, S. Germania, A. Ghedinar, F. Longos, A. López Oramasu, F. Lucarellif, B. Olmiv, A. Stamerraf, V. Testaf, G. Tostio, G. Umanan, L. Zampien, Caraveod and G. Pareschik
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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 E. Amato^{c,j}, L. A. Antonelli^{b,g}, C. Arcaro^{h,k}, J. Becerra González^{l,m}, G. Bonnoli^a, M. Bör G. Brunettiⁿ, A. A. Compagnino^e, S. Crestan^{o,p}, A. D'Aì^e, M. Fiori^{h,f}, G. Galanti^o, A. E. M. de Gouveia Dal Pino^g, J. G. Green^b, A. Lamastra^{b,g}, M. Landoni^a, F. Luca^{c,c}, Jorlino^c, B. Olmi^{r,c}, E. Peretti^s, G. Piano^d, G. Ponti^{a,t}, E. Poretti^{a,u}, P. Romano^a, F. C. Jorlino^c, A. Tutone^b, G. Umana^v, J. A. Acosta-Pulido^{l,m}, P. Barai^g, A. Bonanno^v, P. Bruno^v, A. Bulgarelli^w, V. Conforti^w, A. Costa^v, G. Cusumano^e, M. Del Sa^{c,c}, La Valle^g, R. Della Ceca^a, D. A. Falceta-Gonçalves^g, V. Fioretti^w, S. Germani^{x,y}, F. Lopez-l^m, A. Ghedina^u, V. Giordano^v, M. Kreter^k, F. Incardona^v, S. Iovenitti^a, A. L. A. L. Parola^e, G. Leto^v, F. Longo^{z,aa}, A. López-Oramas^{l,m}, M. C. N. La Palombara^o, V. La Parola^e, G. Leto^v, F. Longo^{z,aa}, A. López-Oramas^{l,m}, M. C. N. La Palombara^o, R. Millul^a, G. Naletto^f, A. Pagliaro^e, N. Parmiggiani^w, C. Righi^a, J. C. Rodríguez-Ramírez^q, G. Romeo^v, P. Sangiorgi^e, R. Santos de Lima^q, G. Tagliaferri^a, V. Testa^b, G. Tosti^{x,y}, M. Vázquez Acosta^{l,m}, N. Żywucka^{k,ab}, P. A. Caraveo^o and G. Pareschi^a

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. M. Capalbi^k, A. Lamastra^a, S. Lombardi^{a,b}, F. Lucarelli^{a,b}, R. Alves Batista^l Jonelli^{a,b}, E. M. de Gouveia Dal Pino^m, R. Della Ceca^j, J. G. Green^{a,b}, A. Pagliaro^k, C. Tavecchioⁿ, S. Vercelloneⁿ, A. Wolter^j, E. Amato^o, C. Bigongiari^{a,b}, M. Böttch^o Joretti^p, P. Bruno^g, A. Bulgarelli^r, M. Cardillo^s, V. Conforti^r, A. Costa^g, G. Cusur Joretti^r, S. Germani^t, A. Ghedina^u, V. Giordano^g, A. Giuliani^v, F. Incardona^g, A. Joretti^g, F. Longo^{w,x}, G. Morlino^o, B. Olmi^y, N. Parmiggiani^r, P. Romanoⁿ, G. Ron Joretti^a, A. Stamerra^a, G. Tagliaferriⁿ, V. Testa^a, G. Tosti^{j,t}, P. A. Caraveo^v and G. Pareschiⁿ

More at..



Astri web site: http://astri.me.oa-brera.inaf.it/

On socials, search for *ASTRIgamma* (FB and Instagram)

IRFs (gammapy and ctools compatible) available on **Zenodo.org**

...THANK YOU!

