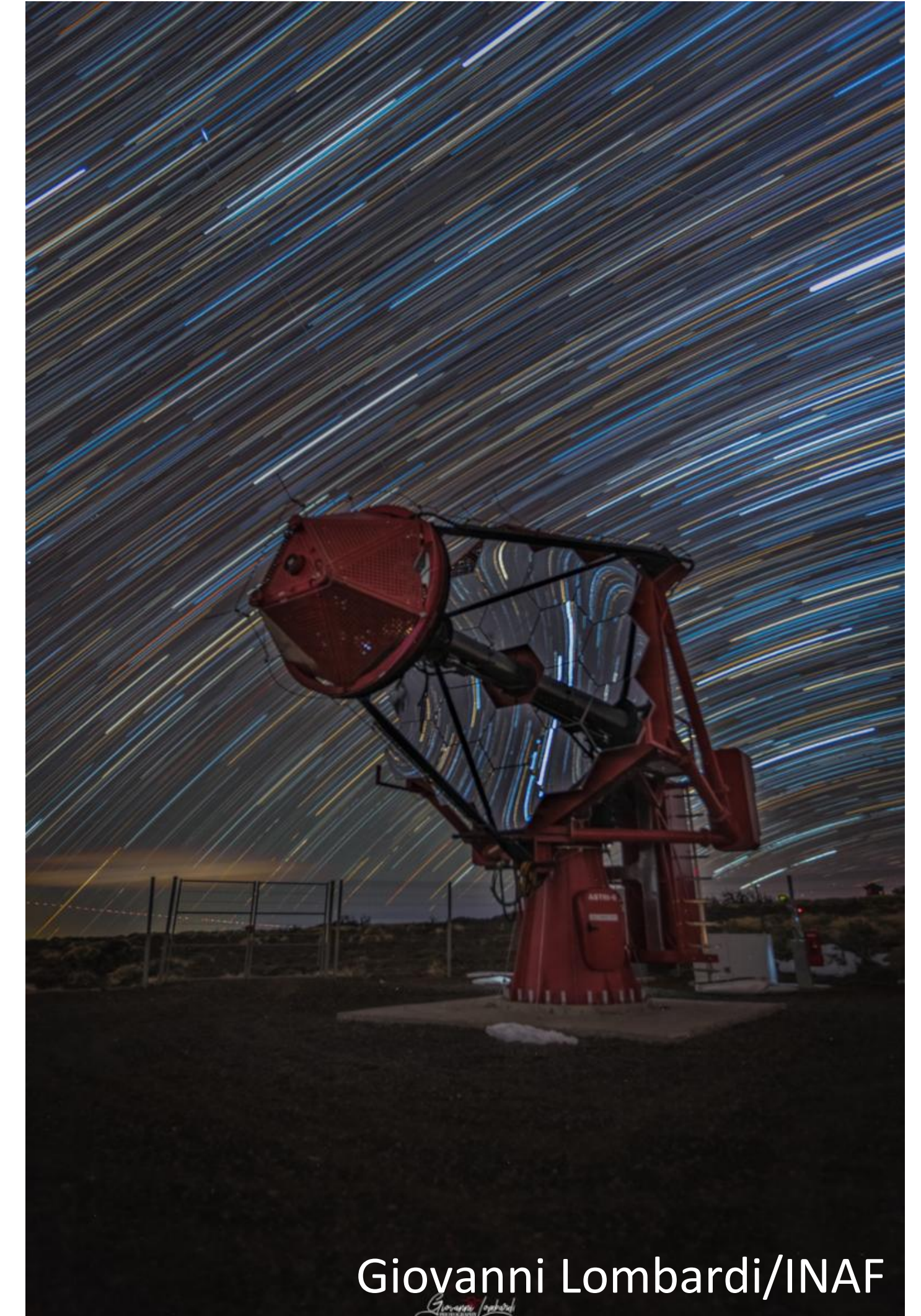




The ASTRI Mini-Array

- The **ASTRI Mini-Array** is a next-generation ground-based gamma-ray experiment including **nine** identical 4-meter class Imaging Atmospheric Cherenkov Telescopes (IACTs).
- It aims to **explore the largely uncharted 1–200 TeV** energy range with exceptional angular and spectral performances and wide field of view.

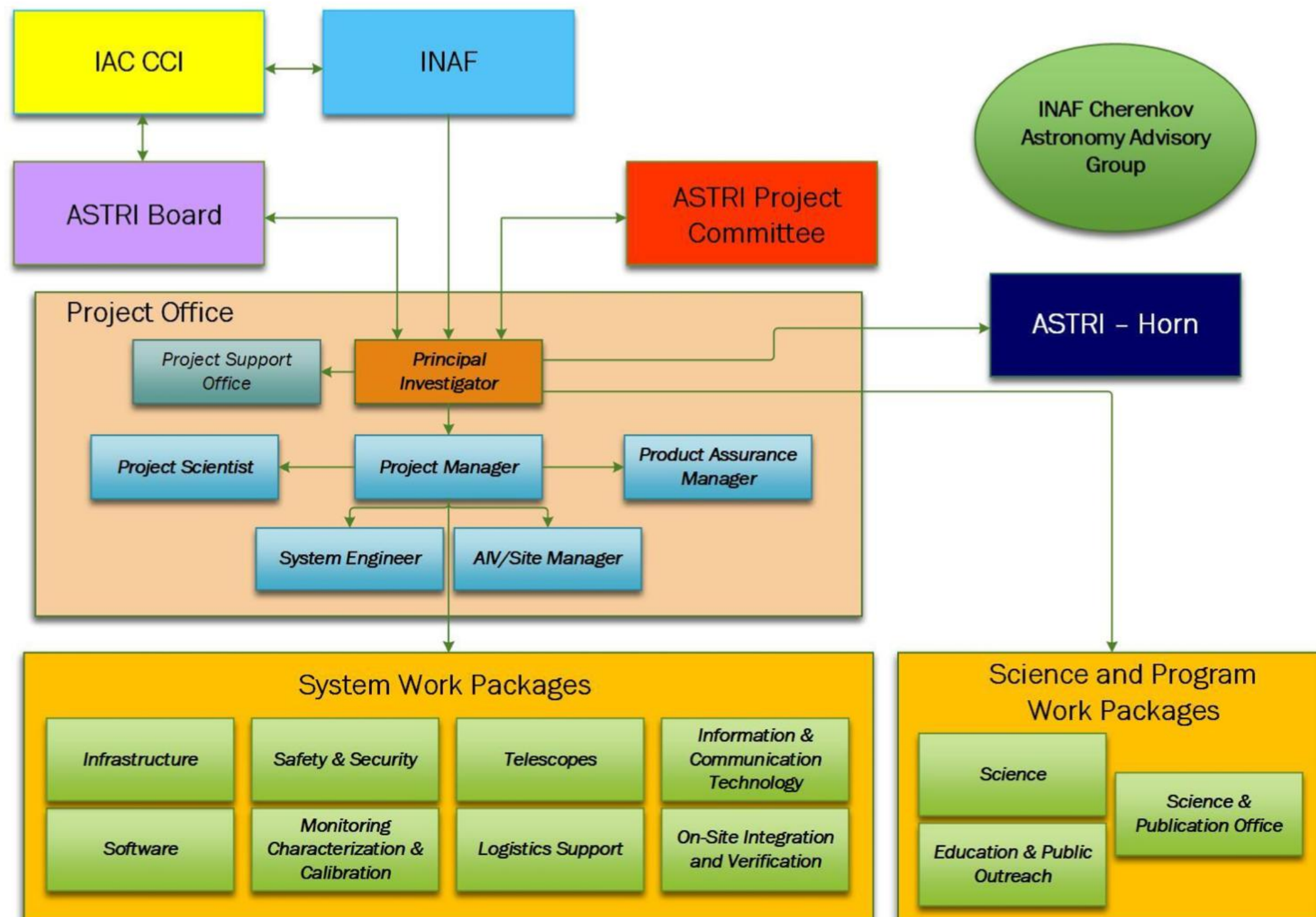


Giovanni Lombardi/INAF

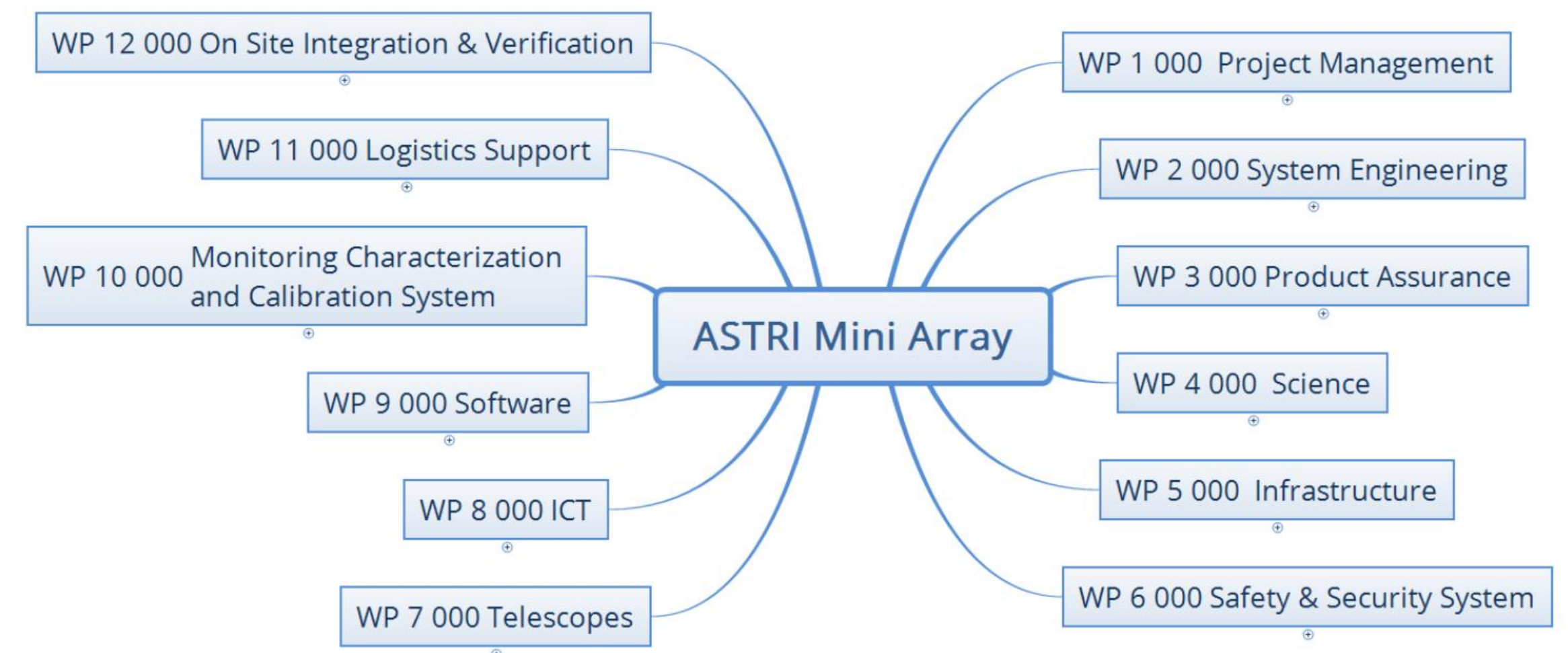
ASTRI Mini-Array Project: organization

- About **200 researchers** belonging to **INAF** institutes (IASF-MI, IASF-PA, OAS, OACT, OAB, OAPD, OAR, OAA, IAPS, OATS, OAPA), **Italian Universities** (Uni-PG, Uni-PD, Uni-CT, Uni-TS, Uni-GE, PoliMi), **INFN**, **Fundacion Galileo Galilei**, **IAC** (Spain), **University of Sao Paulo** (Brazil), **North-West University** (South Africa), **Université & Observatoire de Genève** (CH).

Principal Investigator: Giovanni Pareschi
Program Manager: Salvo Scuderi
Project Scientist: Andrea Giuliani
System Engineer: Gino Tosti
PA – Quality Manager: Nicola La Palombara
User Groups Coordinator: Stefano Vercellone



Work Breakdown Structure



ASTRI Mini-Array Science



A rich menu of scientific topics will be accessible with the Astri Mini-Array

Origin of Cosmic ray:

- PeVatrons
- CR acceleration and propagation
- Pulsar wind nebula and TeV Halos
- Blazars

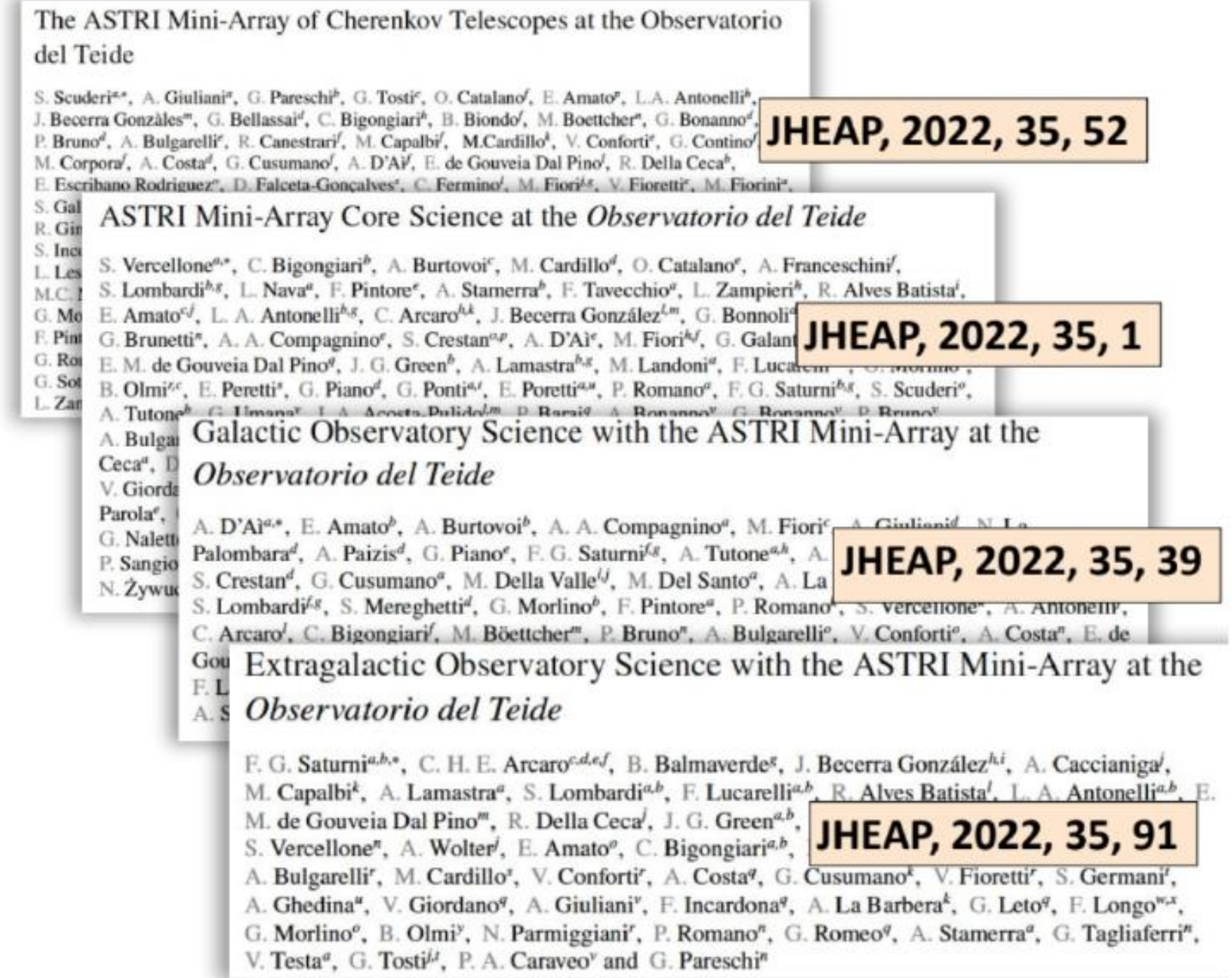
Fundamental Physics

- Intergalactic fields
- LIV, ALP and DM

Transient Follow-up

Non-gamma-ray science (e.g., Stellar Interferometry)

