The ASTRI Mini Array of Cherenkov telescopes

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for the ASTRI Project

GAMMA 2022

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 HORN

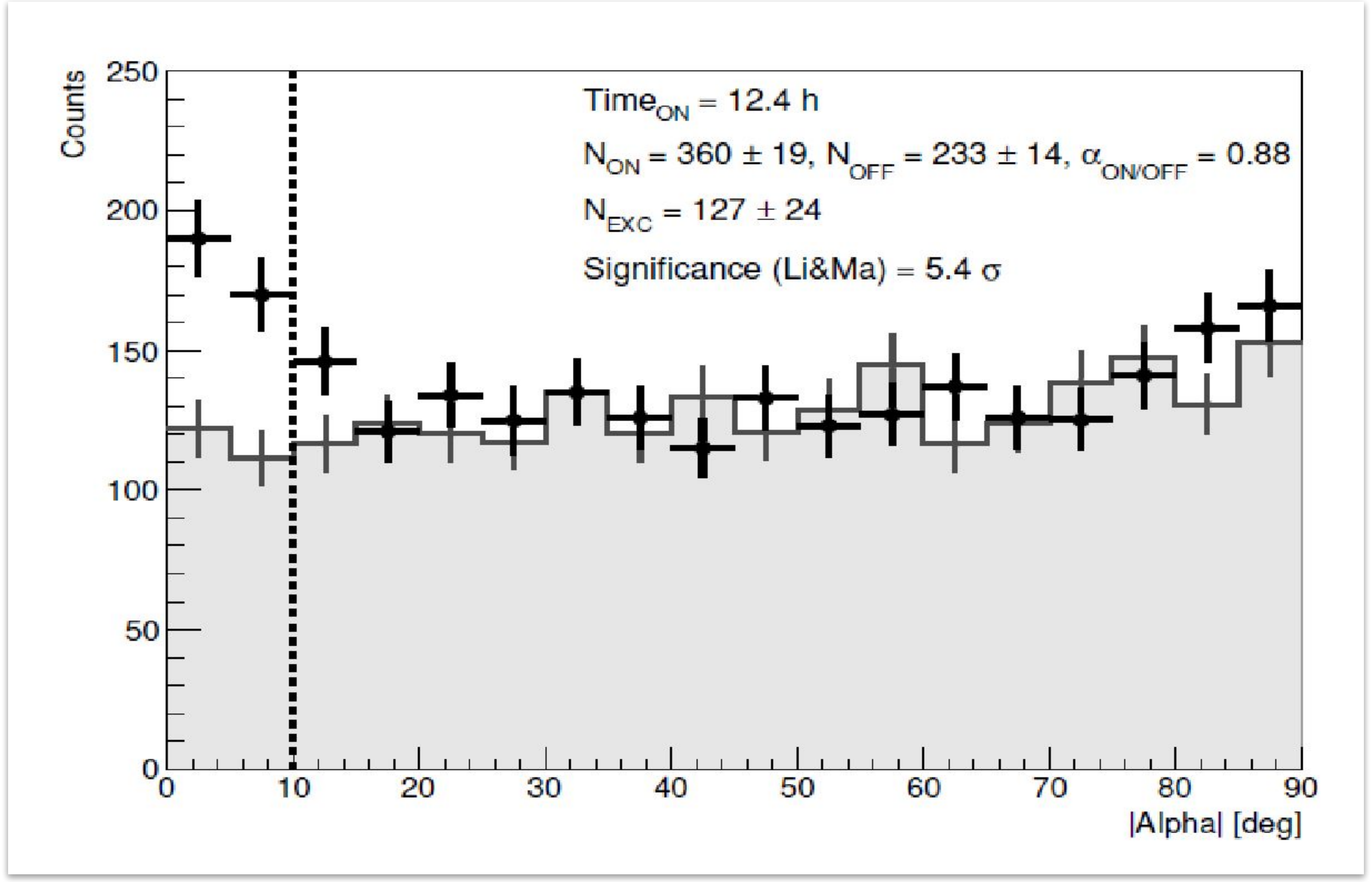
ASTRI

(Astrofisica con Specchi a Tecnologia Replicante Italiana)

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



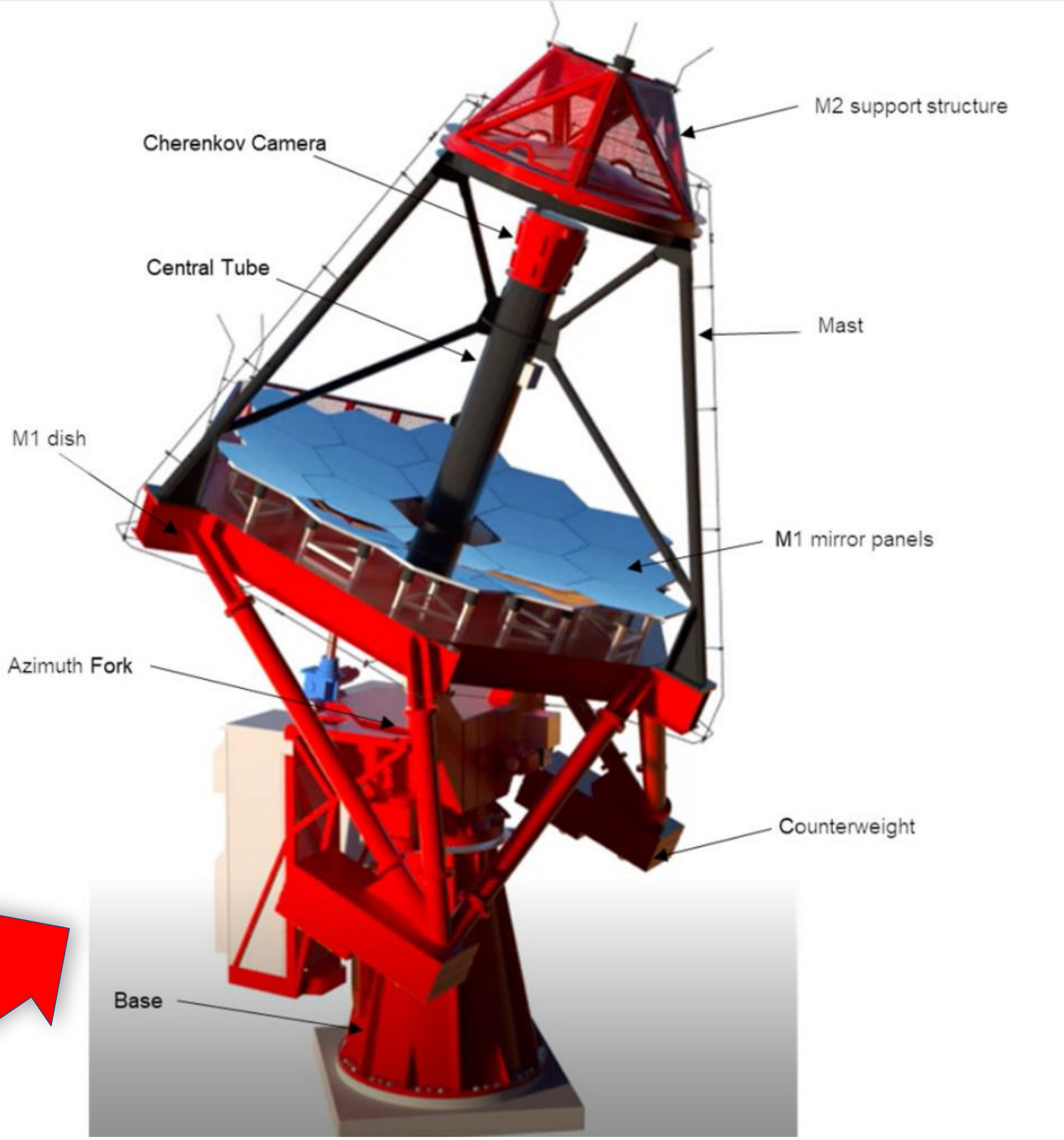
First detection of a gamma-ray source (Crab Nebula) above 5σ **with a dual-mirror, Schwarzschild-Couder Chrenkov telescope** (Lombardi et al., 2020)

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%).