See talks by: Vercellone, Quartiroli, Sunny, La Palombara, Vercellone, Carosi, Zampieri



- **Science Program** : 4 (Core) + 4 (Observatory)
- **Important synergies** with other Northern ground-based gamma-ray facilities (LHAASO, HAWC, MAGIC, VERITAS, CTAO-N)

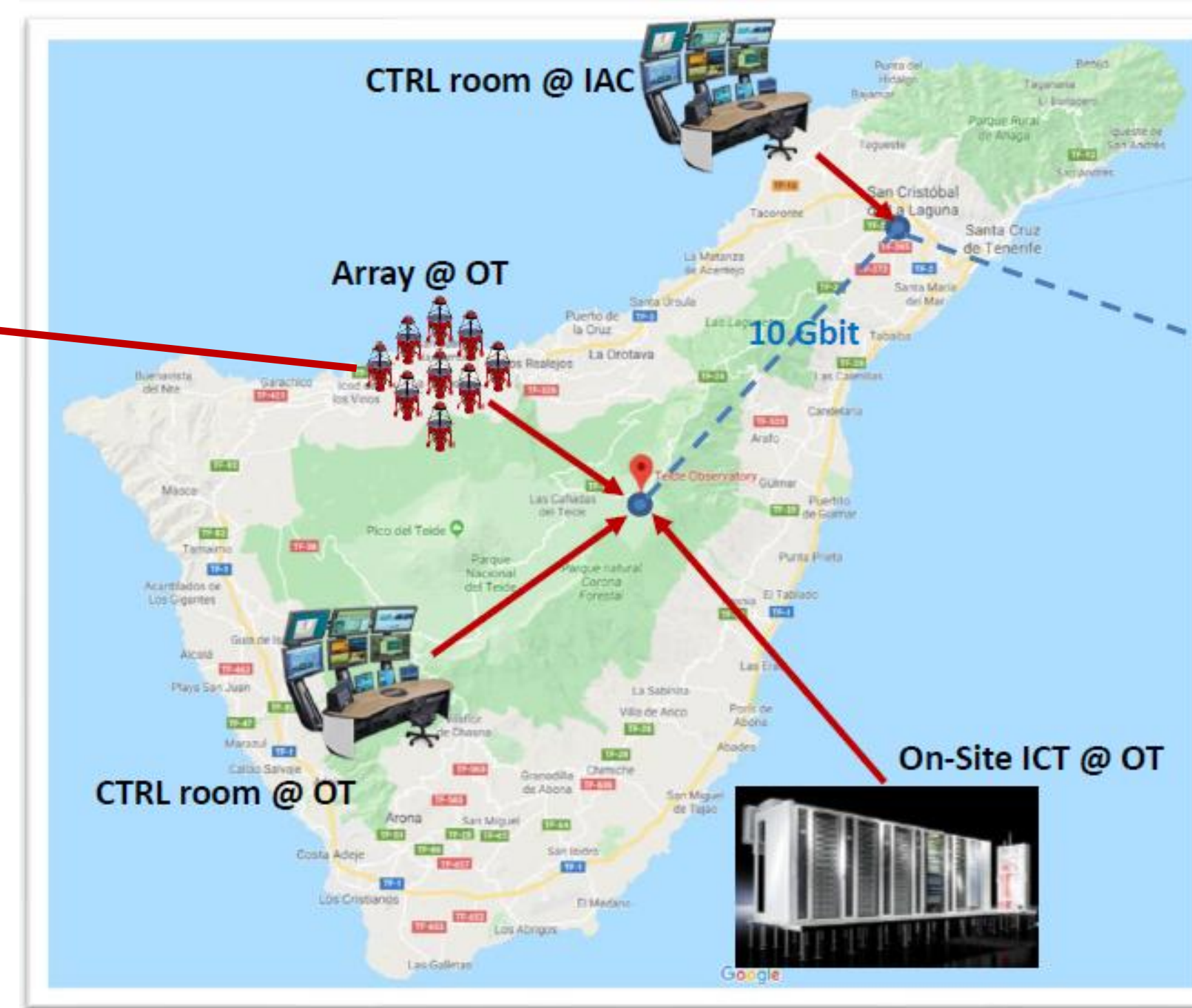
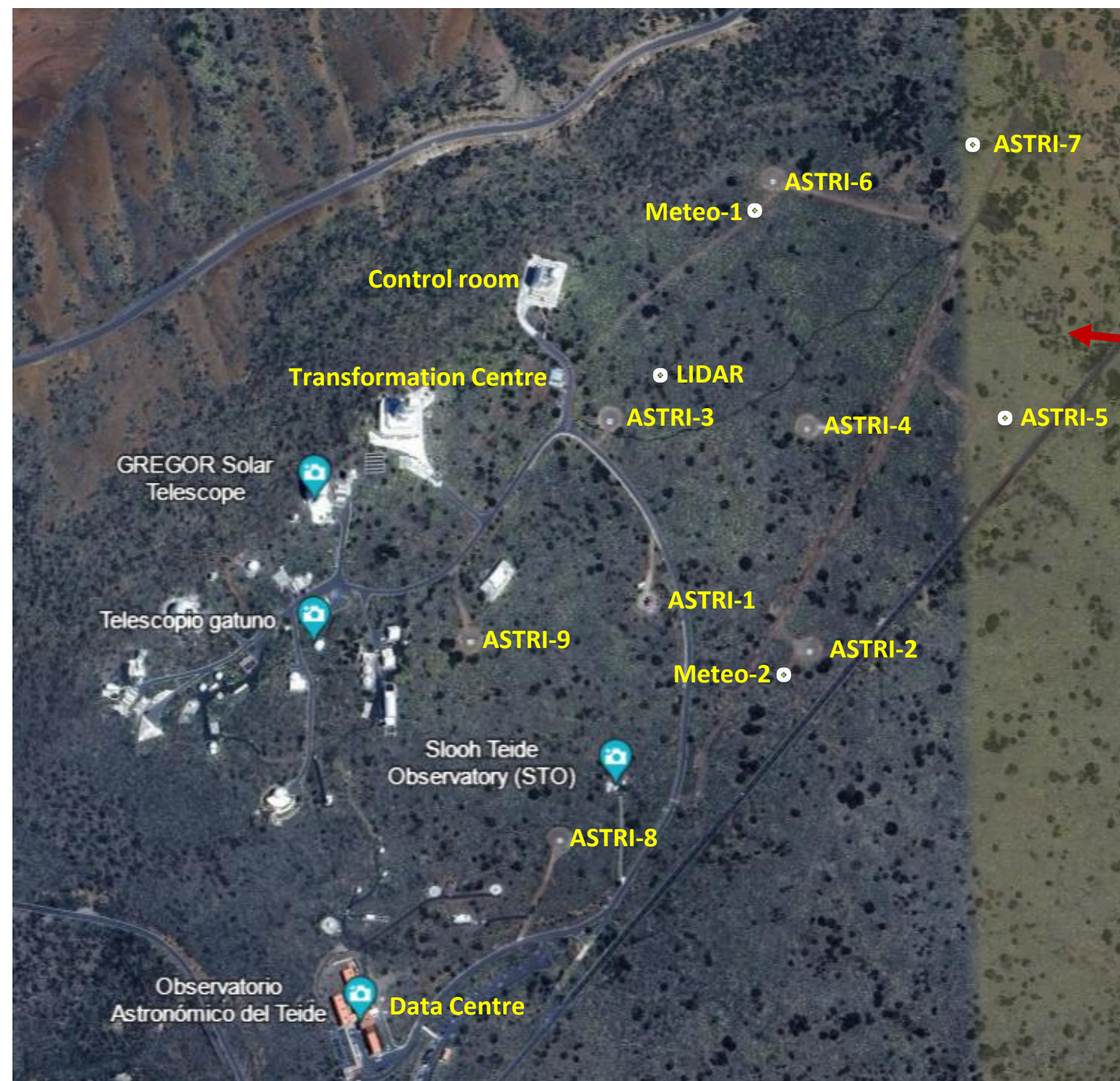
ASTRI Mini-Array: Locations

The ASTRI Mini-Array in Tenerife

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

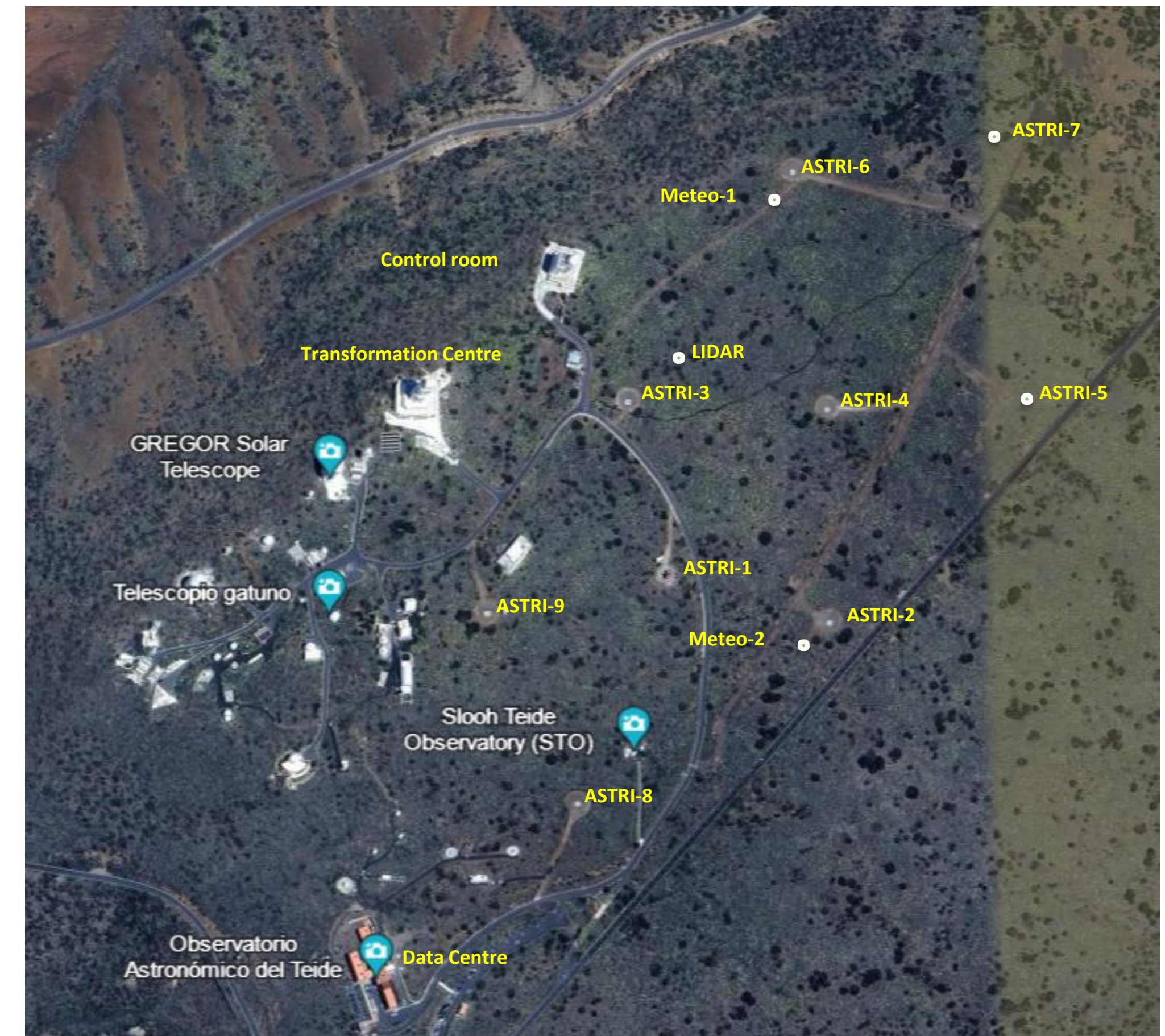
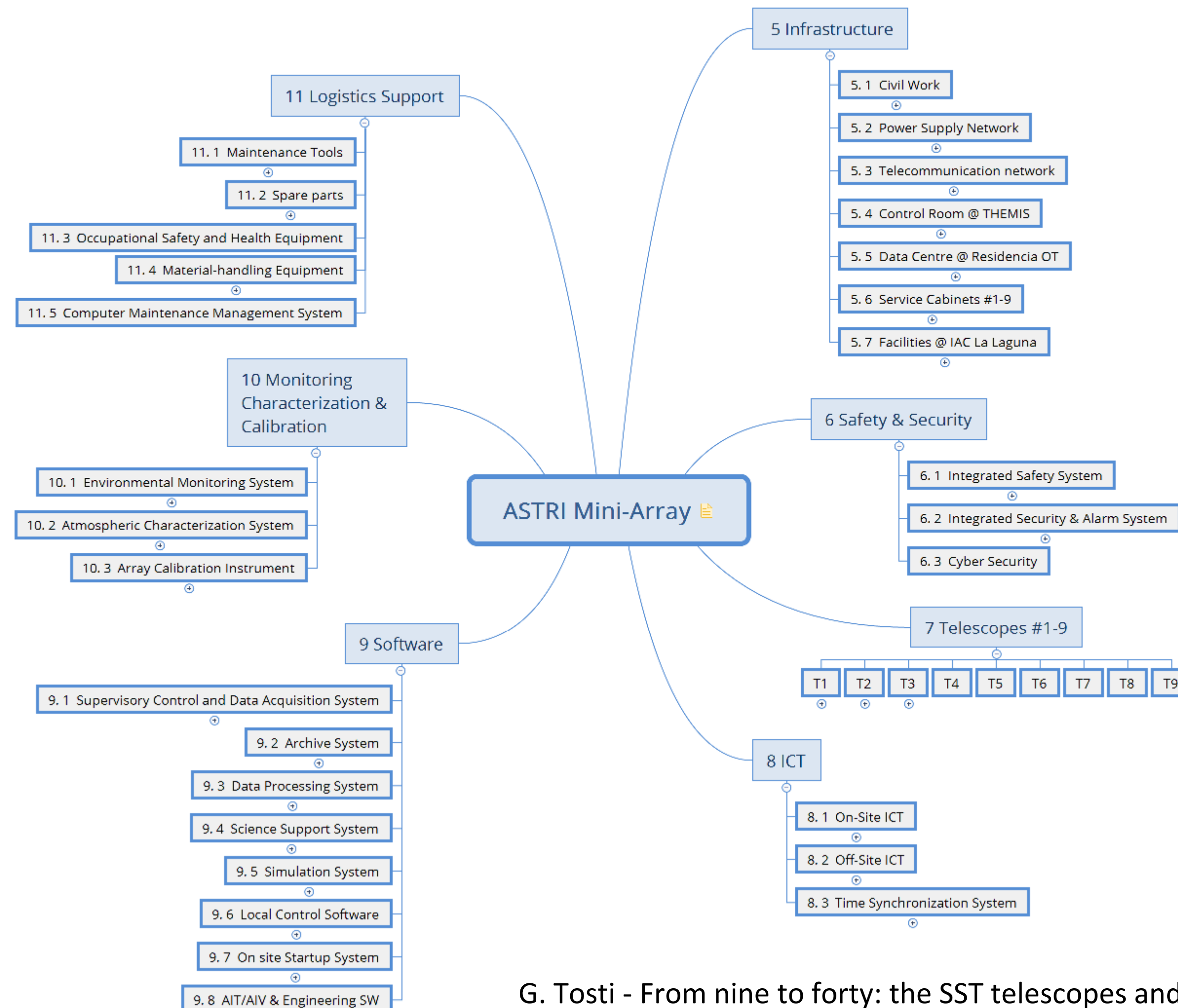
The ASTRI Mini-Array in Italy

- Data Centre in Rome
- Remote Array operation centers



ASTRI Mini-Array: A Complex Infrastructure

The Astri Mini- Array is being realized with an end-to-end approach, from design/implementation of all HW/SW components to dissemination of final scientific products.



ASTRI Mini-Array: Telescope

- **Dual-mirror optical layout**
First time for Cherenkov telescopes
Schwarzschild-Couder optical design (see Sironi's talk)
Optimal PSF across the entire FoV
- **Silicon photo-multipliers camera** (see Contino's talk)
Small pixel-size (0.19°)
Can work during moonlight condition
- **Wide FoV ($>10^\circ$)**
Important for surveys and multi-target fields
Important for extended sources
Serendipity sources
- **Single telescope performance** (see Vercellone's talk)
Energy threshold around 1 TeV
Energy resolution $< 25\%$
Angular resolution $< 0.25^\circ$
Sensitivity 1 Crab @5 in few hours

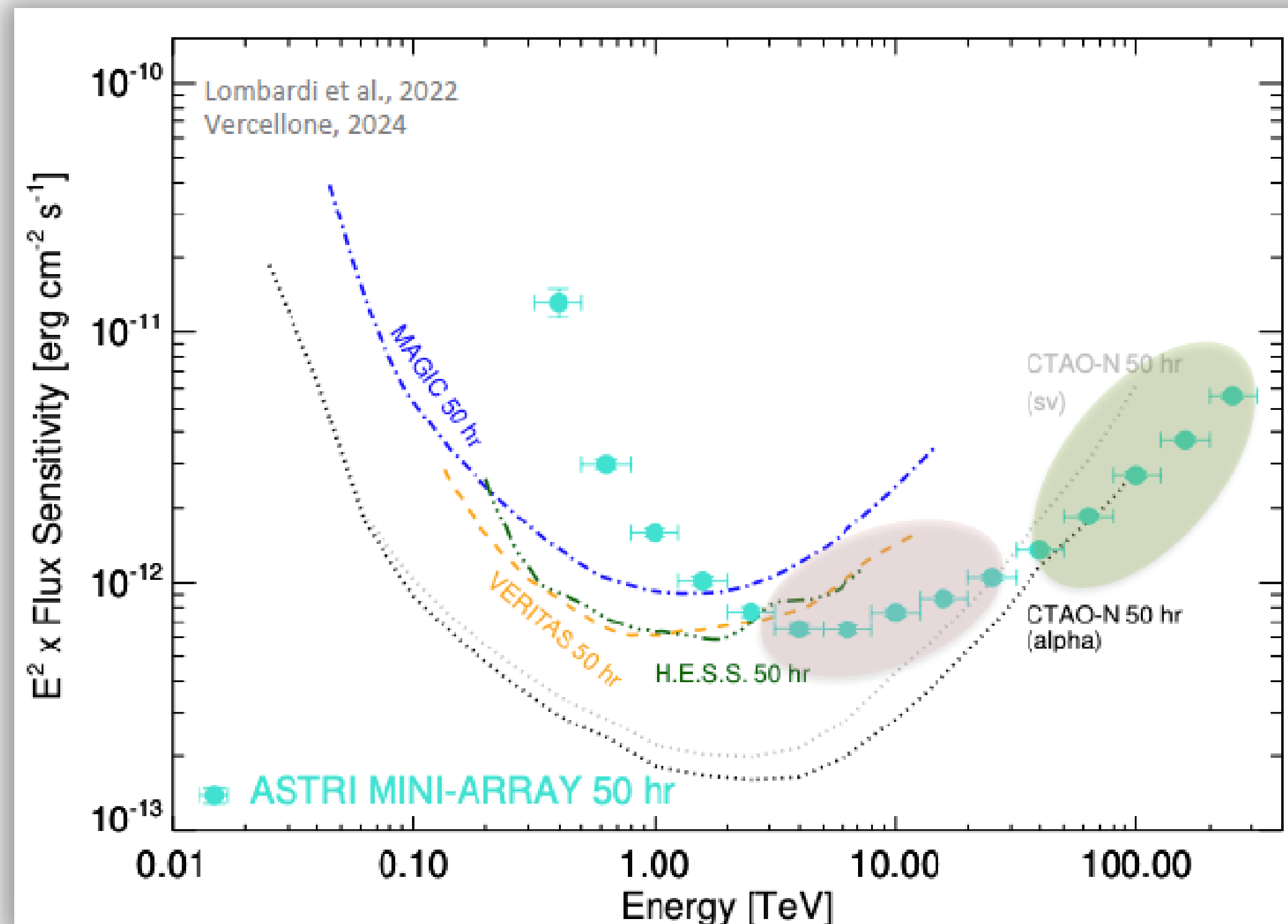


Giovanni Lombardi/INAF

ASTRI Mini-Array – Array Performances

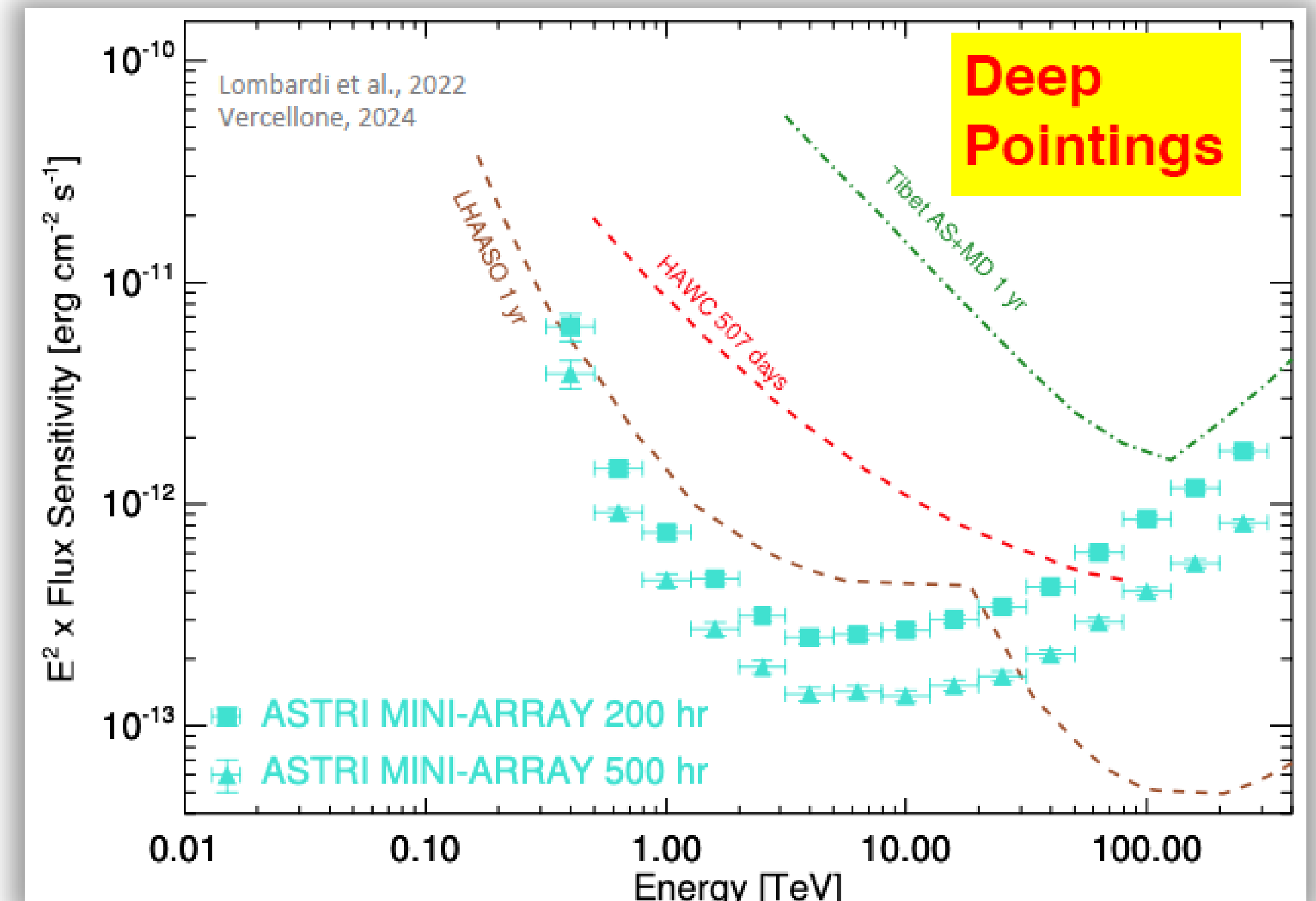
We extend current IACTs **differential sensitivity up to several tens of TeV and beyond**

Broad-band spectra

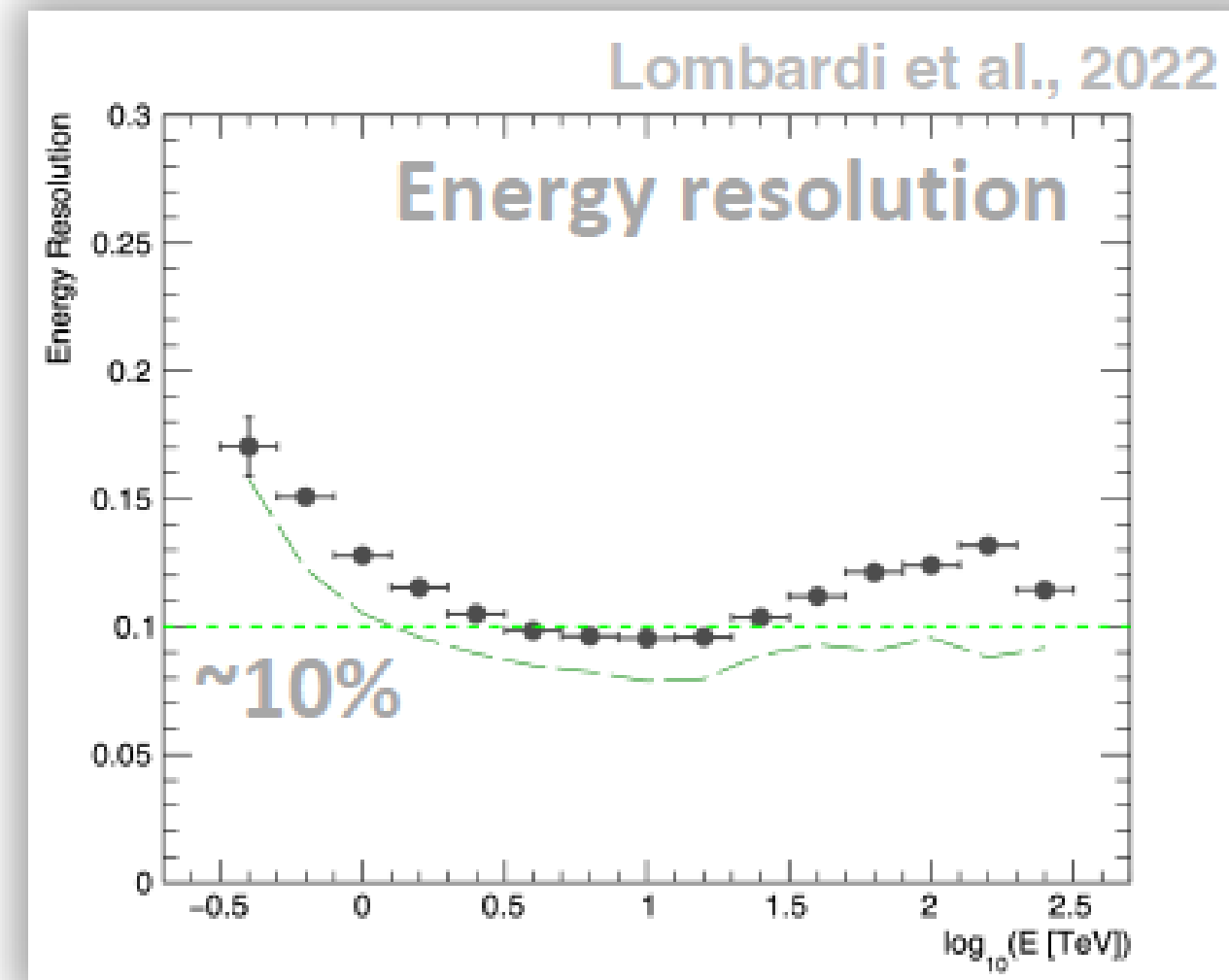
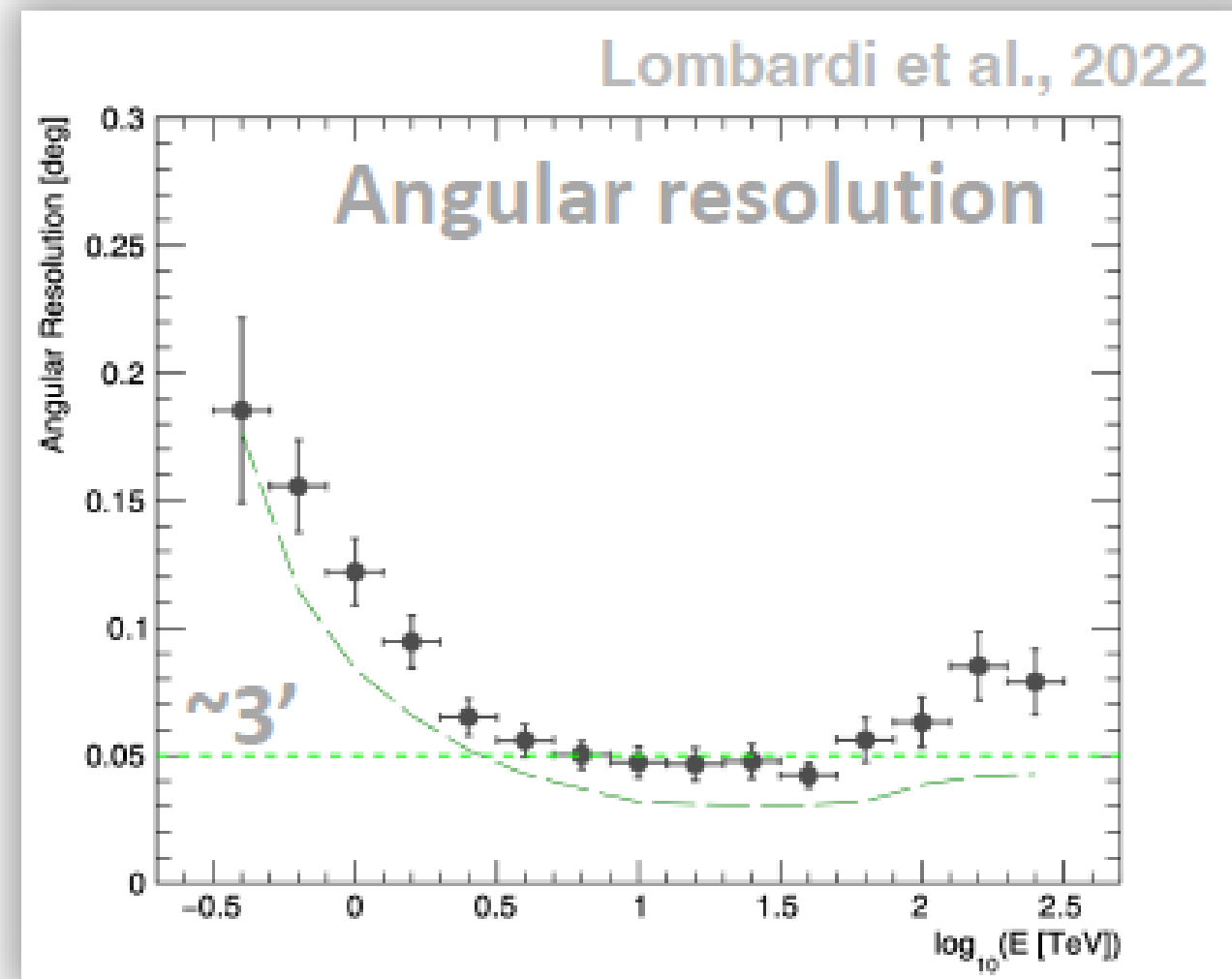