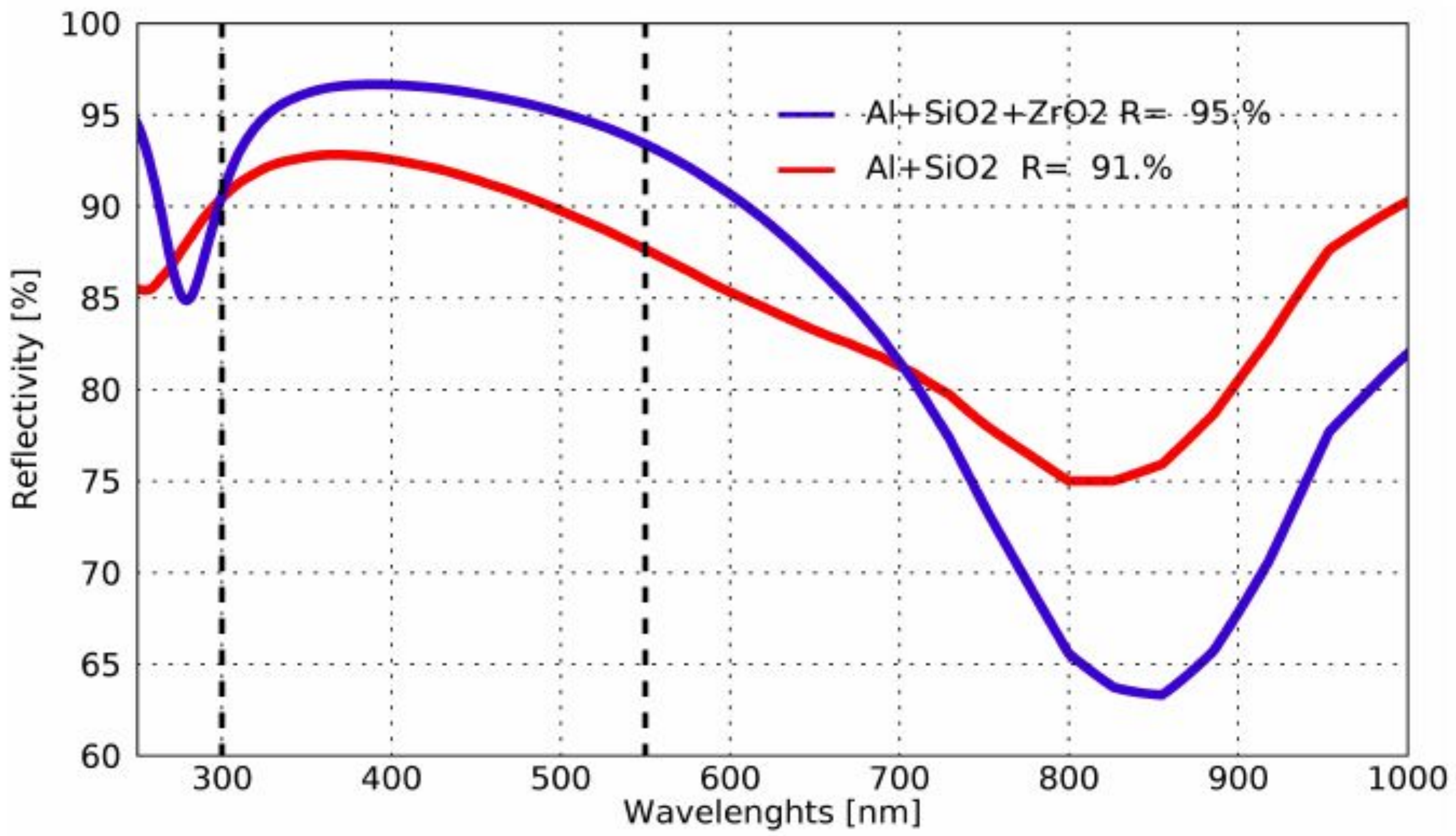


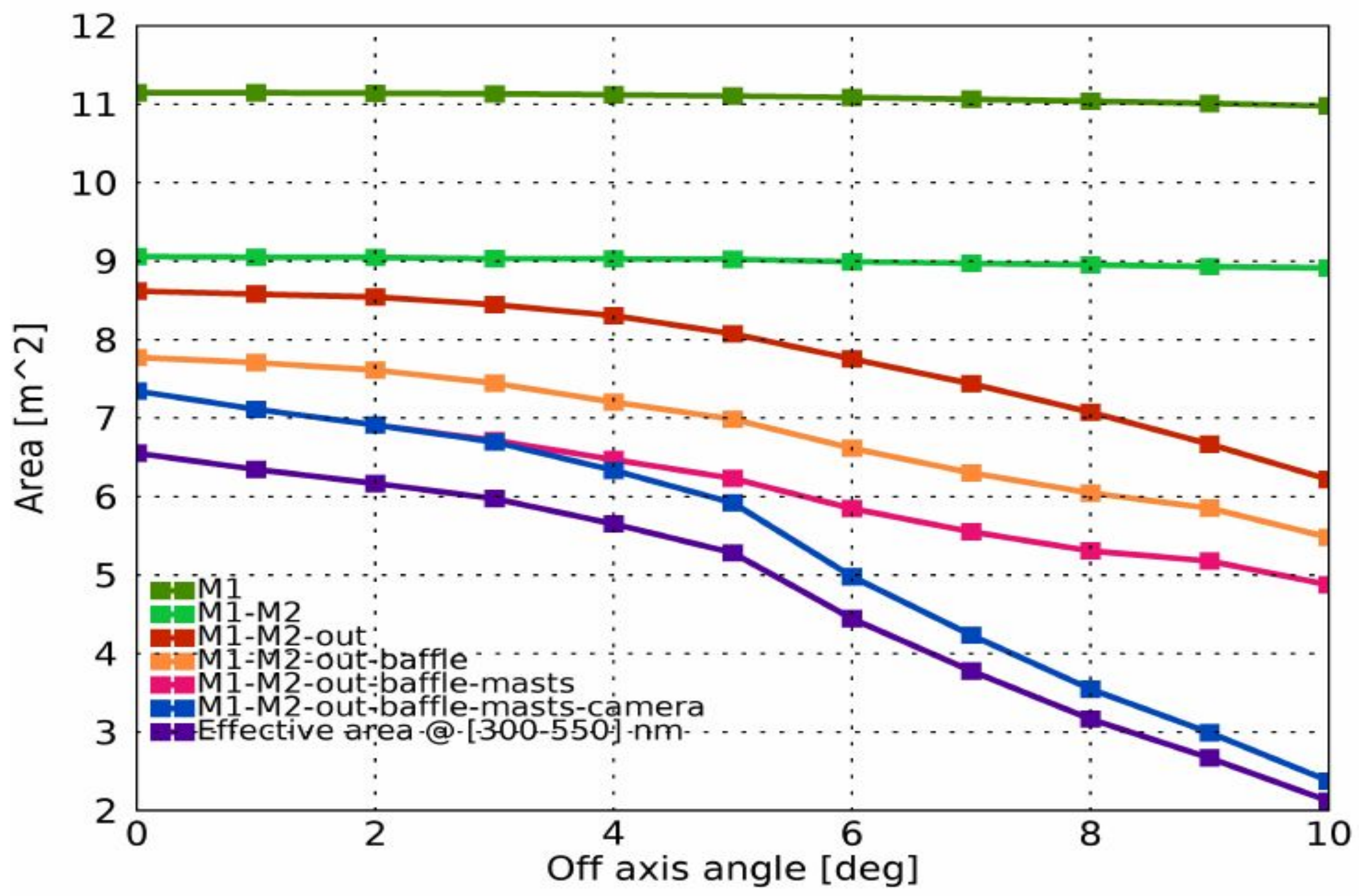
Optics

- 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.





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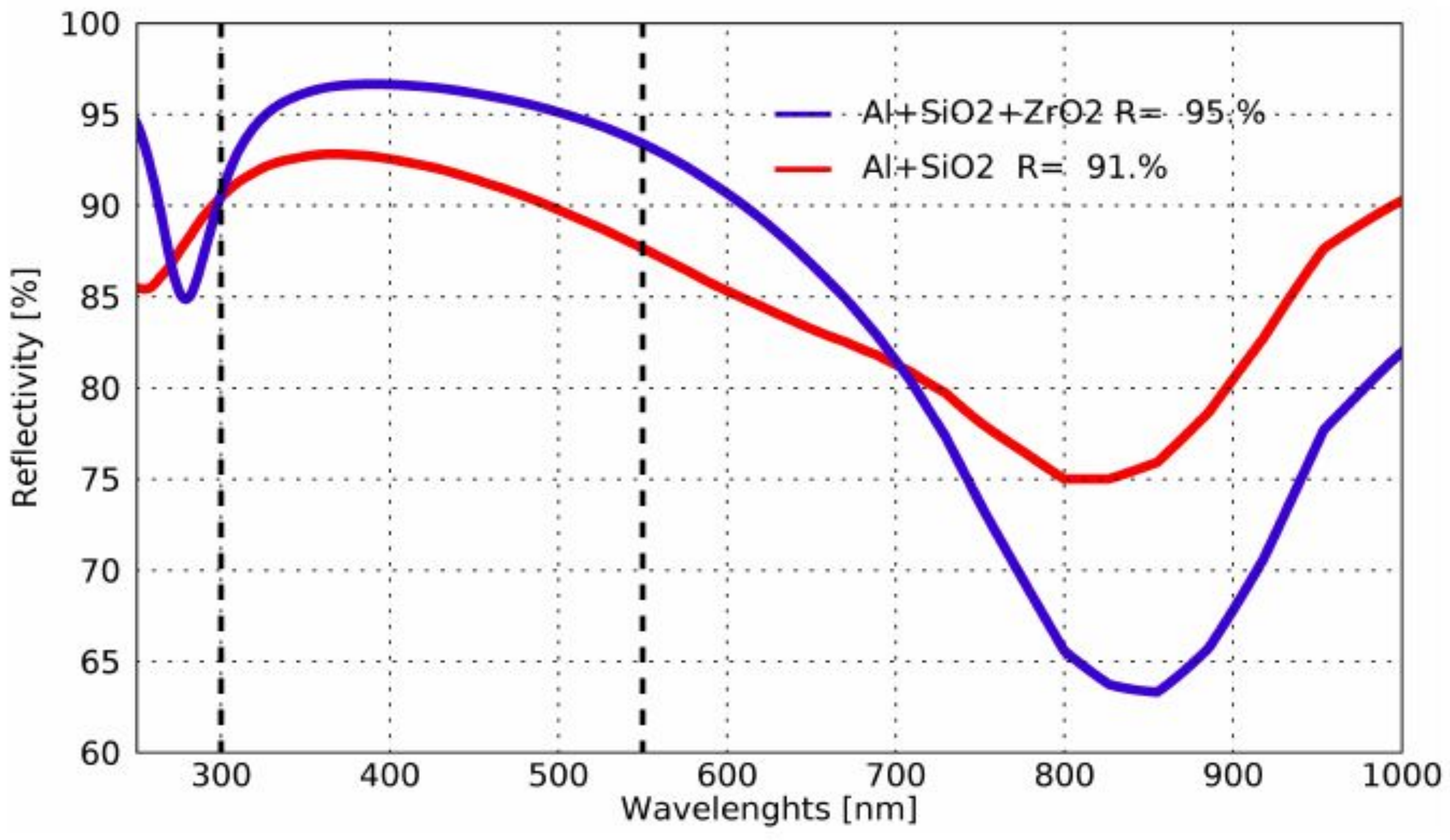
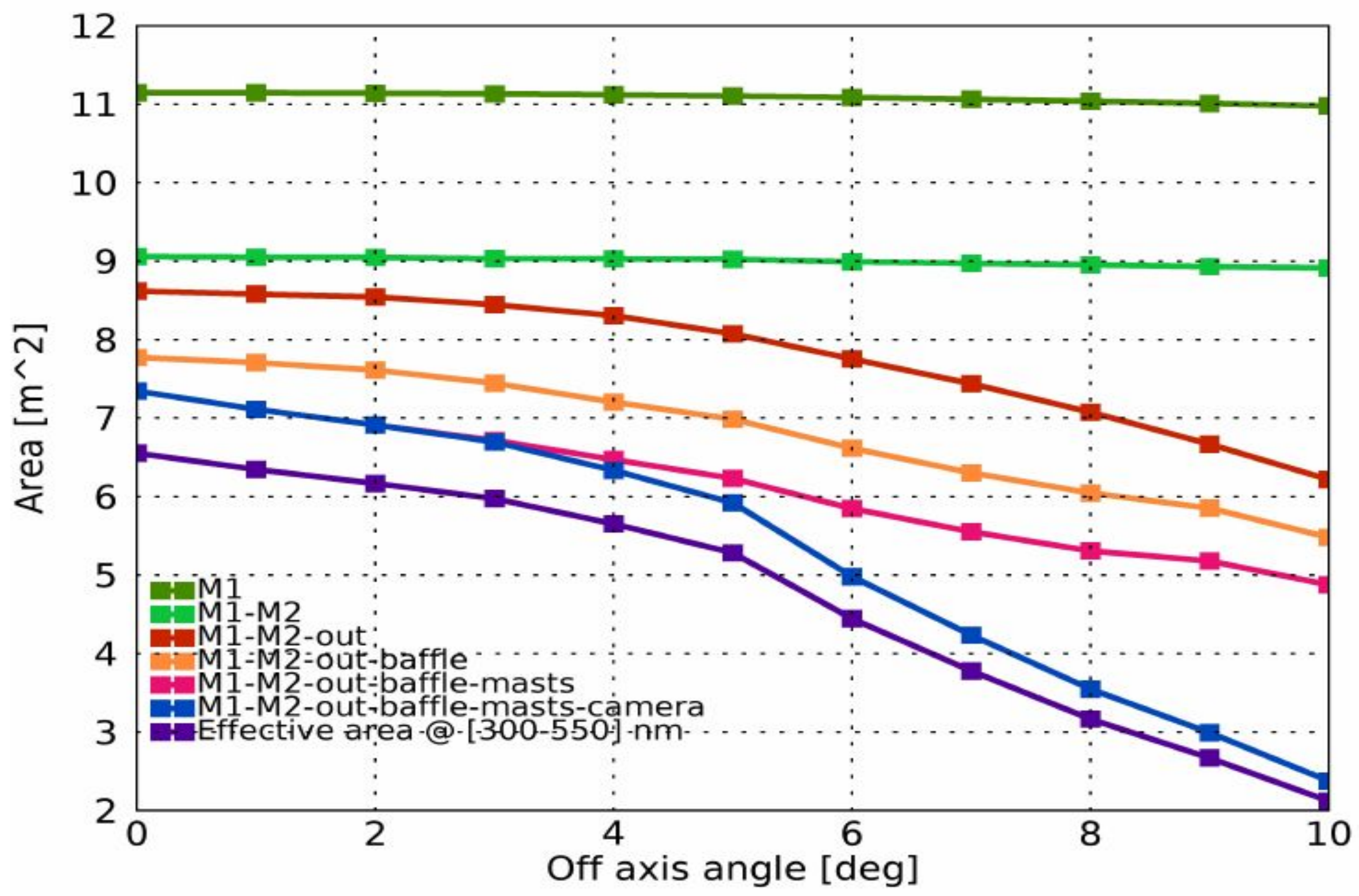
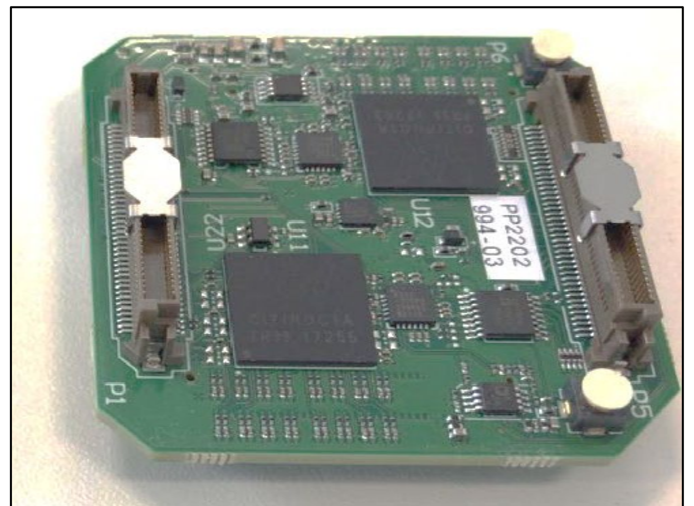