Spectral features at VHE, such as **spectral cut-offs**

Detection of **emission up to (100-200) TeV** expected from **Galactic PeV sources**



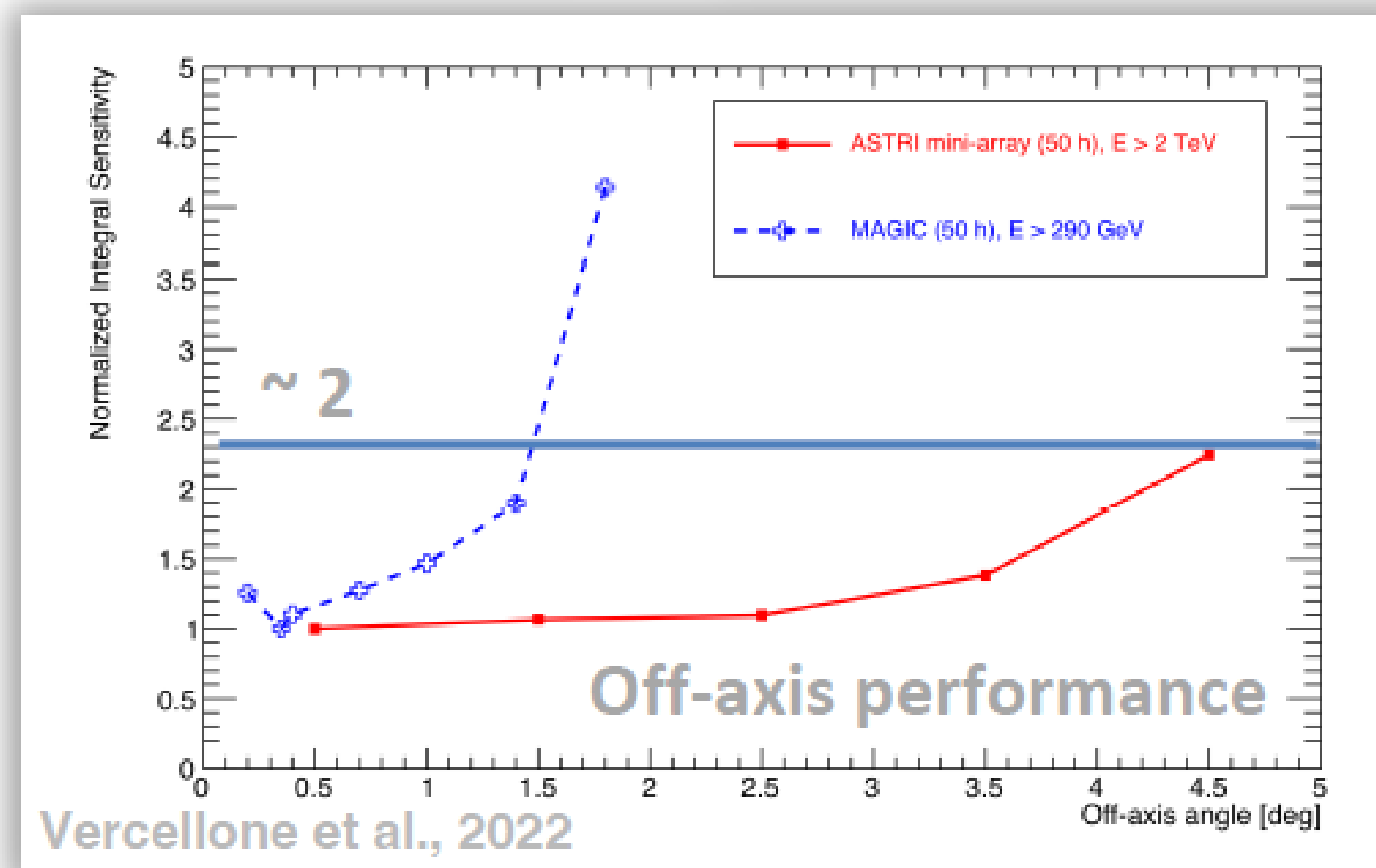
ASTRI Mini-Array – Array Performances



Angular resolution: $\sim 3'$ ($E \sim 10$ TeV)

Energy resolution: $\sim 10\%$ ($E \sim 10$ TeV)

- Morphological and spectral studies of extended sources at VHE

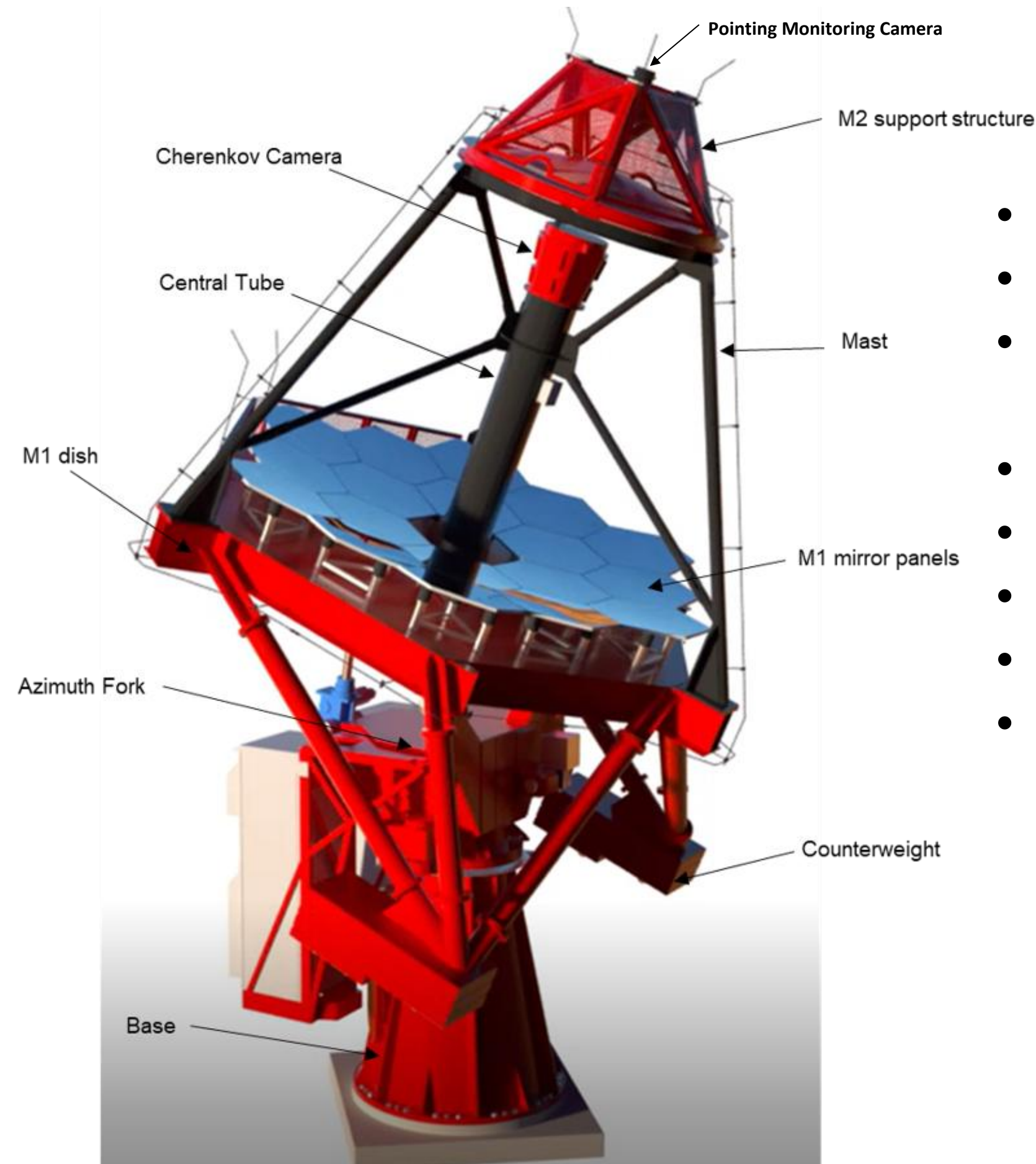


10° field of view with excellent off-axis performance

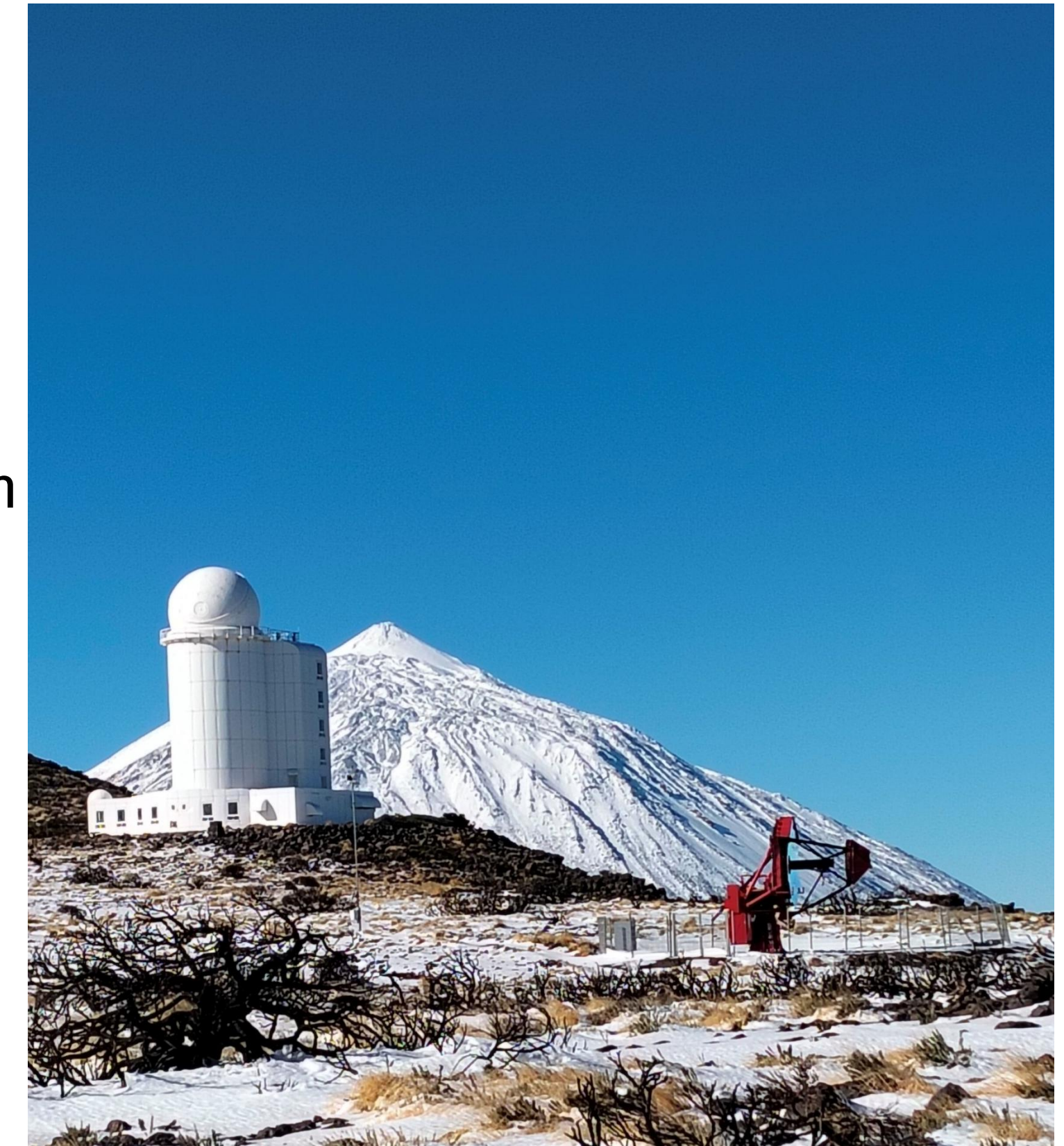
- Several sources in single pointing
- Serendipitous discoveries

ASTRI Mini-Array: Telescopes

**Contribution to opto-mechanics design and production from several companies:
DAL BEN SpA, EIE Group Srl, Media Lario Srl, Flabeg, Vetrolamp, Cilas, ZAOT**



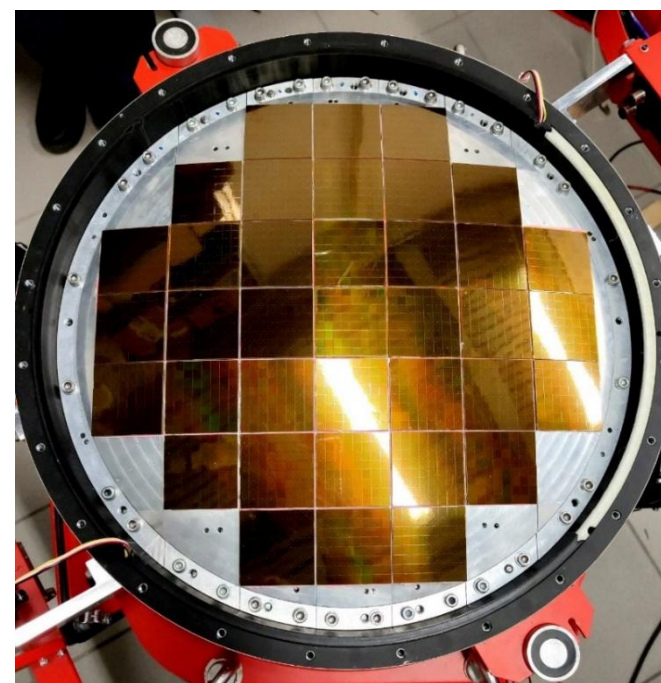
- Alt-azimuthal mount
- Total weight: 17.5 tons
- Dimensions: 8.6 m pointing at zenith, 7.5 m pointing at the horizon
- Modified Schwarzschild-Couder configuration
- Primary Mirror: 4.3 m (18 segments)
- Secondary Mirror: 1.8 m (monolithic)
- F-number: 0.5
- Average effective area $> 5.0 \text{ m}^2$