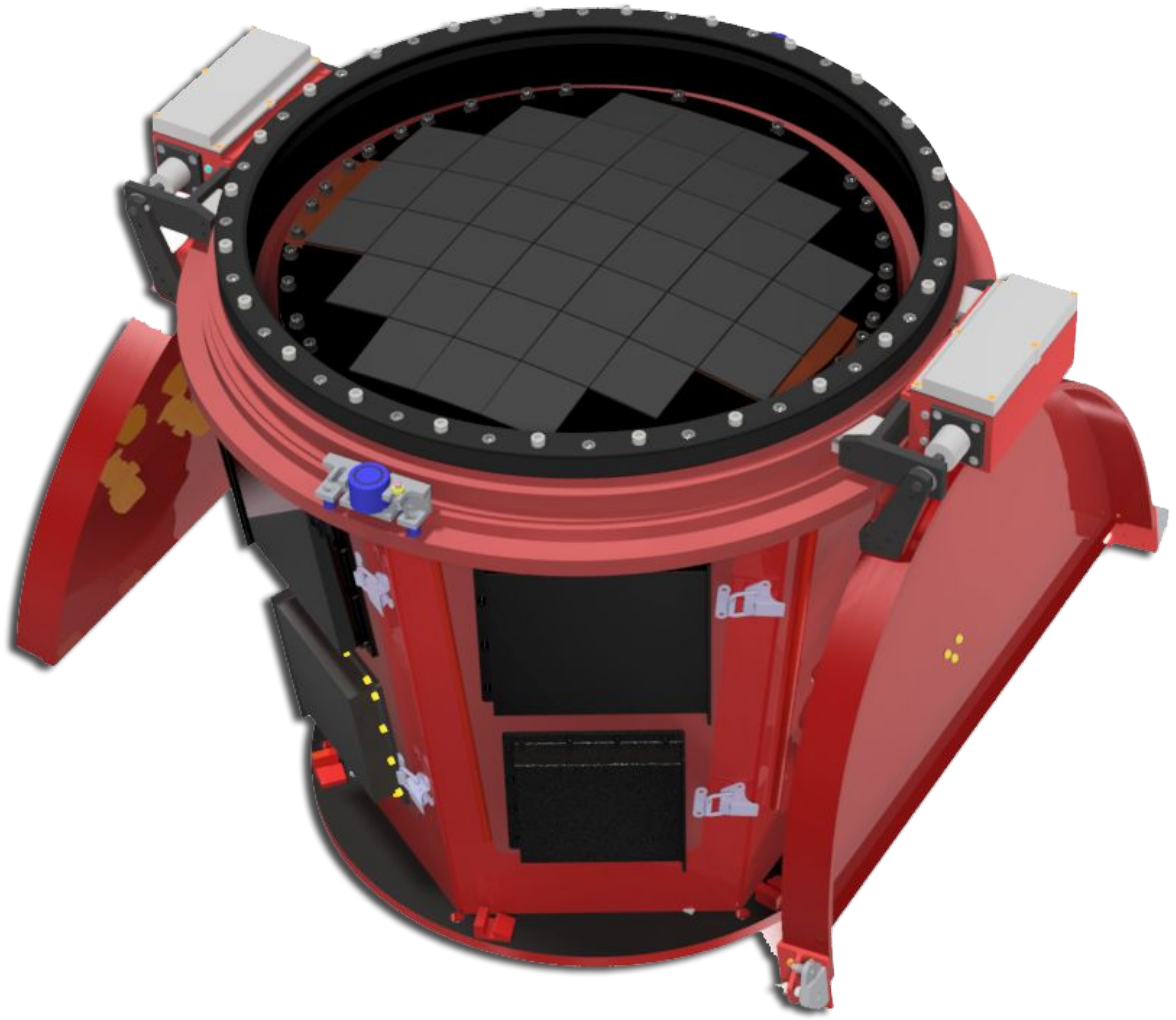
ASTRI Camera

SiPM matrices



ASIC board

- The SiPM produced by Hamamatsu photonics (7x7 mm^2) 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.



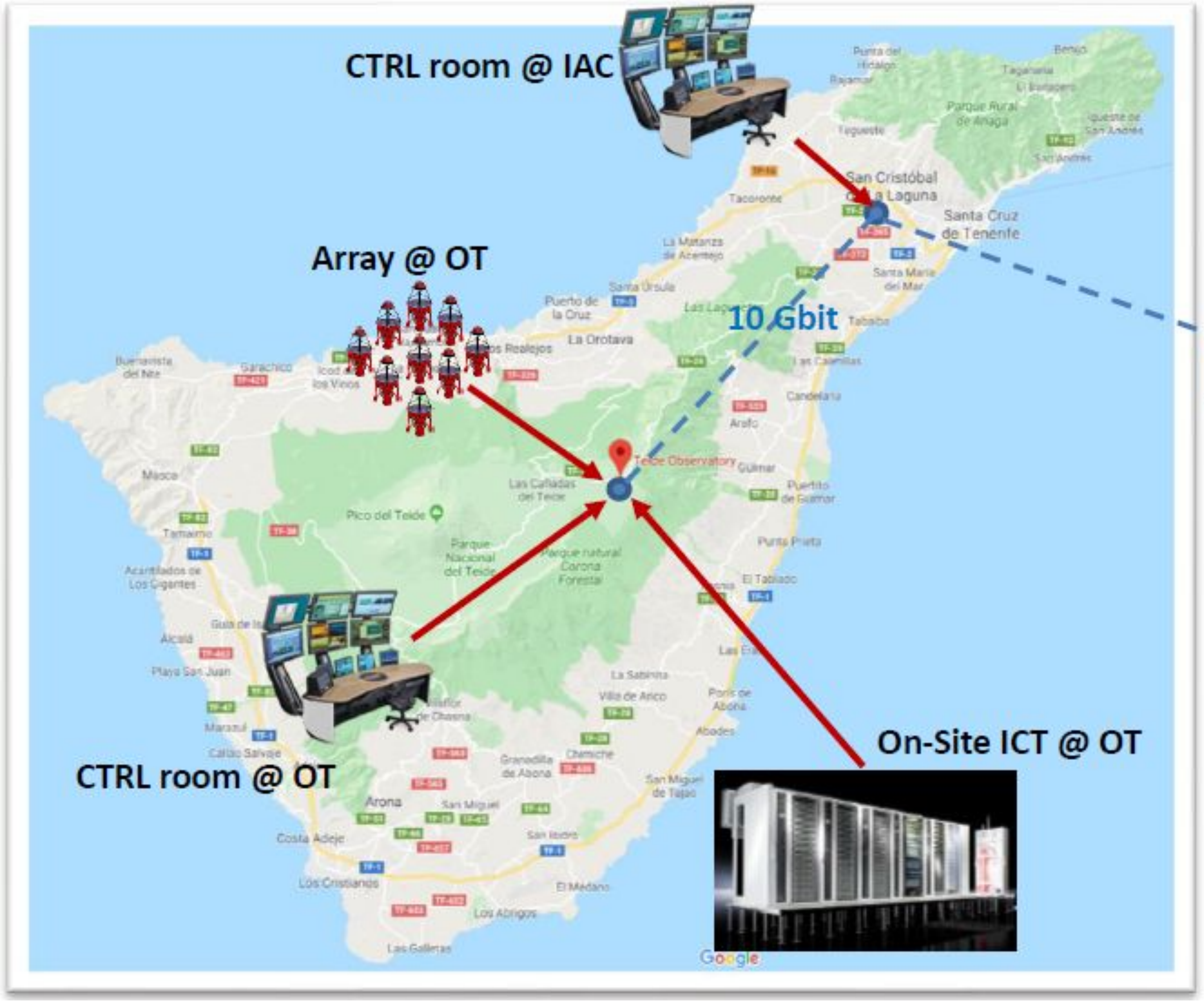
The ASTRI Mini-Array locations

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

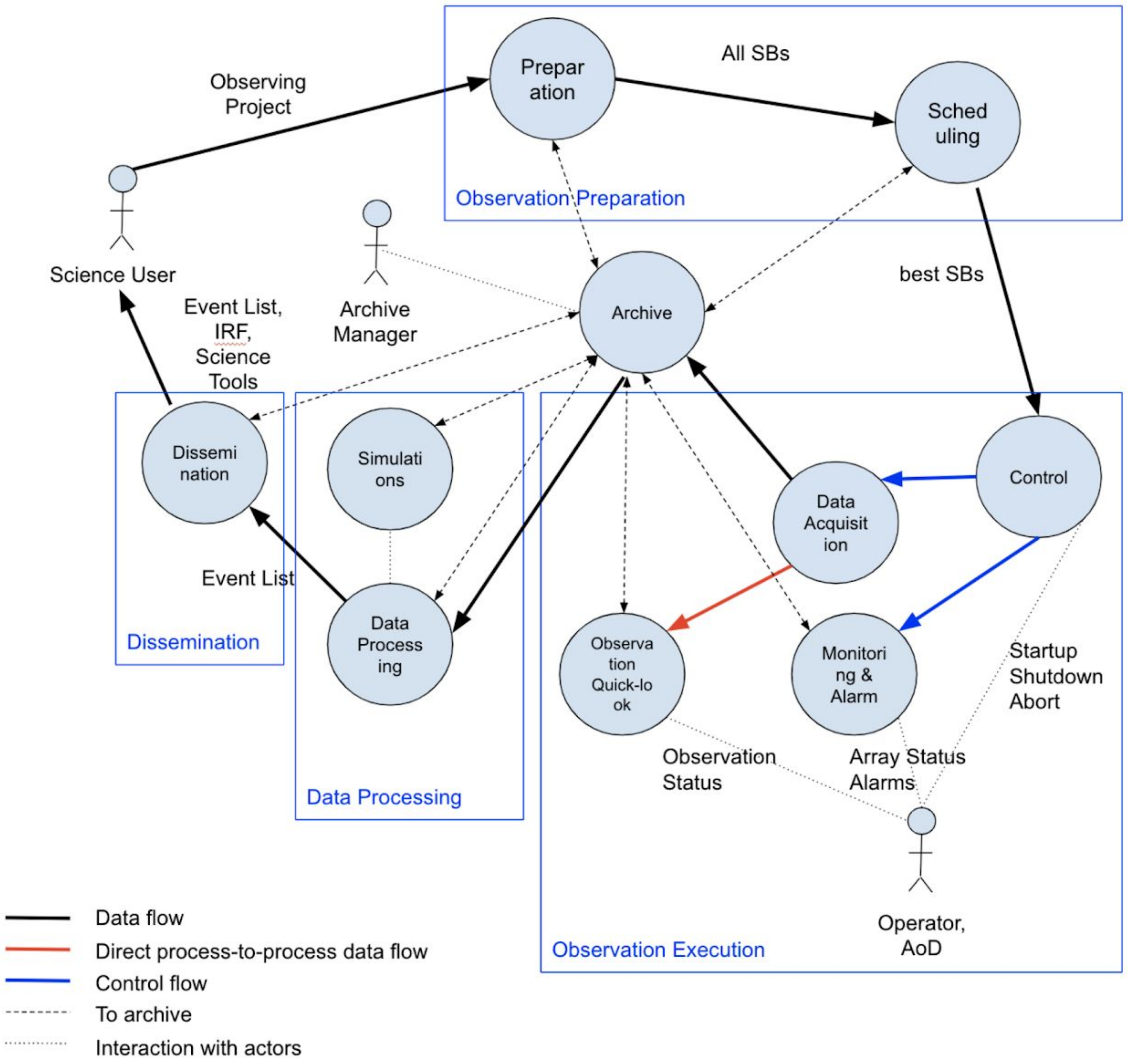
The ASTRI Mini-Array in Italy

- Data Centre in Rome
- Remote Array operation centers



10 Gbit

Software: data & information flow



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:

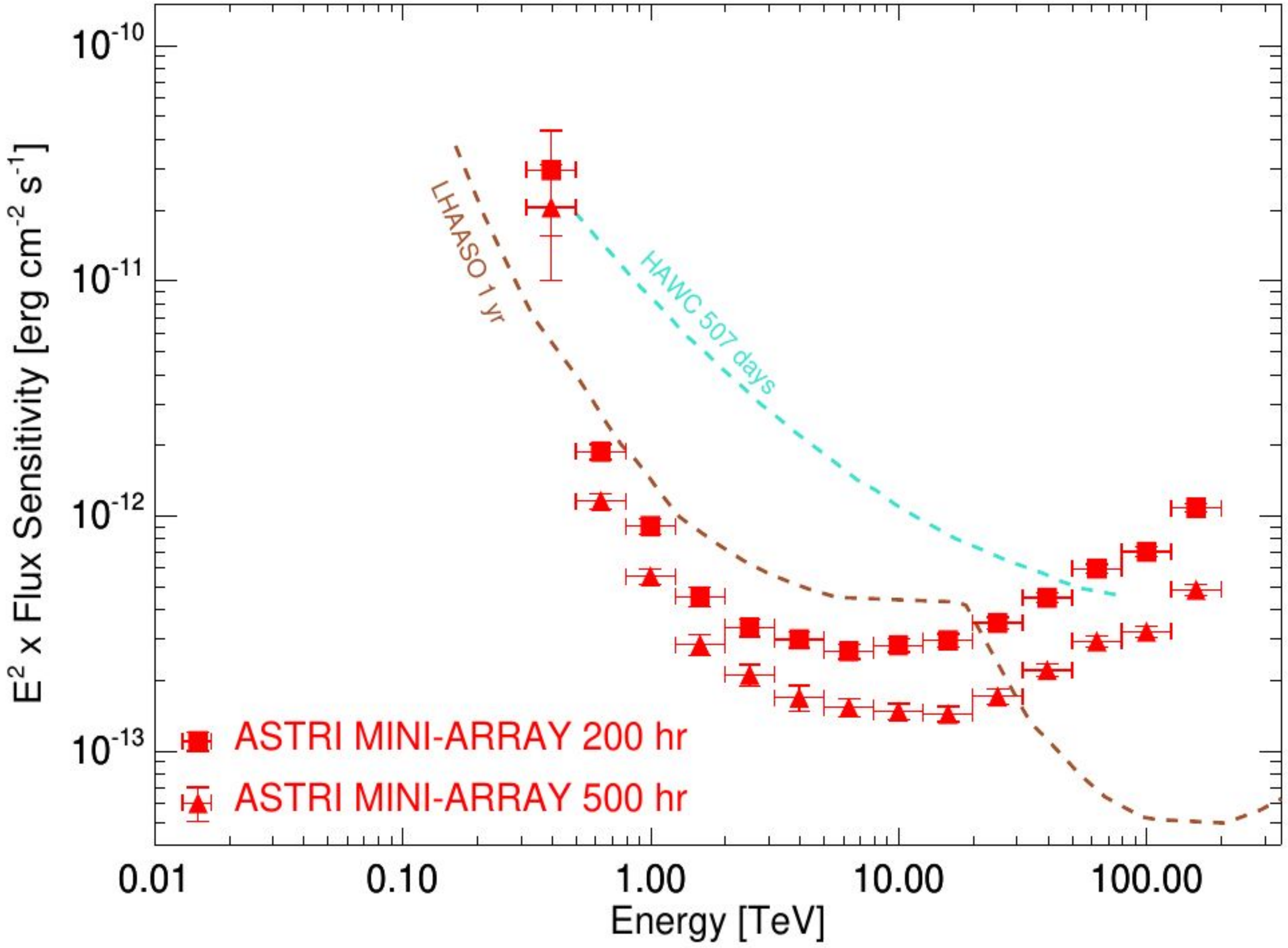
1. Observation preparation
2. Observation execution
3. Data Processing
4. Dissemination

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

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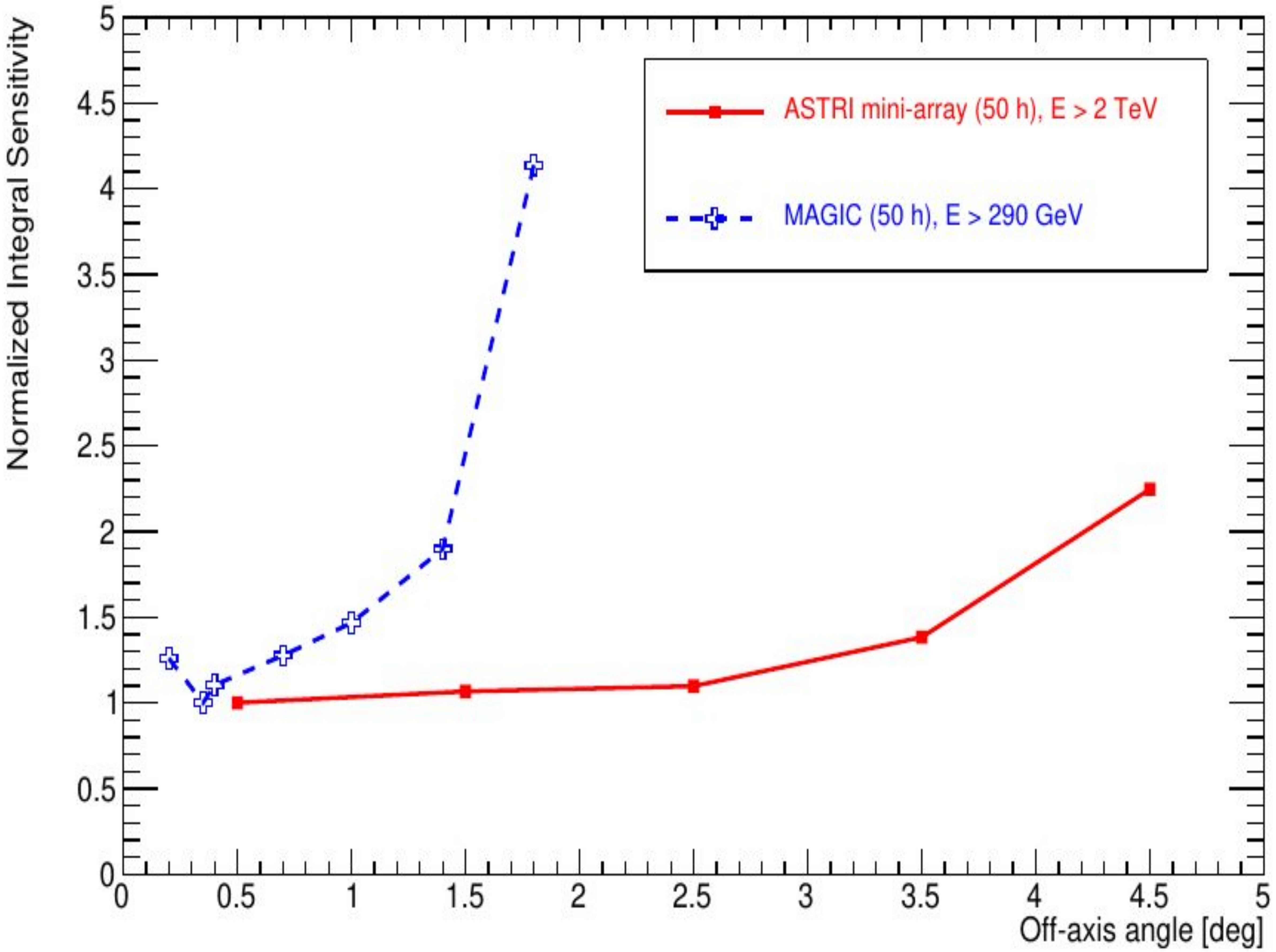

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Energy/Angular resolution: ~ 10% / ~ 3‘ (E > a few TeV)

- 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

ASTRI Science

*see **S. Vercellone** talk and **M. Cardillo** poster*

Pillar 1 : **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	SNR+PWN	500
G106.3+2.7	SNR	200
γ-Cygni	SNR	500
W28	SNR/MC	500
M82	Starburst	400
Crab	PWN	300
Geminga	PWN	500
IC 310	Radio gal	10-500
M87	Radio gal	10-500
Mkn 501	Blazar	5-500
1ES 0229+200	Blazar	200-250

ASTRI Science

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Large exposures are required

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 : Large exposures are required

Strategy :

Focus on few sky fields → Long exposures

3 aces up the sleeve :

- Large FoV → Several sources in the FOV
- Large Z.A. → Increase Aeff @ high energies
- Observations with moonlight → ASTRI Camera can deal with high NSB

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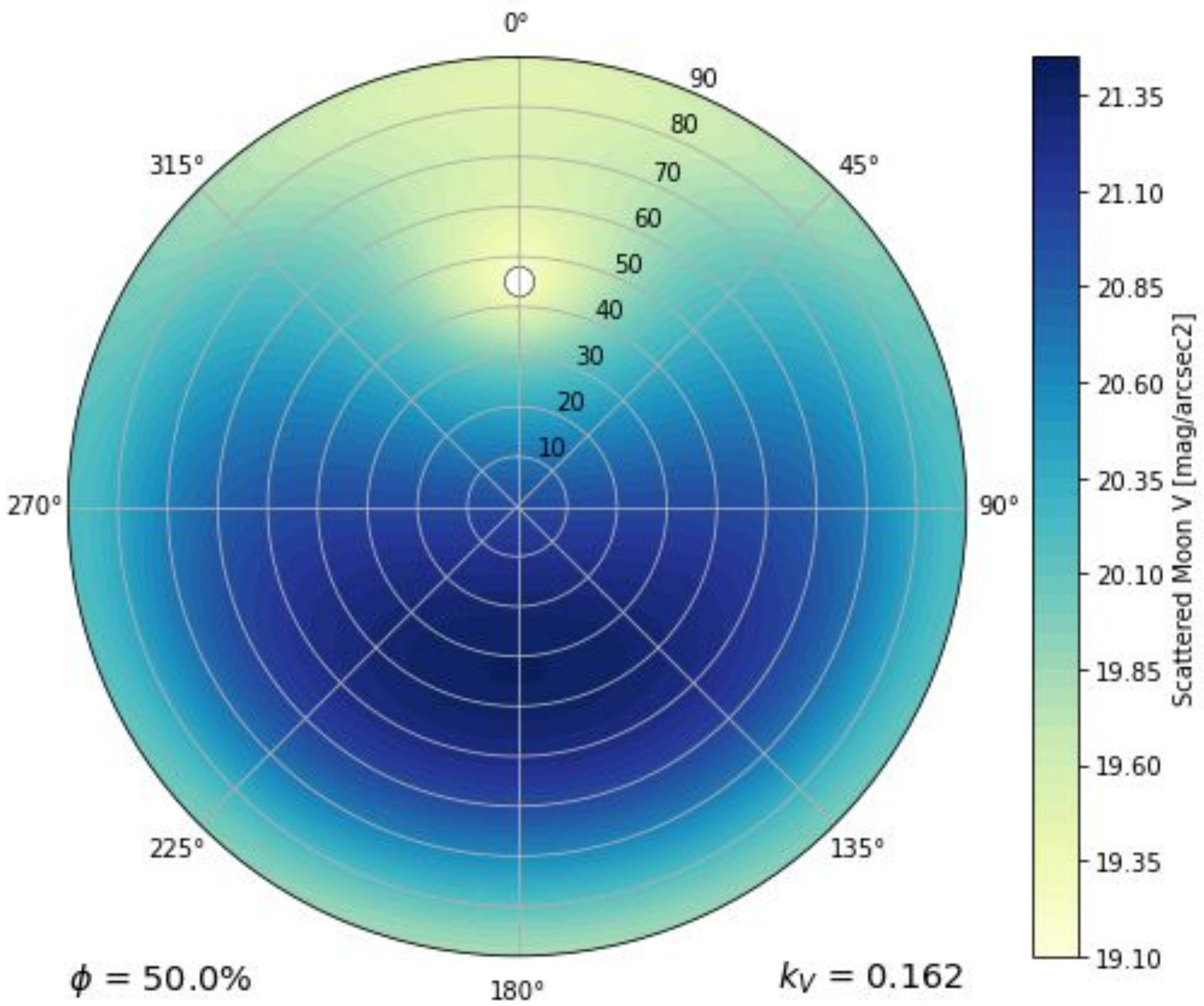
NSB with MoonLight