Cherenkov cameras

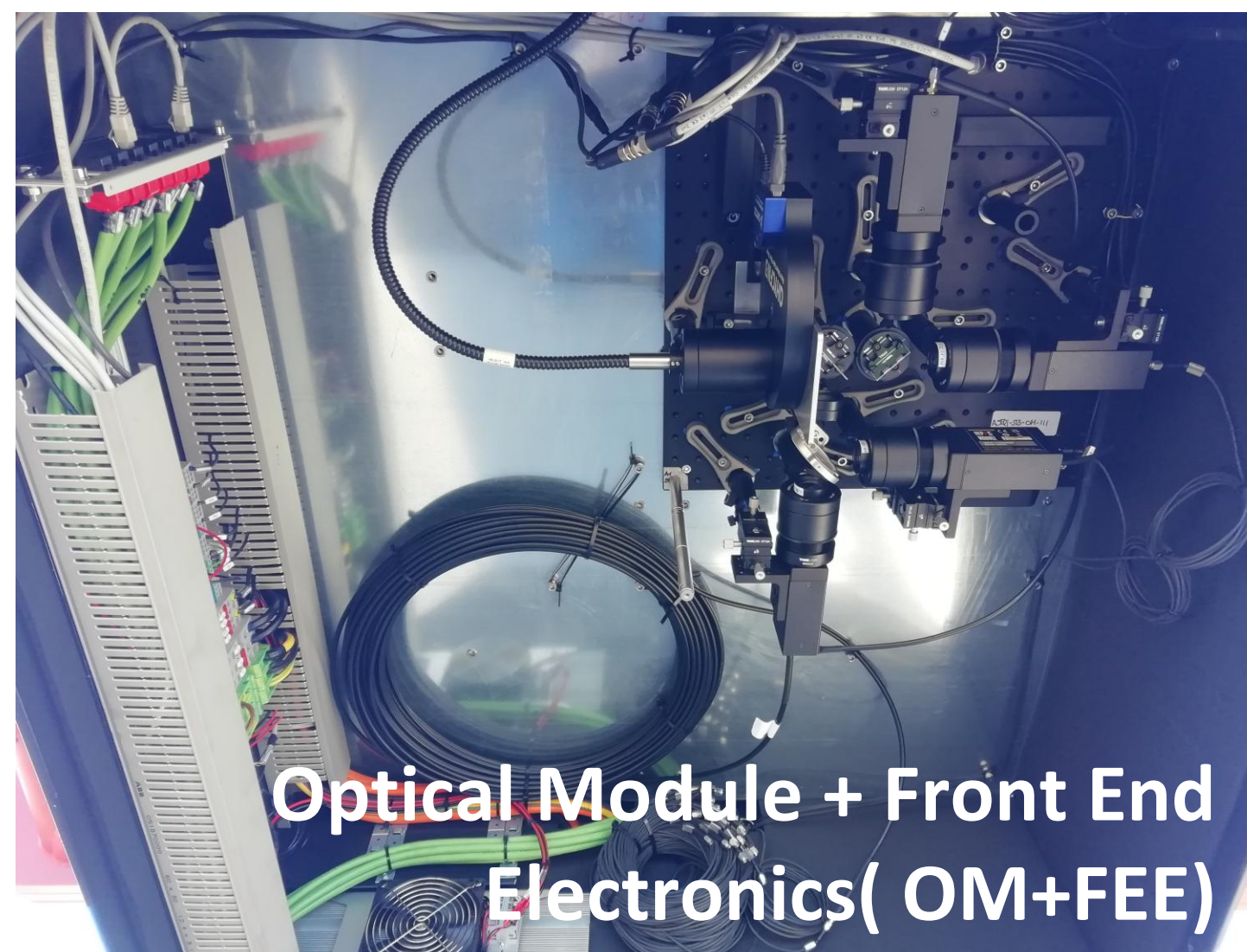
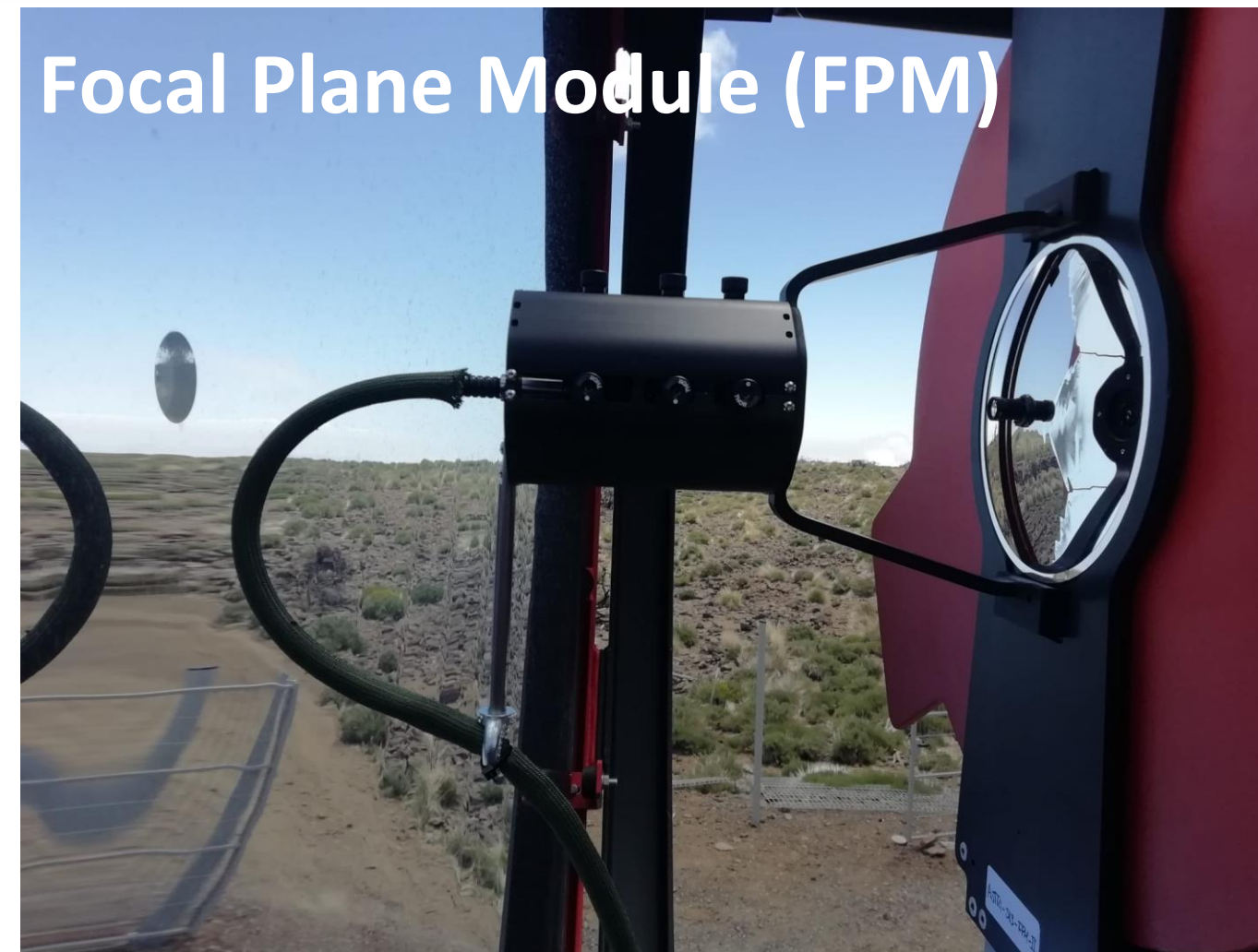
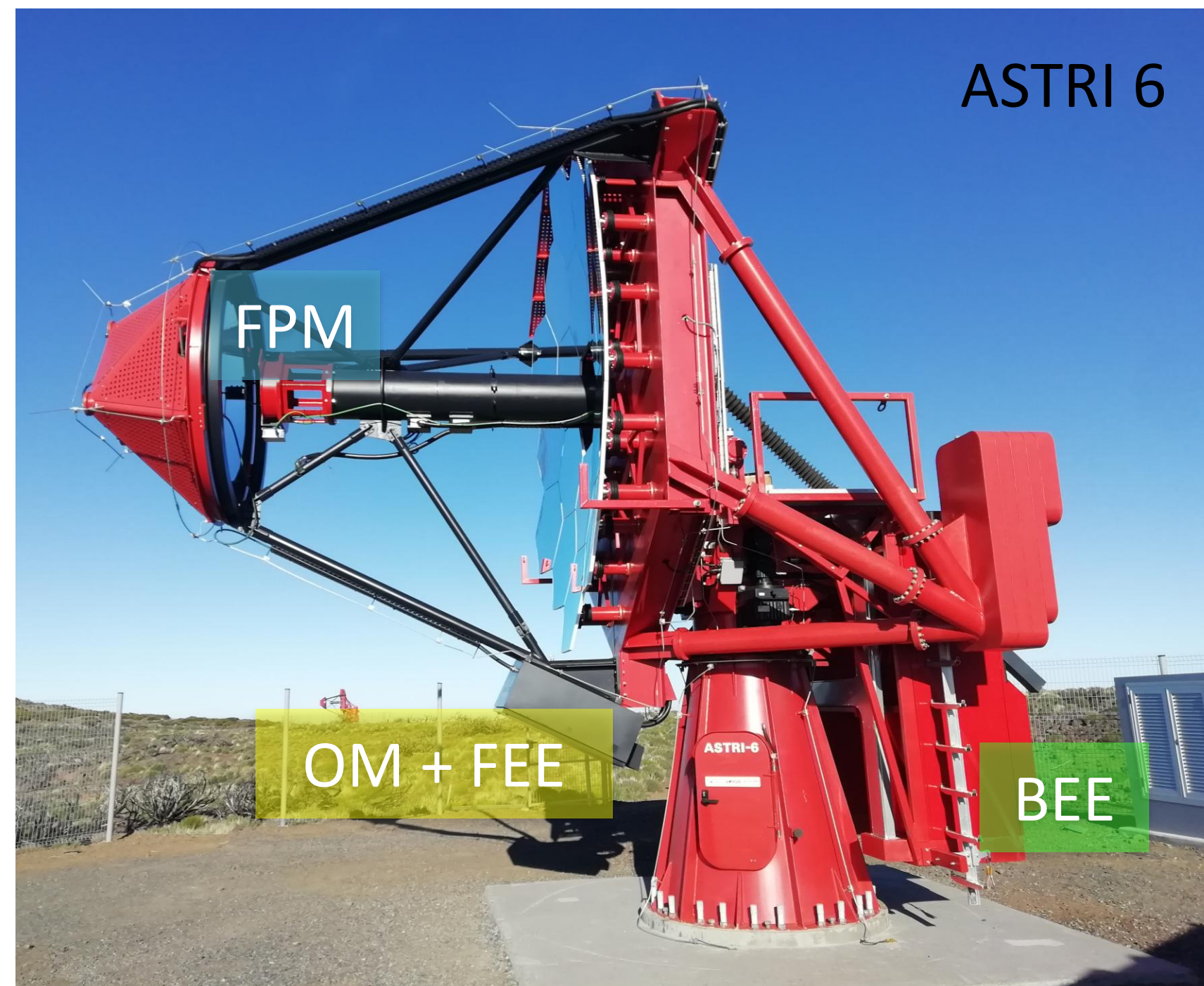
**Contribution to camera design (mainly INAF) and production from several companies:
CAEN SpA, EIE Group Srl, Nuclear Instruments, Hamamatsu Photonics, Weeroc, UMAS**

- **SiPM sensors:** 7x7 mm (series LV3 – 75 μm pixel size)
- 2368 pixels (37 matrices of 8x8 pixels)
- Angular pixel size: 0.19 deg
- Field of View: 10.5 deg
- Power consumption: 1600 W
- Weight: 100 kg
- Filter Window with multilayers dielectric coating
- Thermal control system based on TEC (no chiller)
- **Front-end electronics based on CITIROC-1A ASIC $\rightarrow$ signal shaping not sampling**
- Dynamical range 1 – 2000 pe^-/pixel
- Event Rate ≥ 1 kHz
- Variance channel