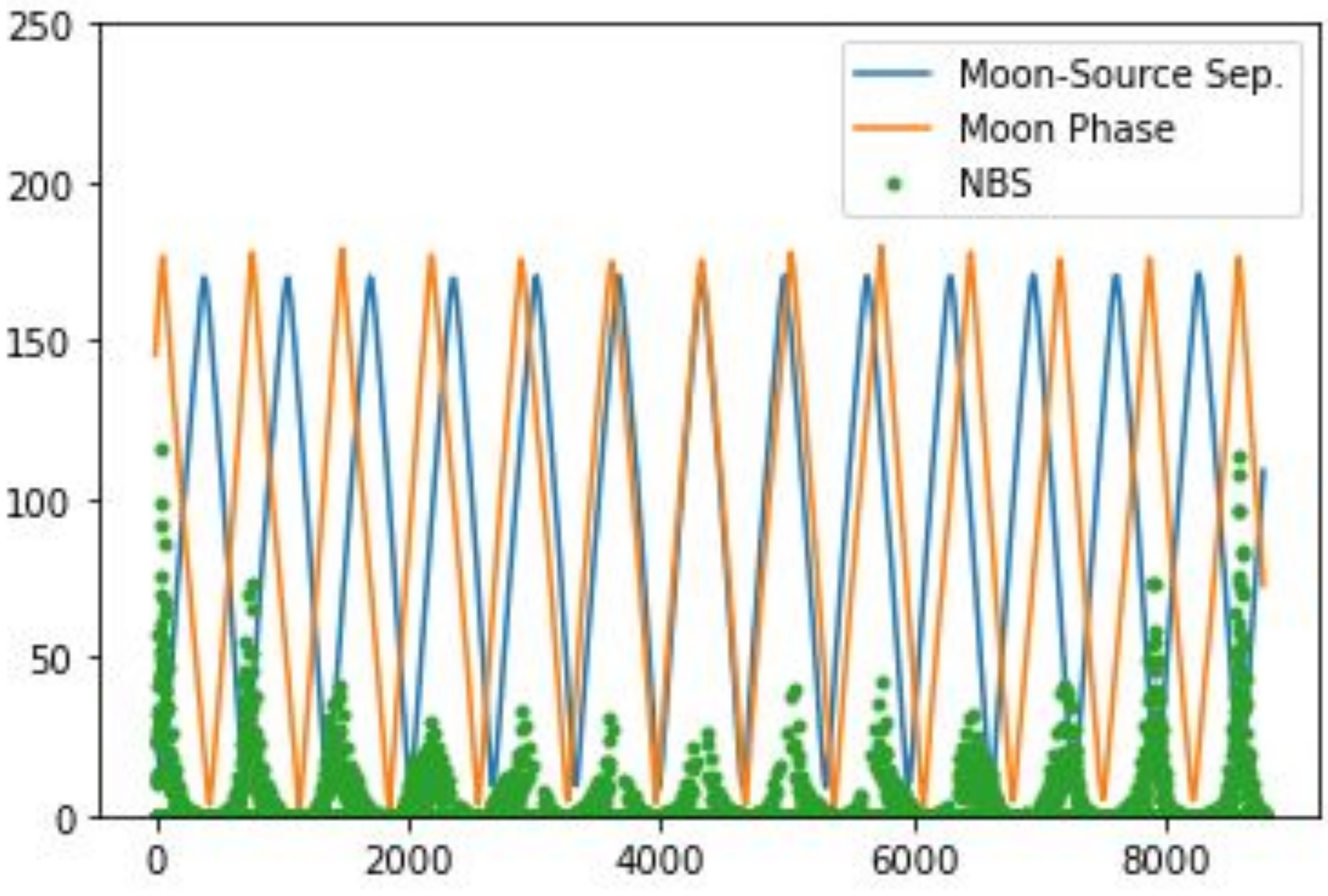


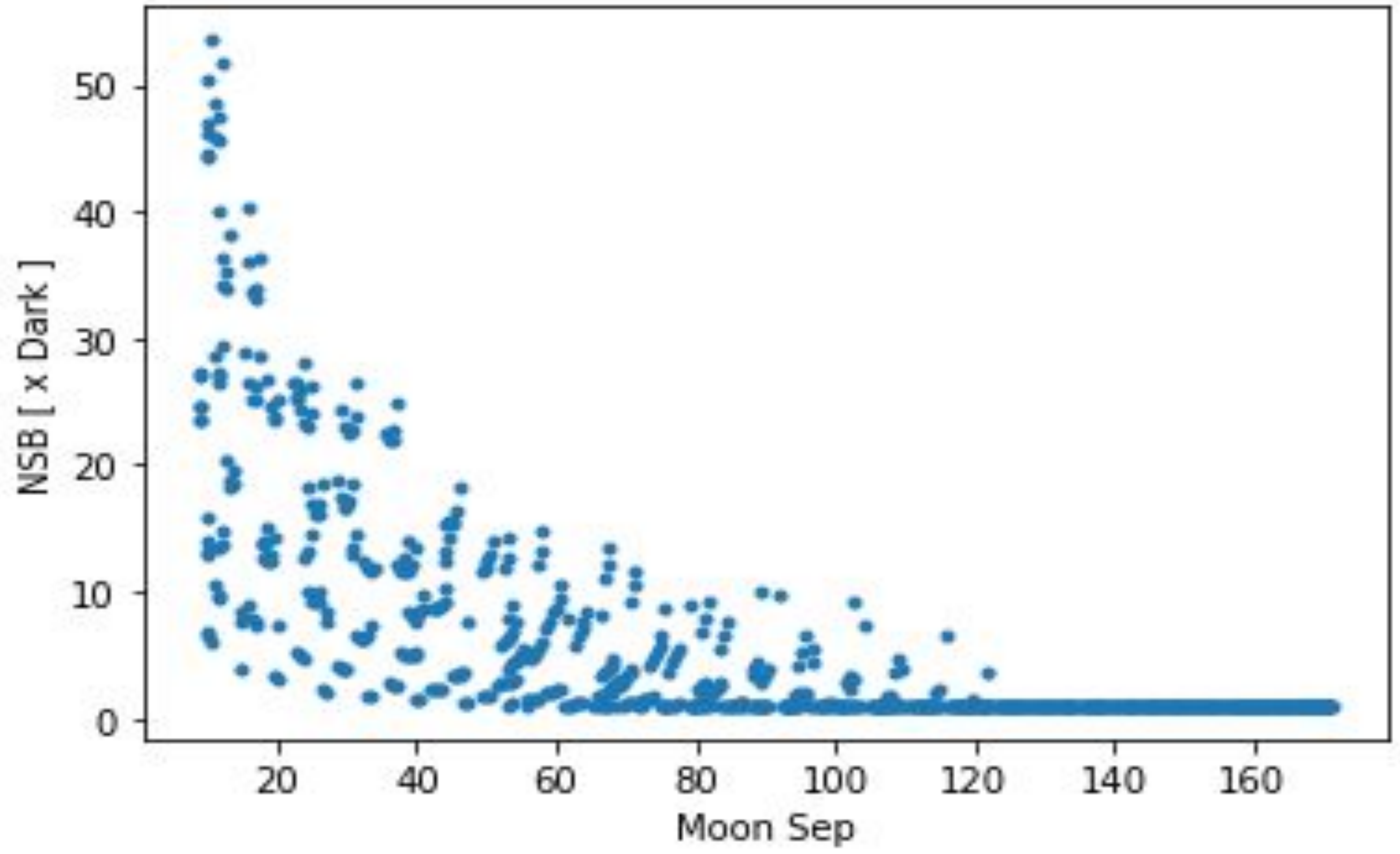
- SkyCalc
- SpecSim
  (https://specsim.readthedocs.io)
  Based on the model by ***Krisciunas&Schaefer***

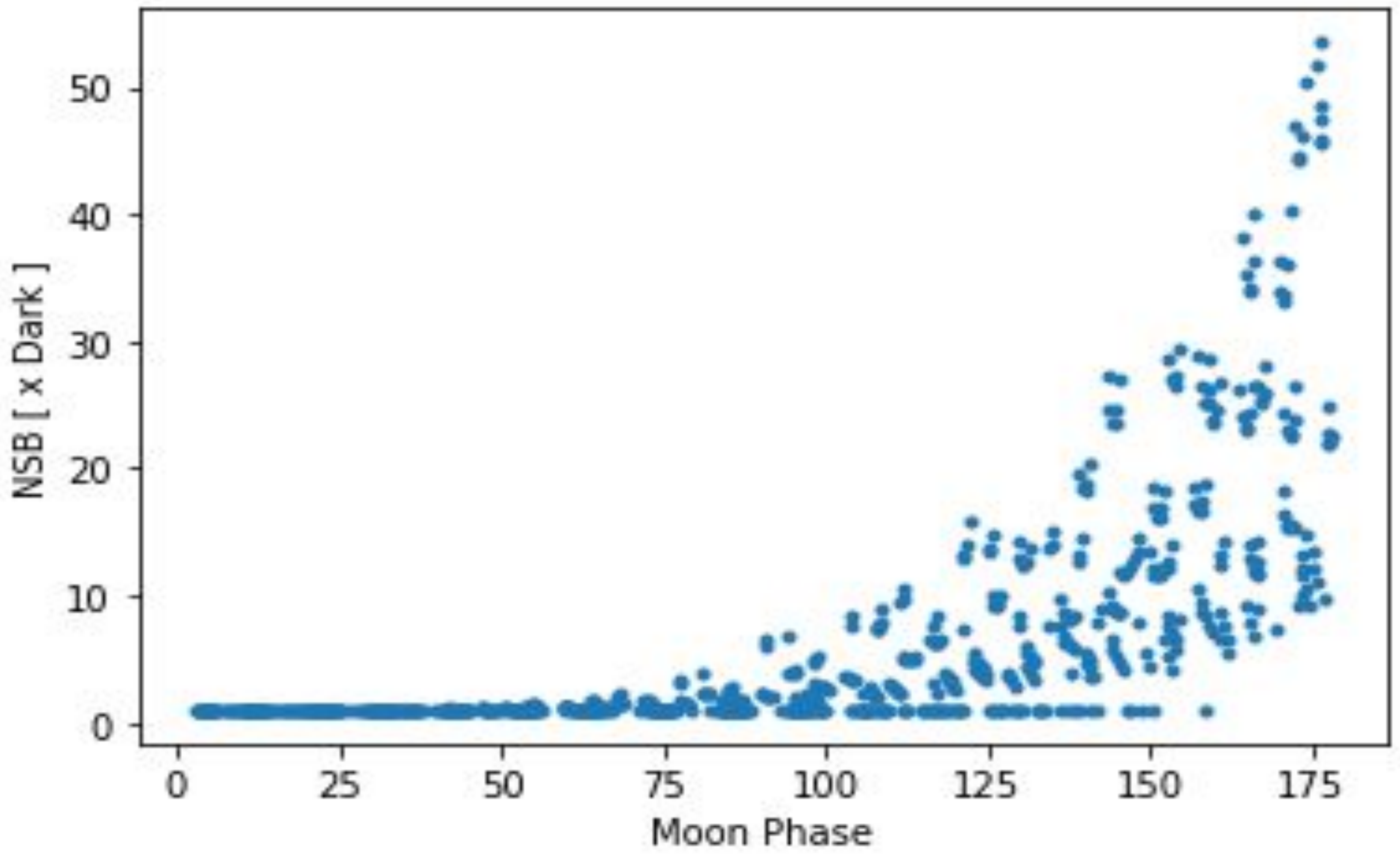
Brightness in V [mag/arcsec^2]

	SkyCalc	**SpecSim**	**diff Fluxes**
halfmoon_sep20	*20.04*	*20.03*	*0.9 %*
halfmoon_sep40	*20.47*	*20.52*	*4.7 %*
halfmoon_sep60	*20.68*	*20.75*	*6.7 %*
fullmoon_sep40	*18.33*	*18.30*	*2.8 %*

NBS with MoonLight – (the Geminga Halo)



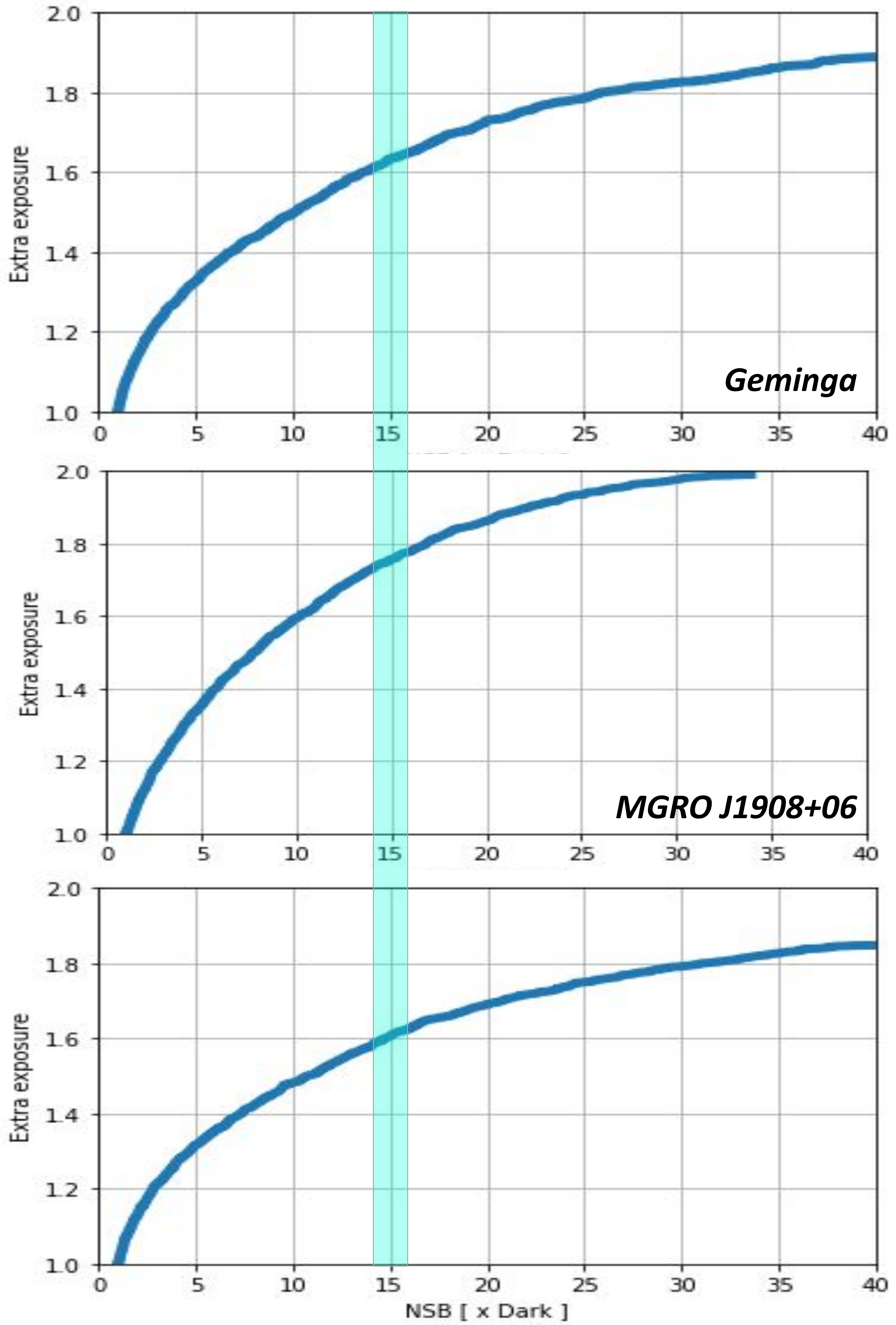




- For year 2026
- Dark : m_V= 21.55

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 ~ 1800 h

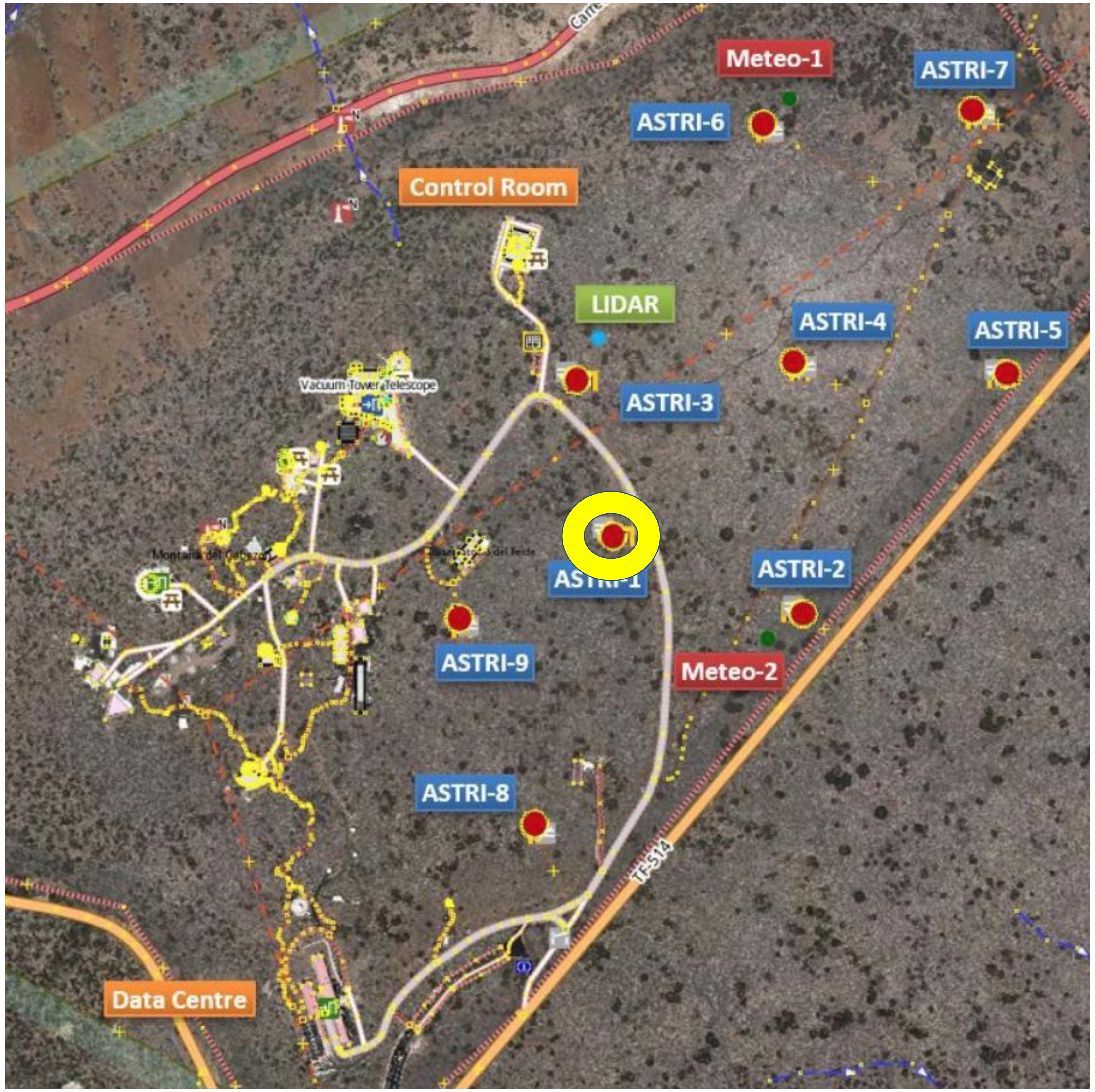
ASTRI Mini-Array - Schedule

June 2022

Phase 0

- 1 Telescope Structure
- m-ICT

Autumn 2022



ASTRI Mini-Array - Schedule

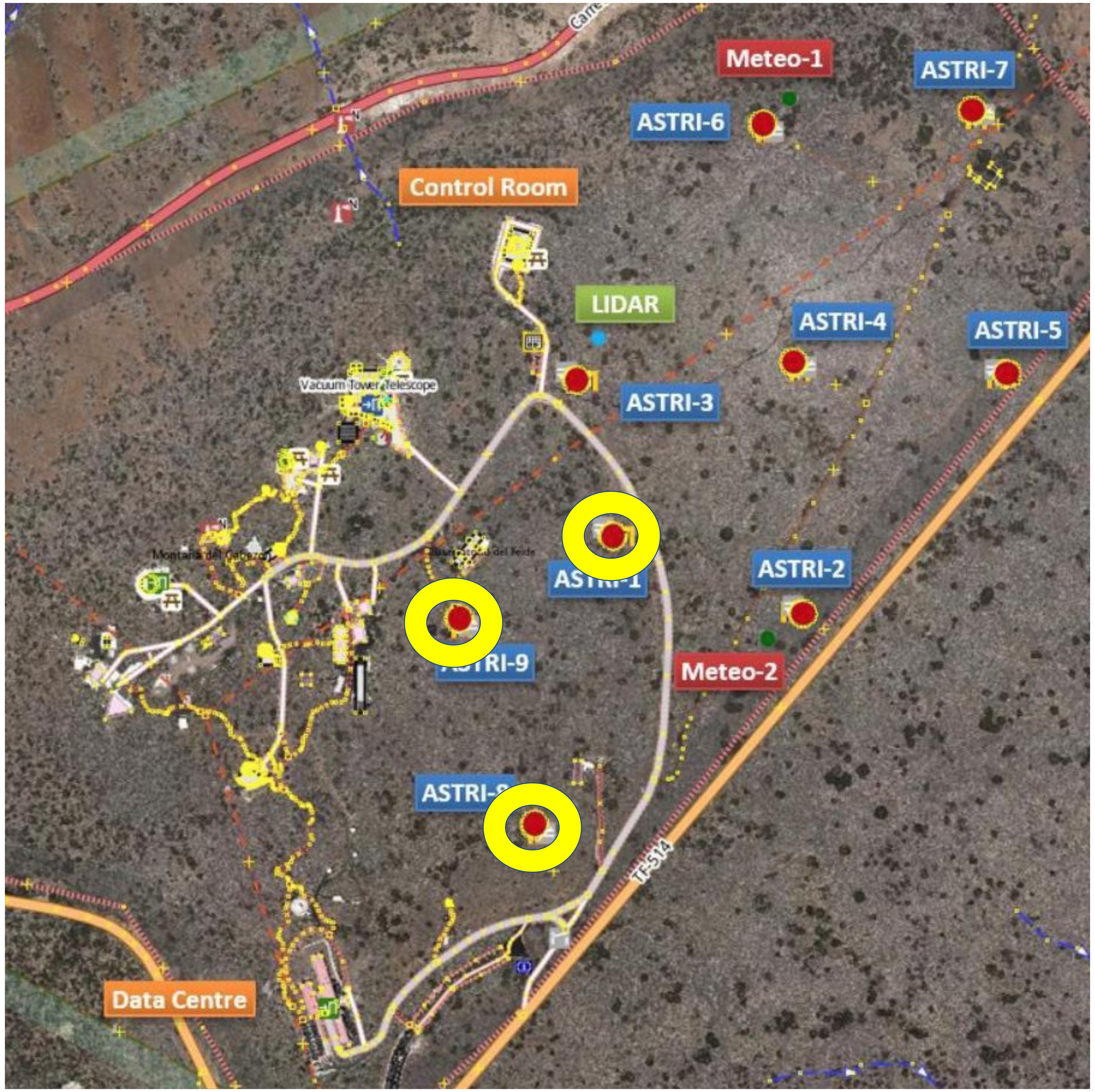
June 2022

Phase 0
- 1 Telescope Structure
- m-ICT

Autumn 2022

Phase 1
- 3 Telescope Structures

Late Spring 2023



ASTRI Mini-Array - Schedule

June 2022

Phase 0

- 1 Telescope Structure
- m-ICT

Autumn 2022

Phase 1

- 3 Telescope Structures

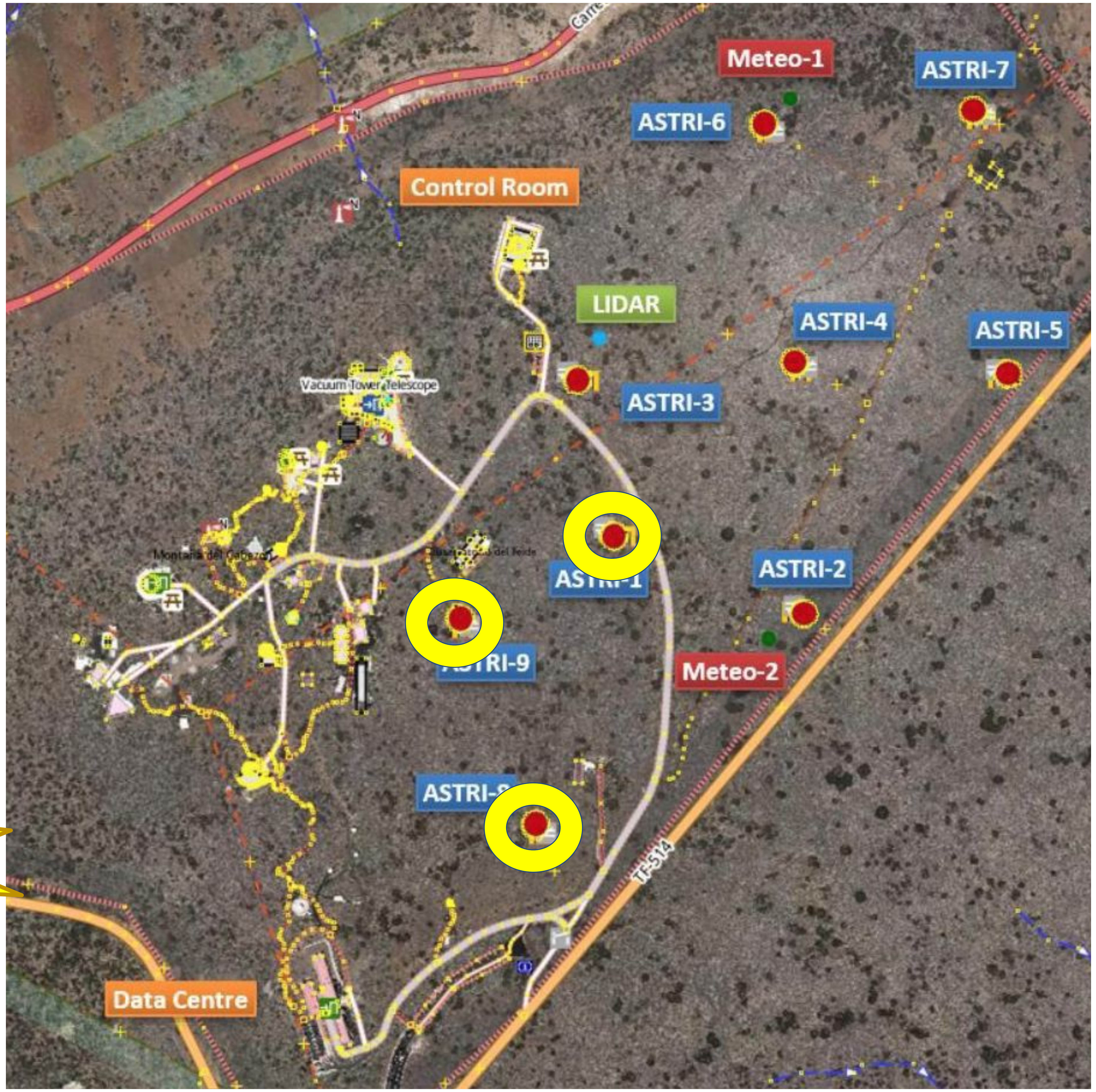
Late Spring 2023

Phase 2

- 3 Telescope Structures + Cameras