follow Contino's talk for details

Stellar Intensity Interferometry Instrument



Commissioning just started

follow Fiori and Zampieri talk for details

ASTRI Mini-Array: Weather Stations



Dashboard for real-time data visualization for night-shift operators



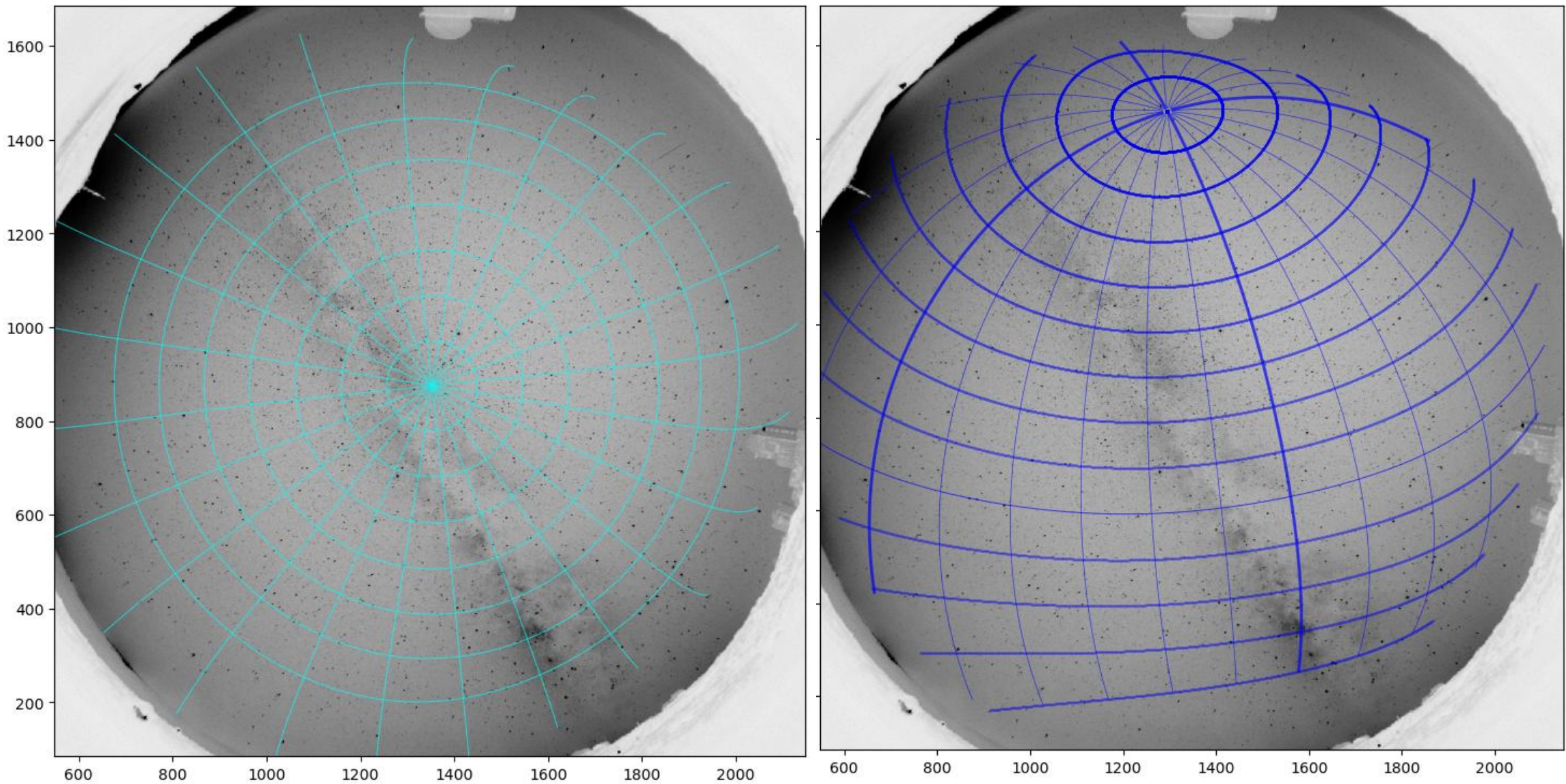
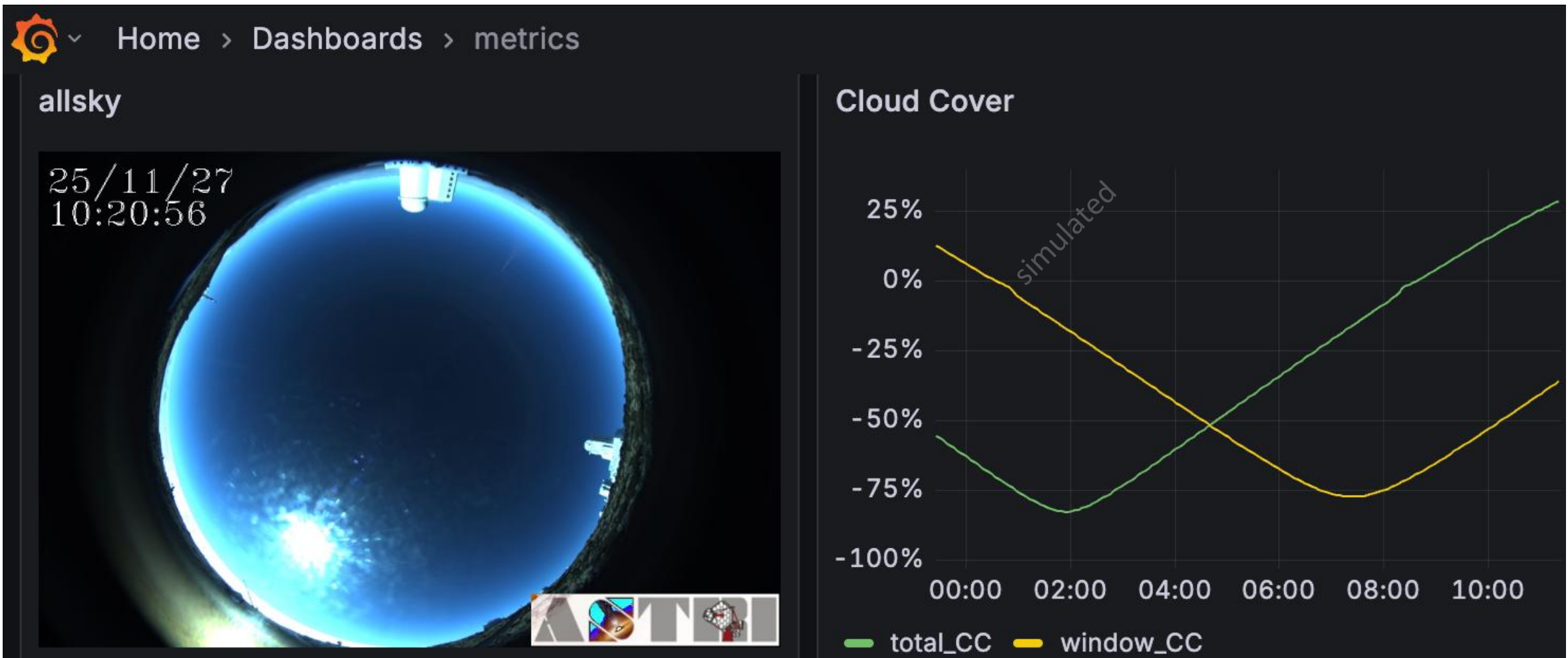
- Rain gauge
- Air temperature and humidity sensors
- Anemometer
- Solar radiation sensor
- UV radiation sensor
- Barometric sensor



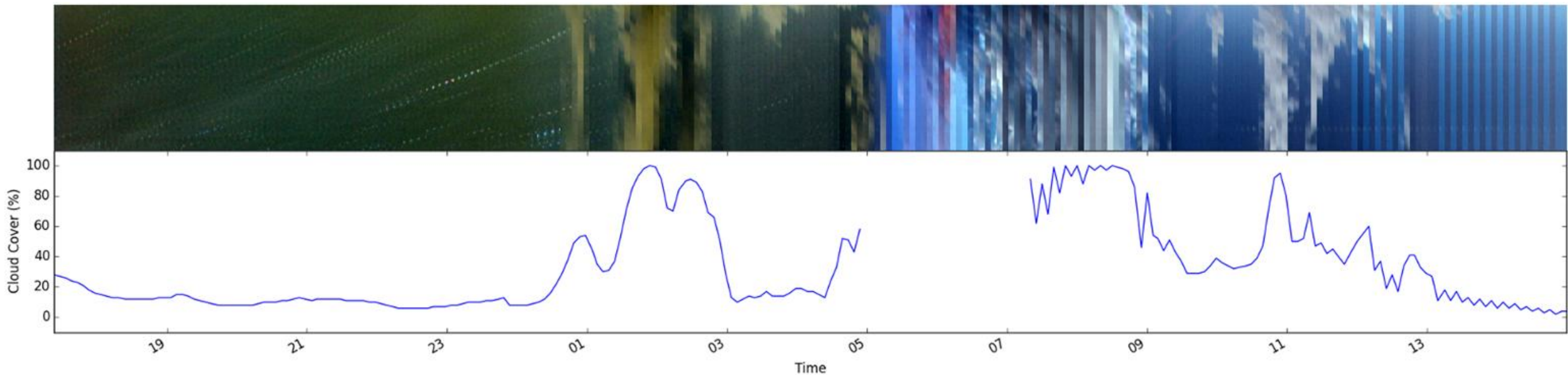
ASTRI Mini-Array: All Sky Camera



- ✓ Hardware installation
- ✓ OPC-UA server
- ✓ WCS
- ☐ Cloud detection

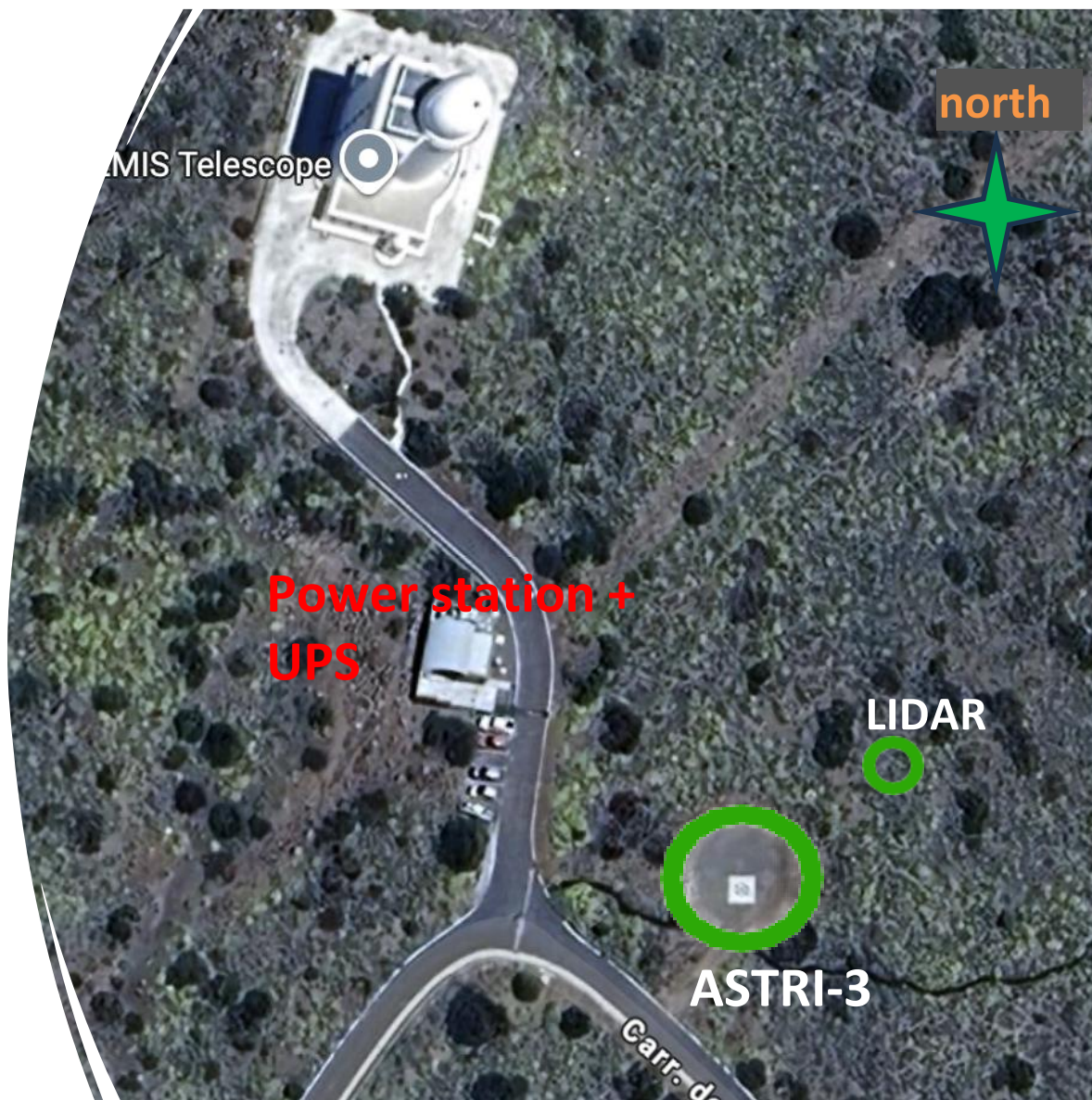


👷 **TODO** 👷

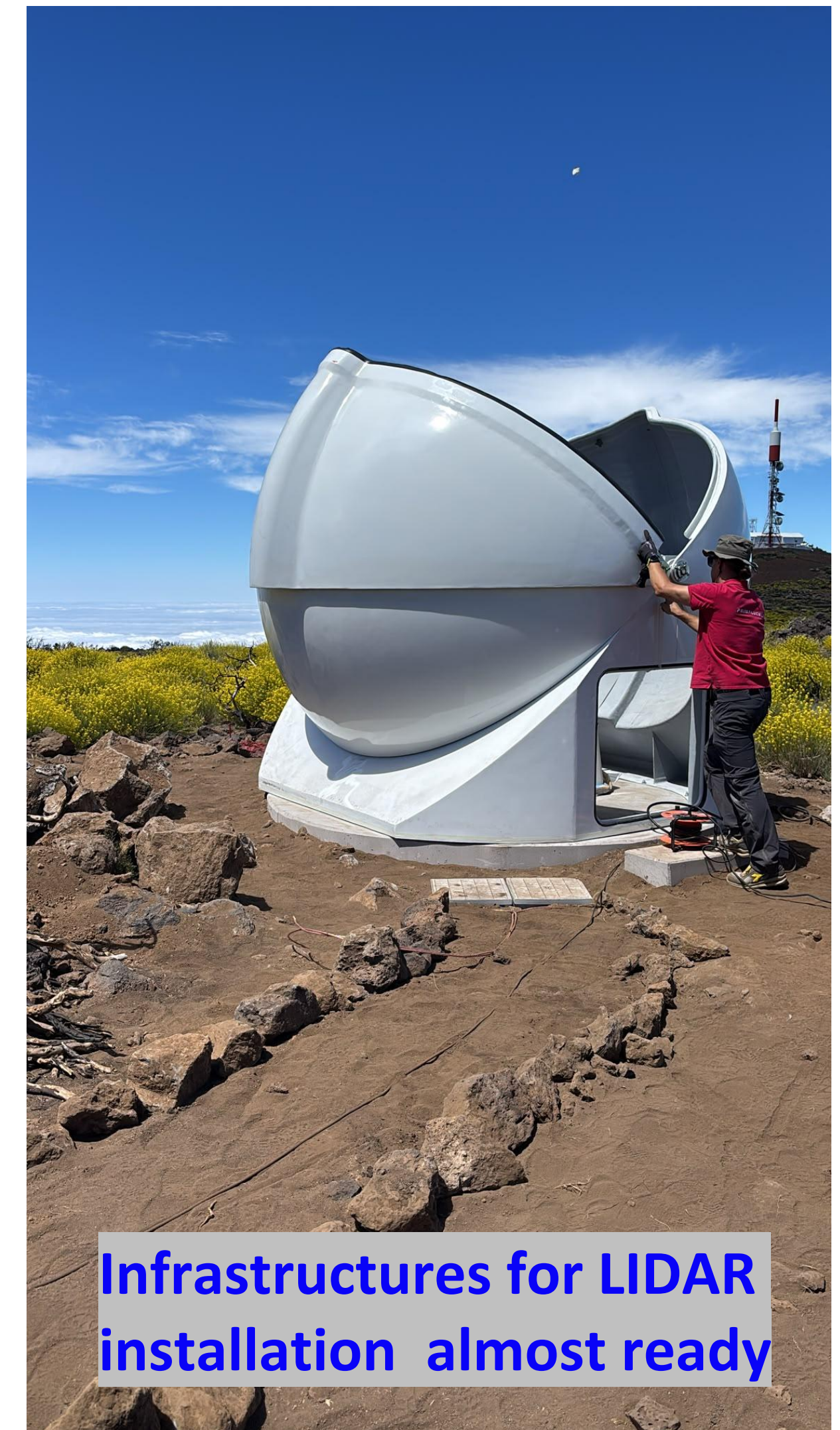


WCS

ASTRI Mini-Array: LIDAR soon at Teide



- LIDAR “Tenerife” INAF
 - two-wavelength elastic-Raman monostatic LIDAR
 - laser emissions in the UV (355 nm) and visible (532 nm) regions
 - four detection channels: 355 nm elastic and N₂ Raman channel at 386 nm, elastic P/S polarized at 532 nm,
 - advanced scanning system, providing three-dimensional and high precision measurements.