Autumn 2023

Early observations



ASTRI Mini-Array - Schedule

June 2022

Phase 0
- 1 Telescope Structure
- m-ICT

Autumn 2022

Phase 1
- 3 Telescope Structures

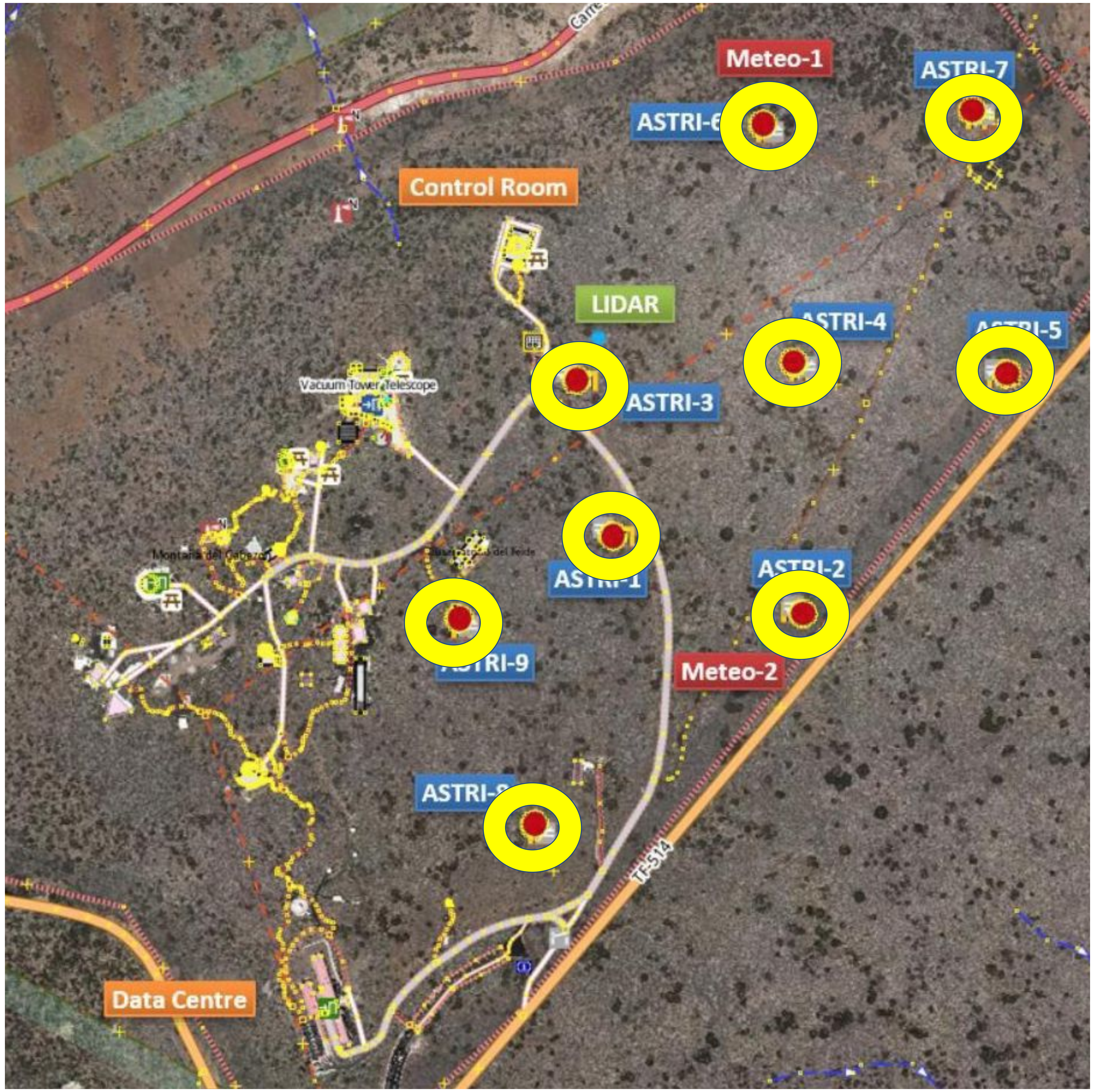
Late Spring 2023

Phase 2
- 3 Telescope Structures + Cameras

Autumn 2023

Phase 3
- Full Array

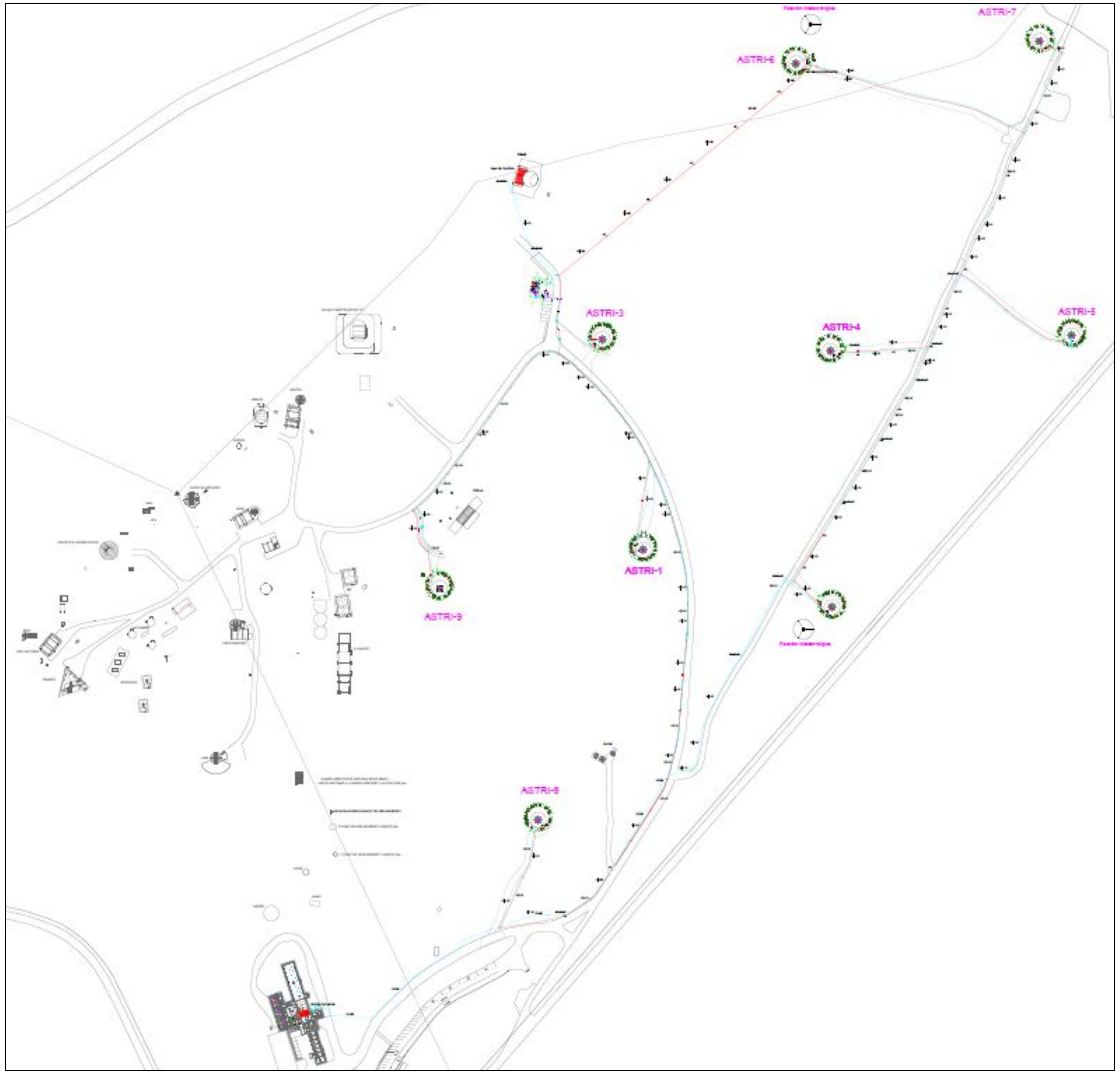
End of 2024



Status of the infrastructure

- All telescope foundations completed
- Excavations and tubes for power and data network completed
- Control room @ Themis completed

- Data Centre completed by half June
- Transformation Centre to be completed by the end of June with UPS and Power diesel generator
- Electric cables & optical fibres being laid