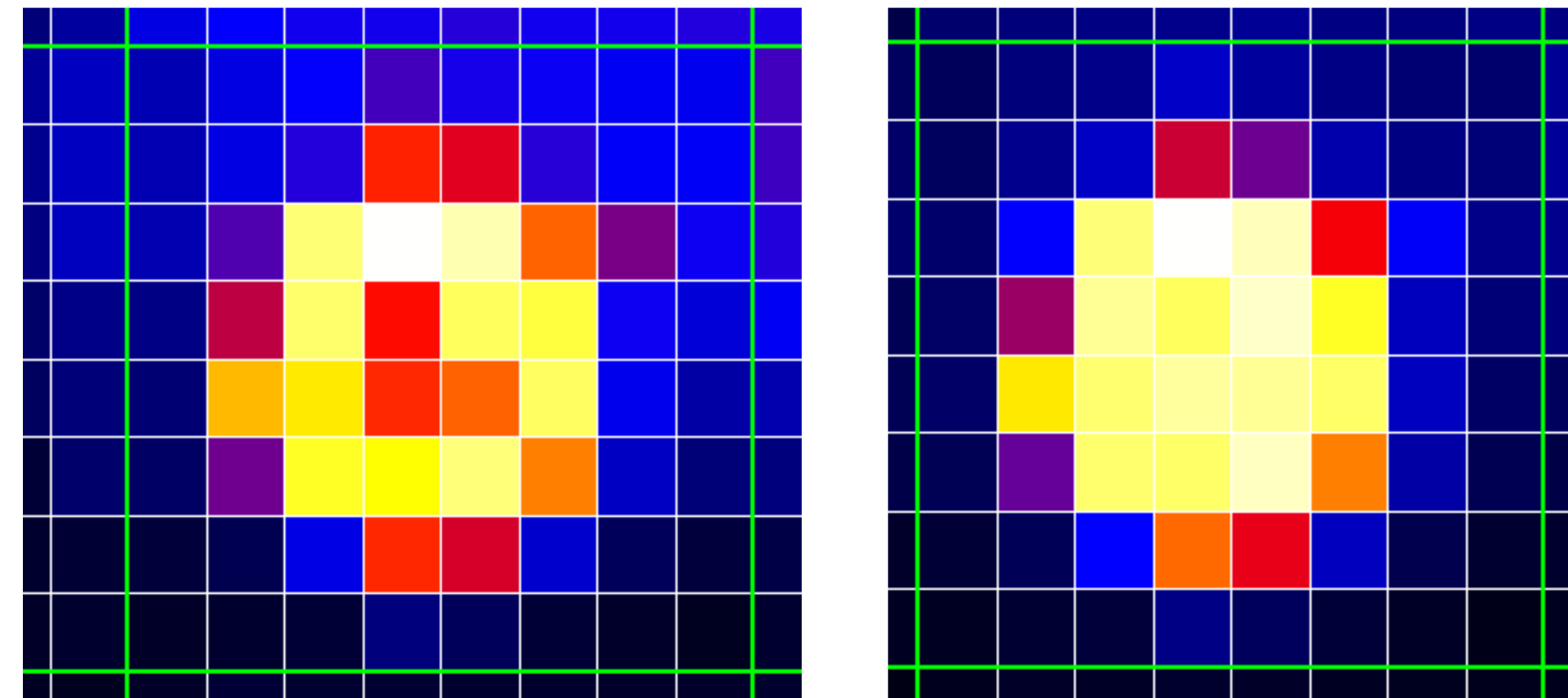
**Infrastructures for LIDAR
installation almost ready**

ASTRI Mini-Array: Illuminator



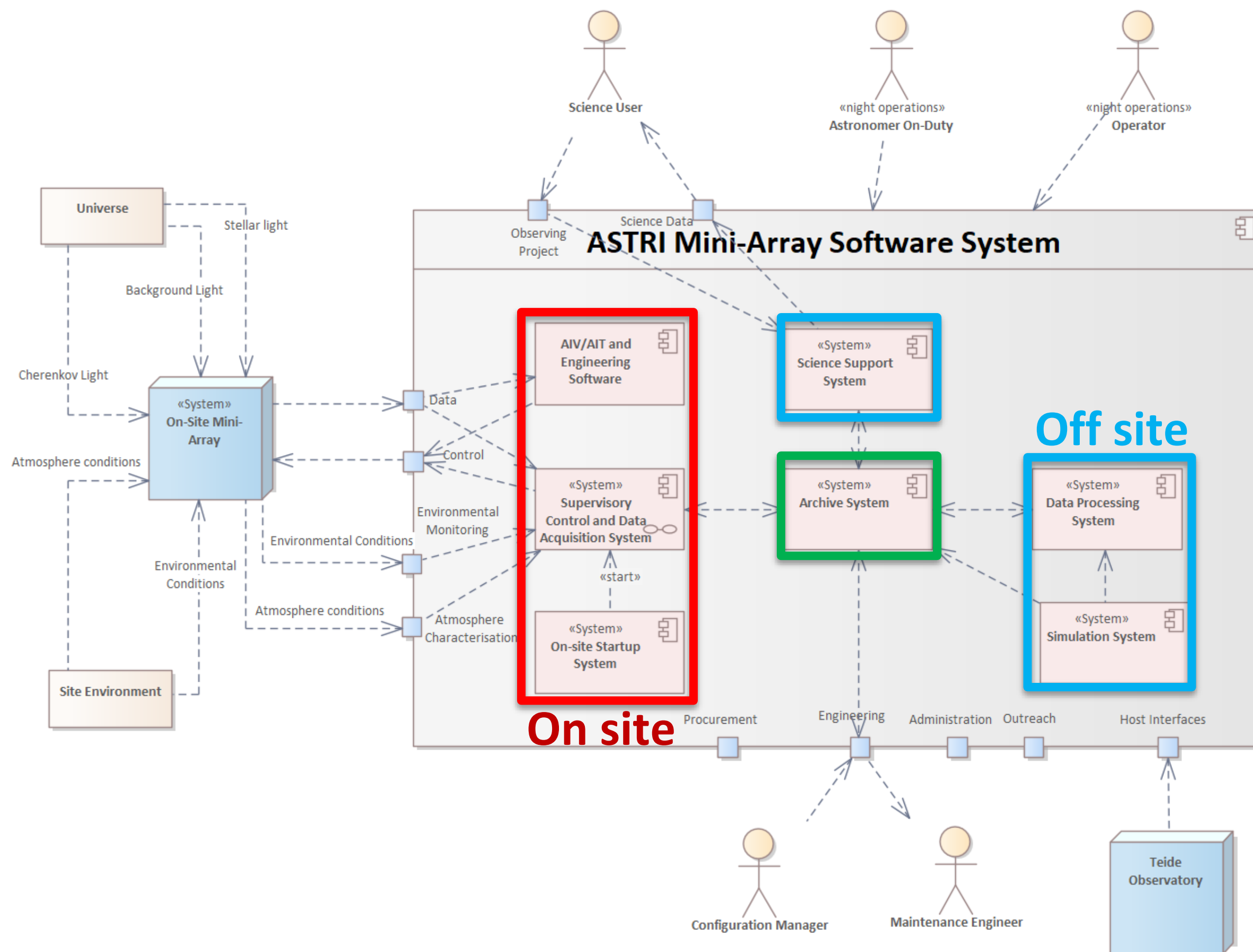
(credit A. Segreto)

Calibration of the optical throughput of ASTRI telescopes by illuminating them uniformly with a given pulsed reference flux covering the Cherenkov spectrum.



We can illuminate more than one telescope

ASTRI Mini-Array: Software systems



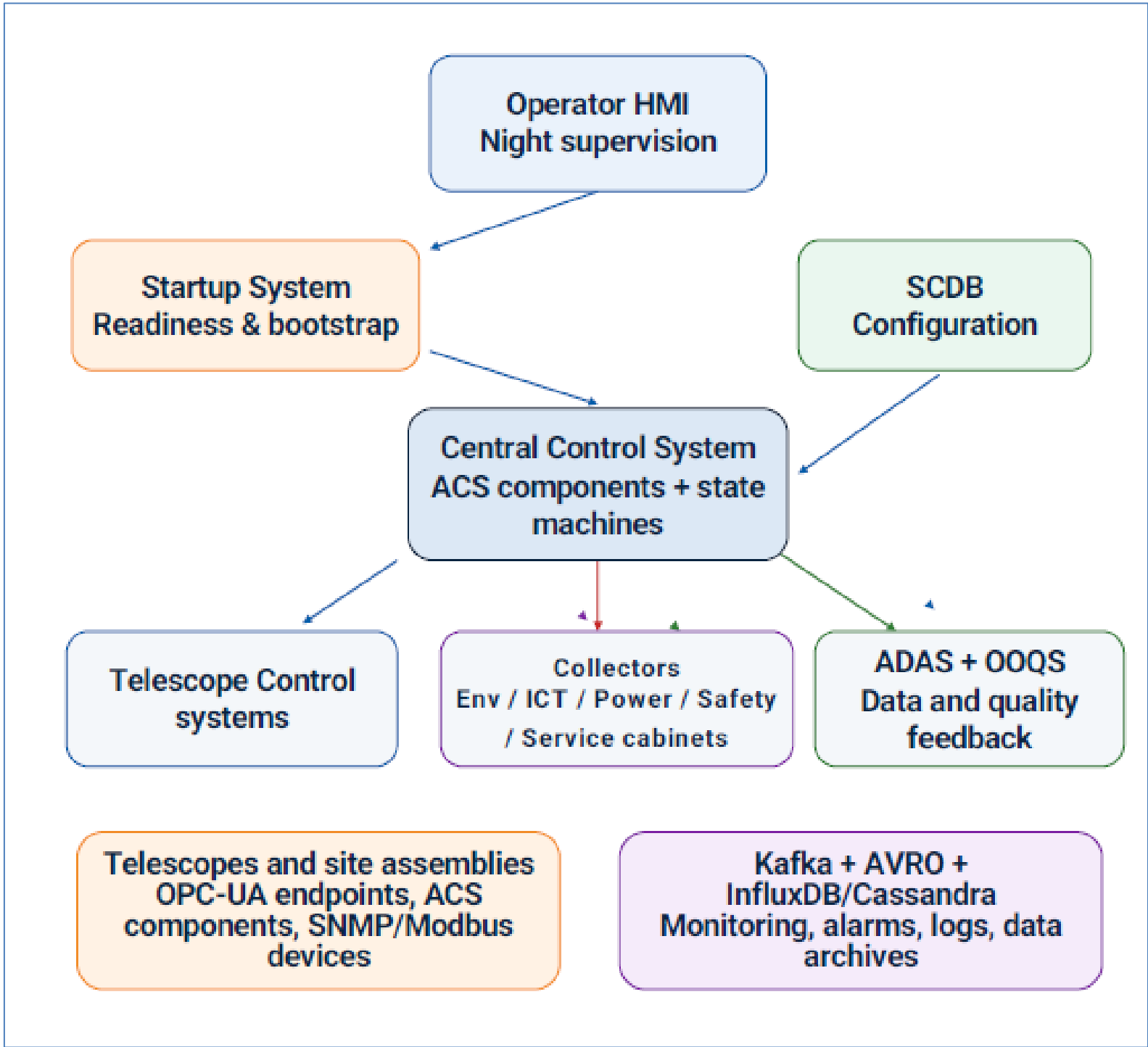
follow Panebianco's talk for details

- **Startup System:** manage the sequence of the startup and shutdown of the critical on-site systems before the start of the Mini-Array operations.
- **AIV/AIT and engineering software:** used during the AIT/AIV phases and during the maintenance activities.
- **Supervisory Control And Data Acquisition (SCADA) System:** devoted to control all the operations carried out at the Mini-Array site. SCADA interfaces and communicates with all equipment and dedicated software installed On-Site.
- **Archive System:** provides storage and organization for all data, data products, and metadata generated for and by the Mini-Array and defined by the Mini-Array Data Models.
- **Data Processing System:** used to calibrate and reduce the data acquired. This software is also used to check the quality of the final data products.
- **Science Support System:** provides the main point of access for the exchange of science-related data and information with the ASTRI Science Users, and supports the whole science-related workflow, from the Observing Project submission to the access to the archived high-level Mini-Array science data products and the corresponding Science Tools to support data analysis.
- **Simulations System:** runs Monte Carlo simulations to provide simulated data for the development of reconstruction algorithms and for the characterization of real observations.

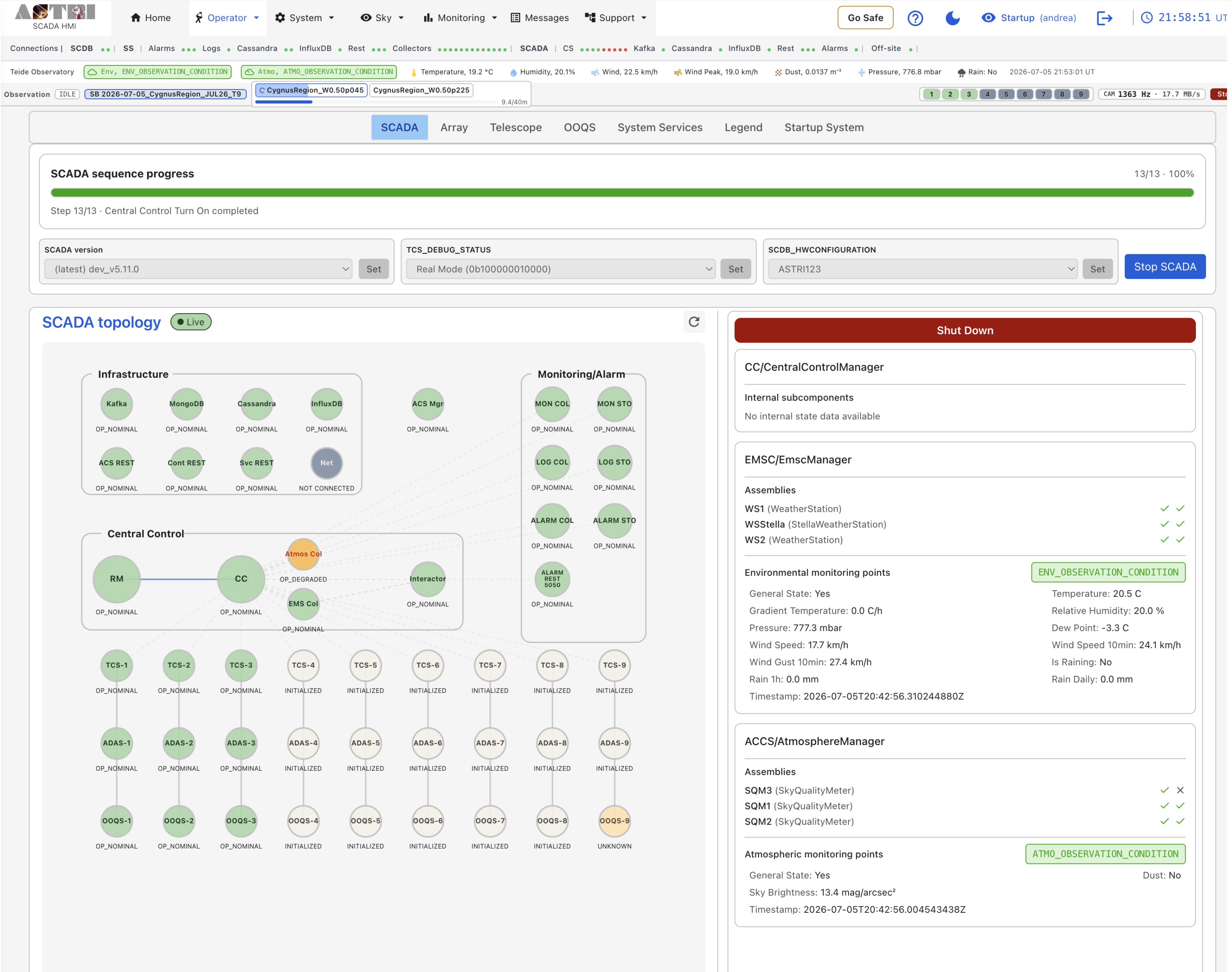
ASTRI Mini Array: SCADA software system (on-site)