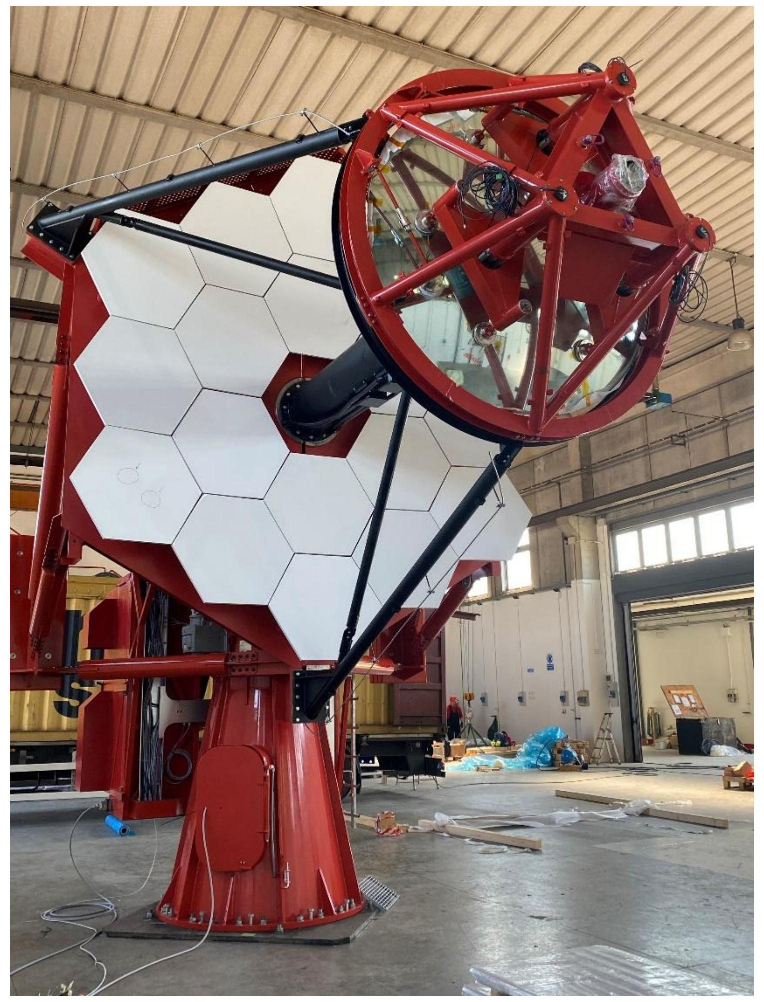
Infrastructure: foundations

ASTRI Mini-Array

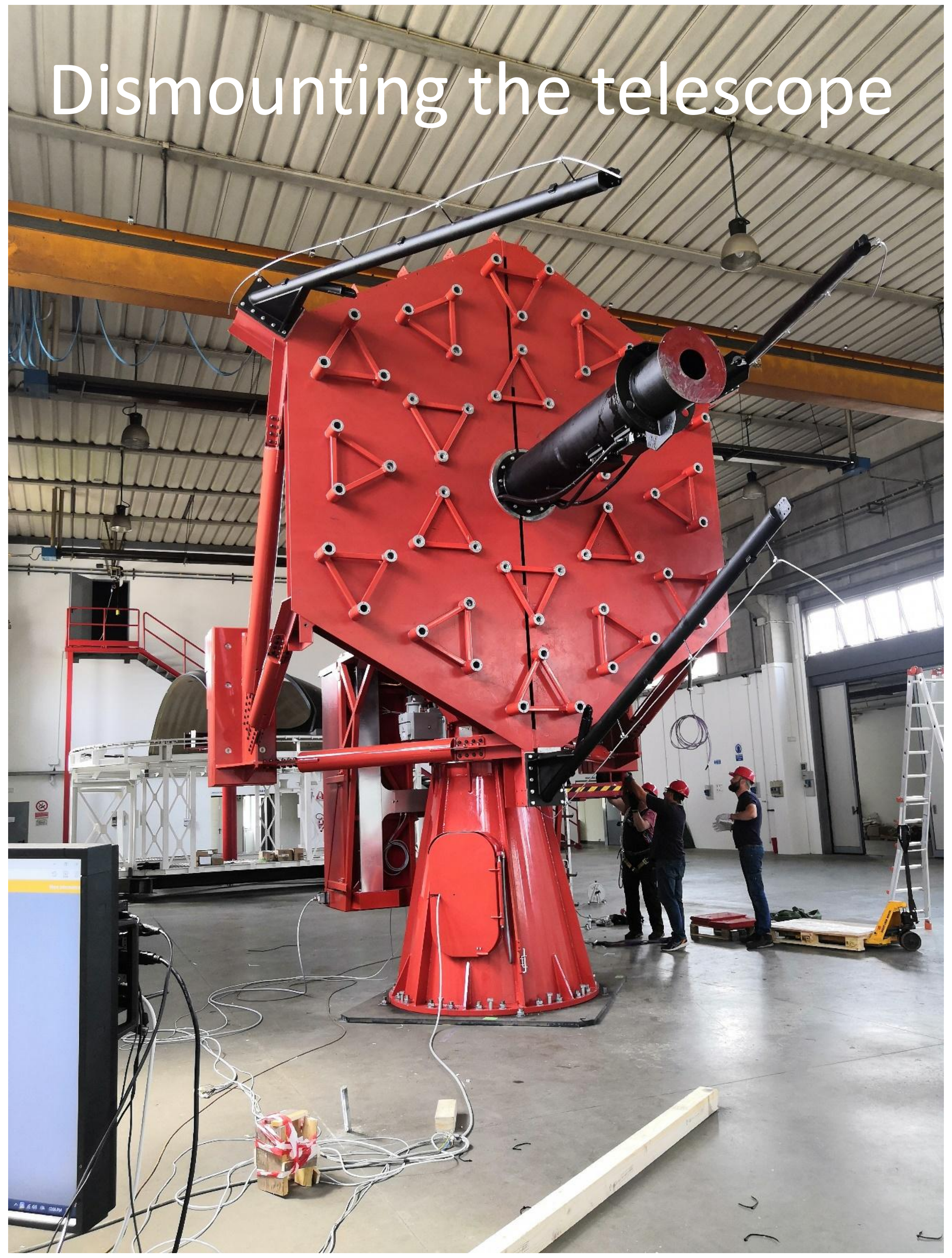
Status of production: ASTRI-1 integration

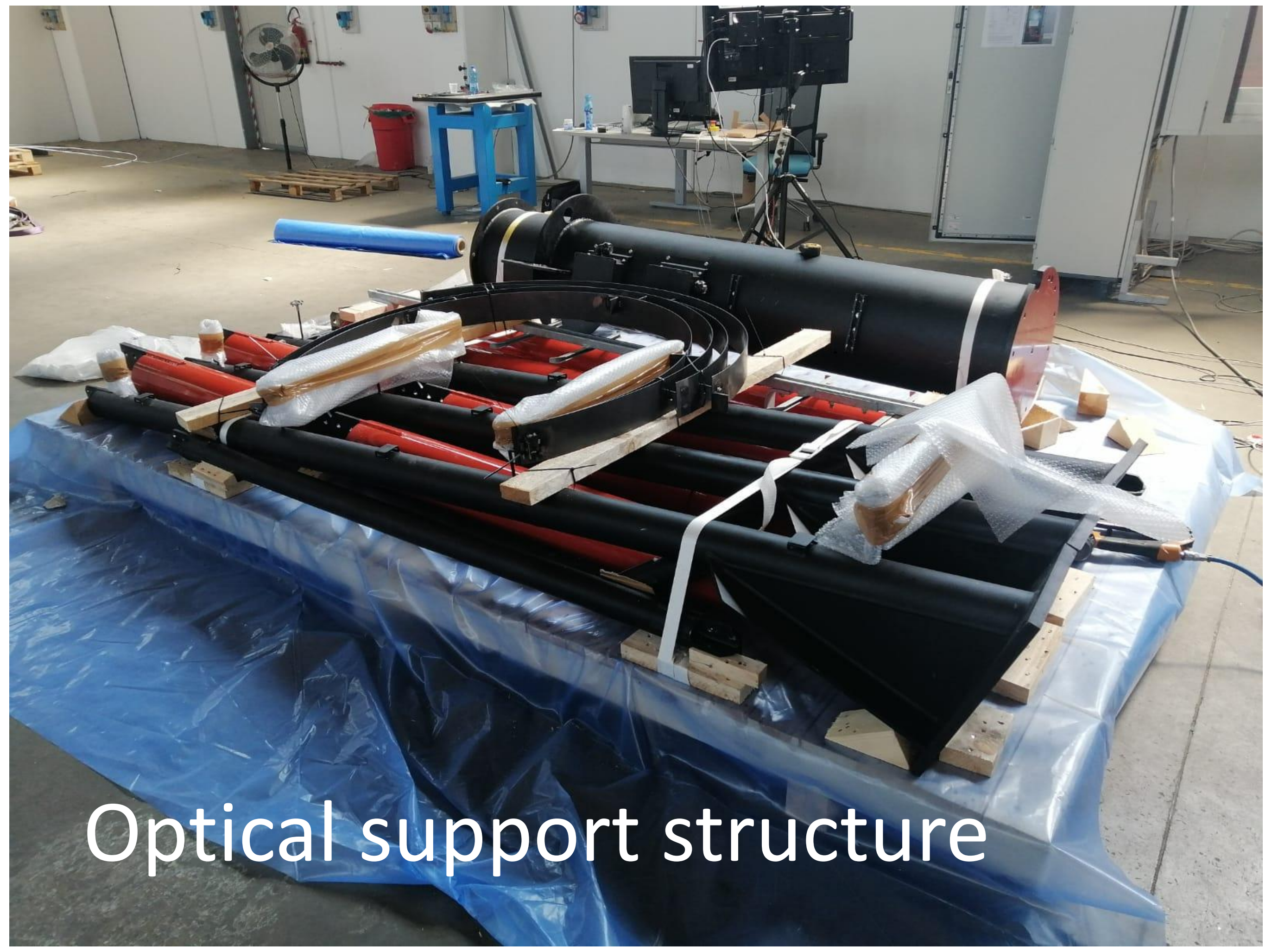
ASTRI Mini-Array

EIE GROUP



ASTRI-1: disassembling, packing and transportation





Assembling ASTRI-1

ASTRI-1

Photo CREDITS Tommaso Marchiori

ASTRI-1 : mirrors

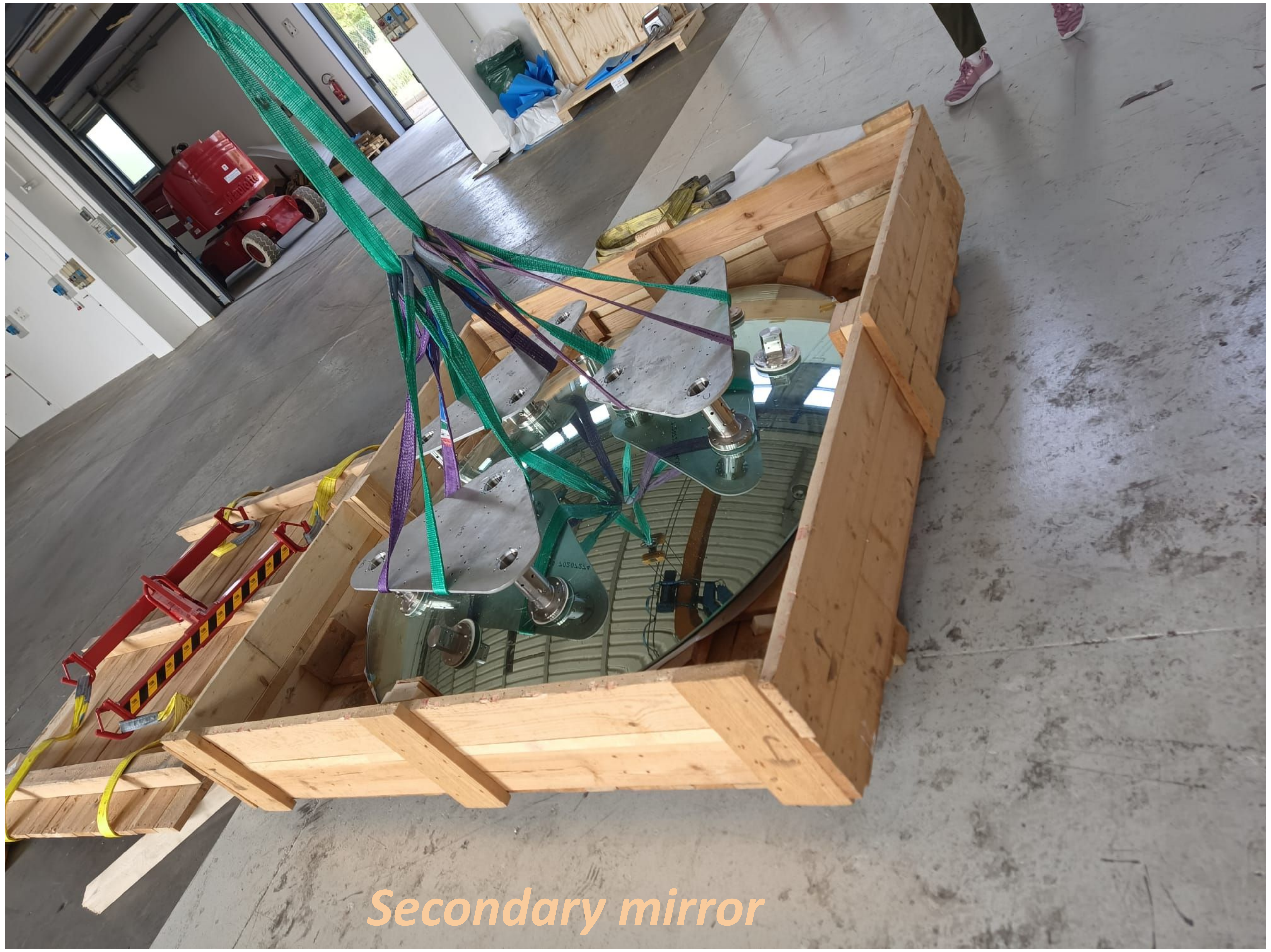


Photo CREDITS Tommaso Marchiori

More at..

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

Science papers on **JHEAP, 2022, 35**

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

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

…THANK YOU !

Photo CREDITS Tommaso Marchiori

Back up slides

The ASTRI Mini-Array – Performance

Mini-Array

- We extend current IACTs **differential sensitivity up to several tens of TeV and beyond**
- Investigate possible spectral features at VHE, such as the presence of **spectral cut-offs** or the detection of emission at several tens of TeV expected from **Galactic PeVatrons**