Logic Architecture



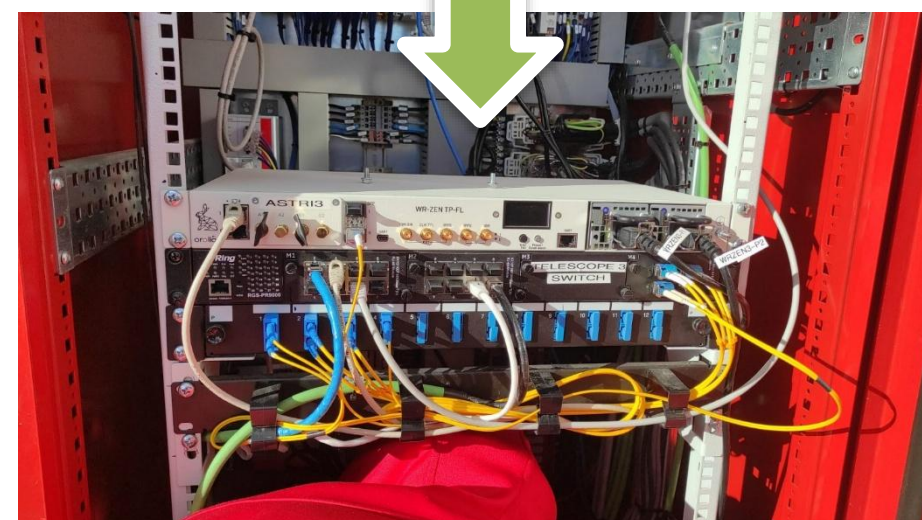
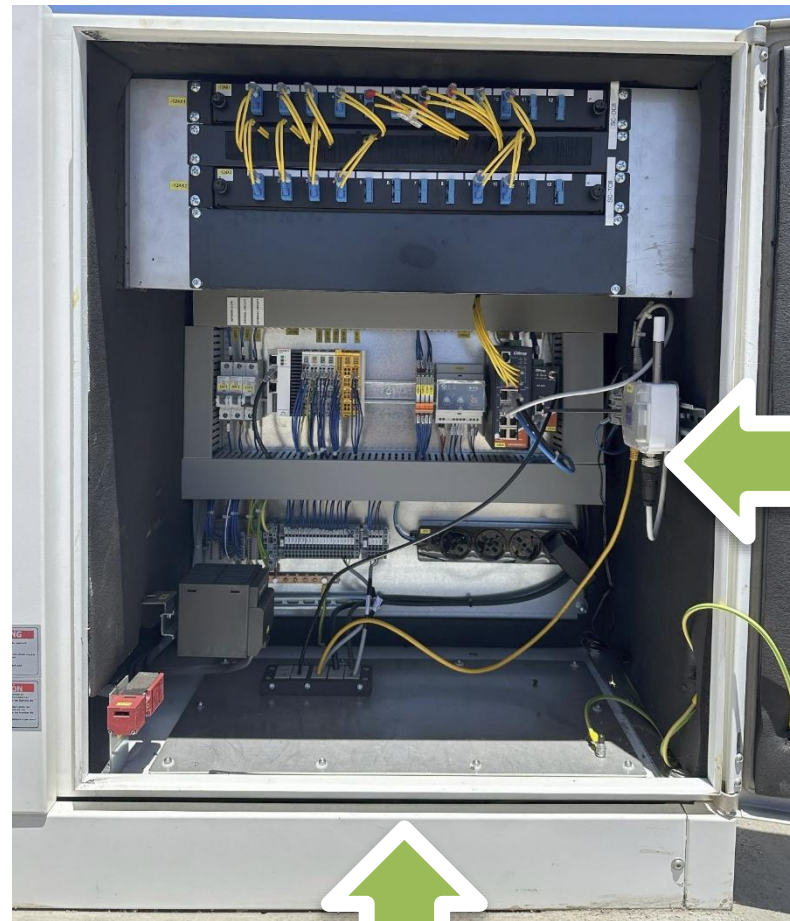
follow Panebianco’s talk for details



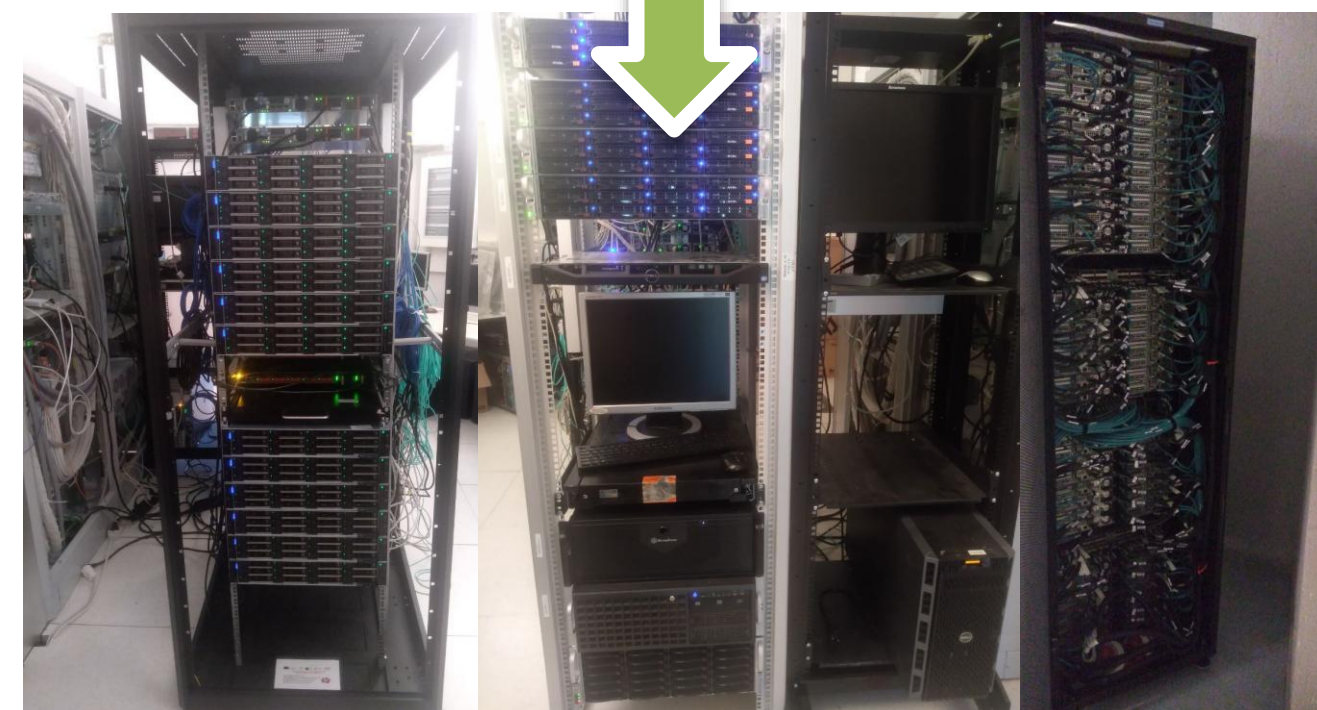
ASTRI Mini-Array: ICT infrastructure

On site ICT

Service cabinet



Telescopes



Offsite ICT

- Onsite data center
- Master Clock (GPS receiver)-PPS/NTP signals distribution
- 4G Backup link for emergency
- Fiber-Optic network backbone
- Service cabinets ICT equipment (Telescope Area)
- Telescope ICT Equipment
- Control room (@Themis)
- White Rabbit timing system
- Offsite data center



Control room @ Themis

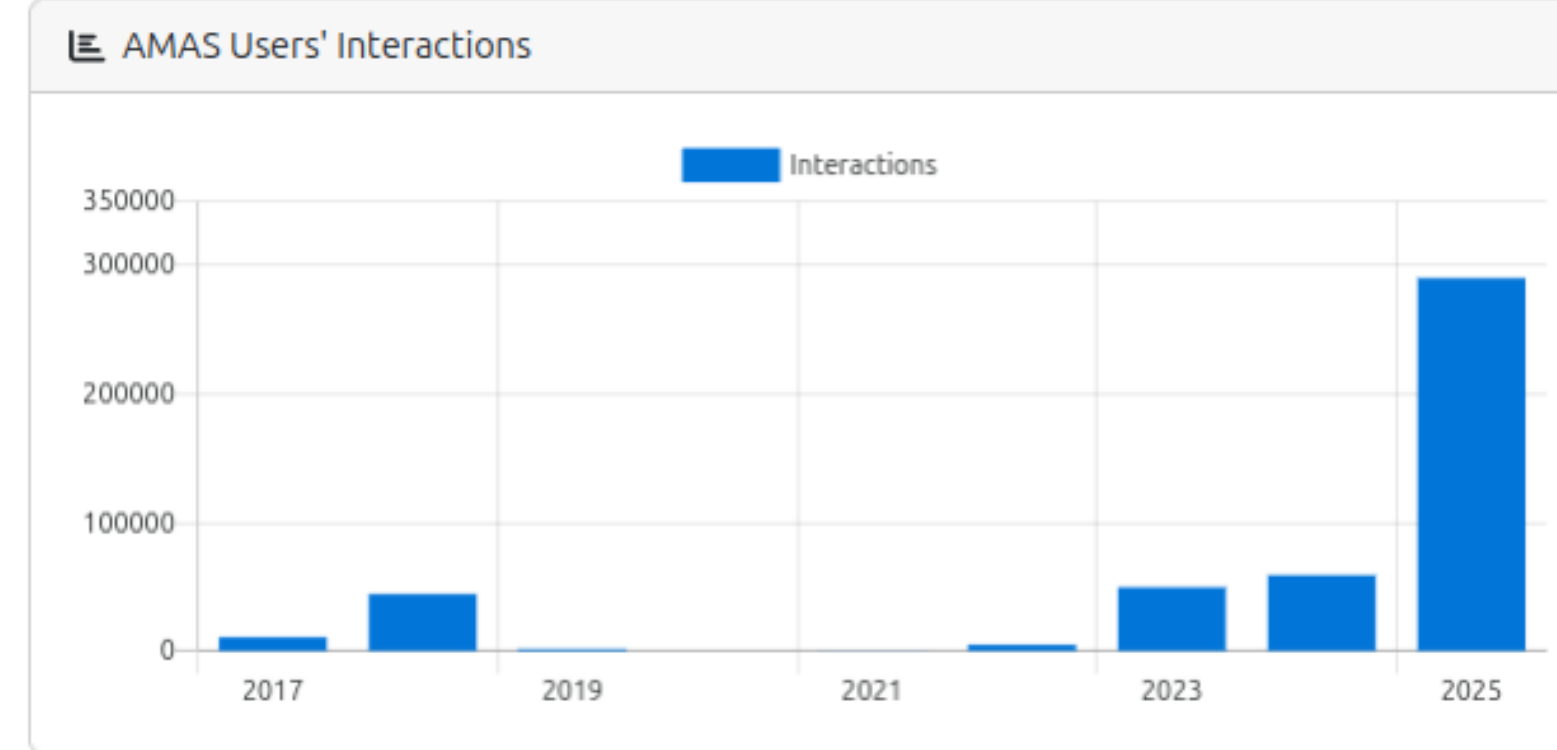
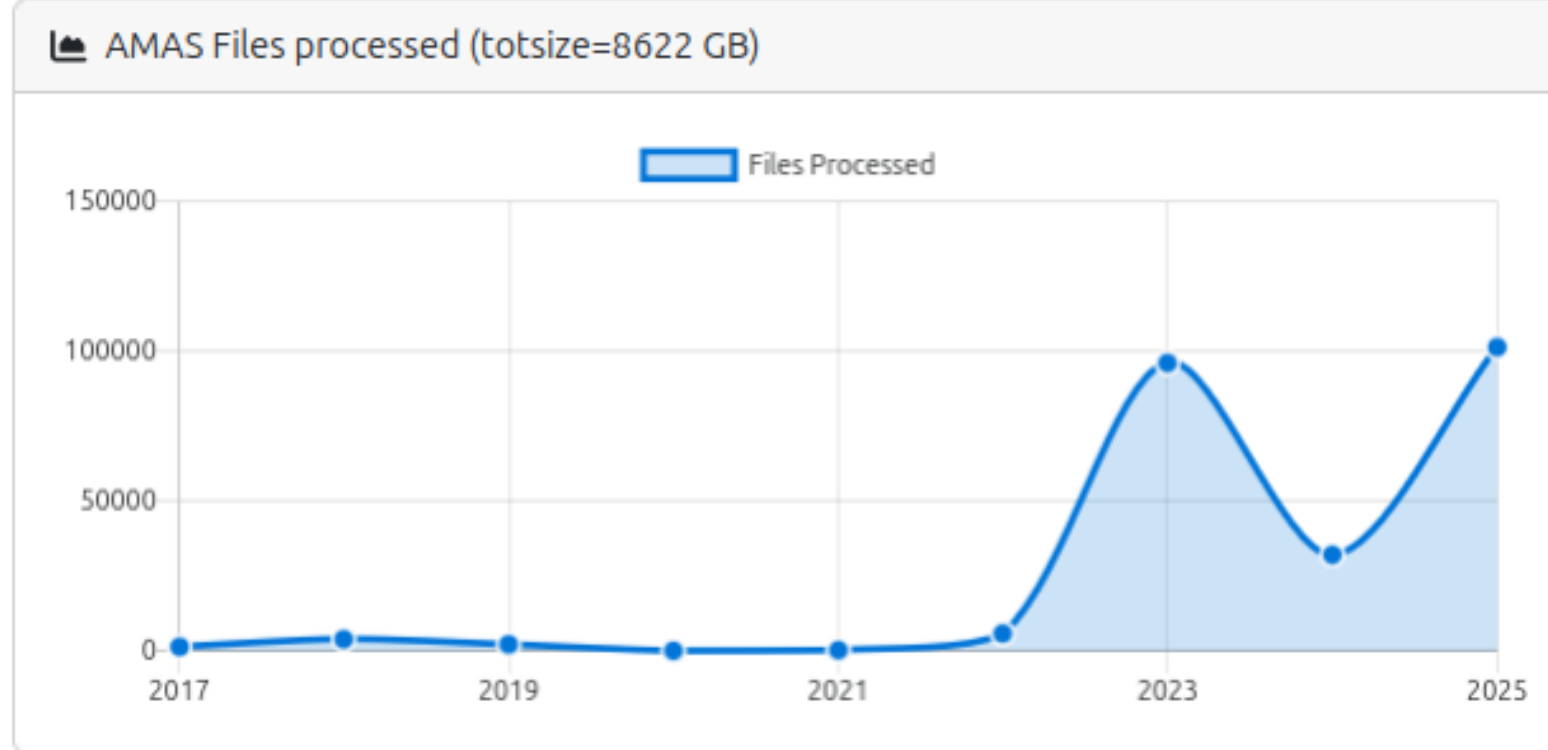
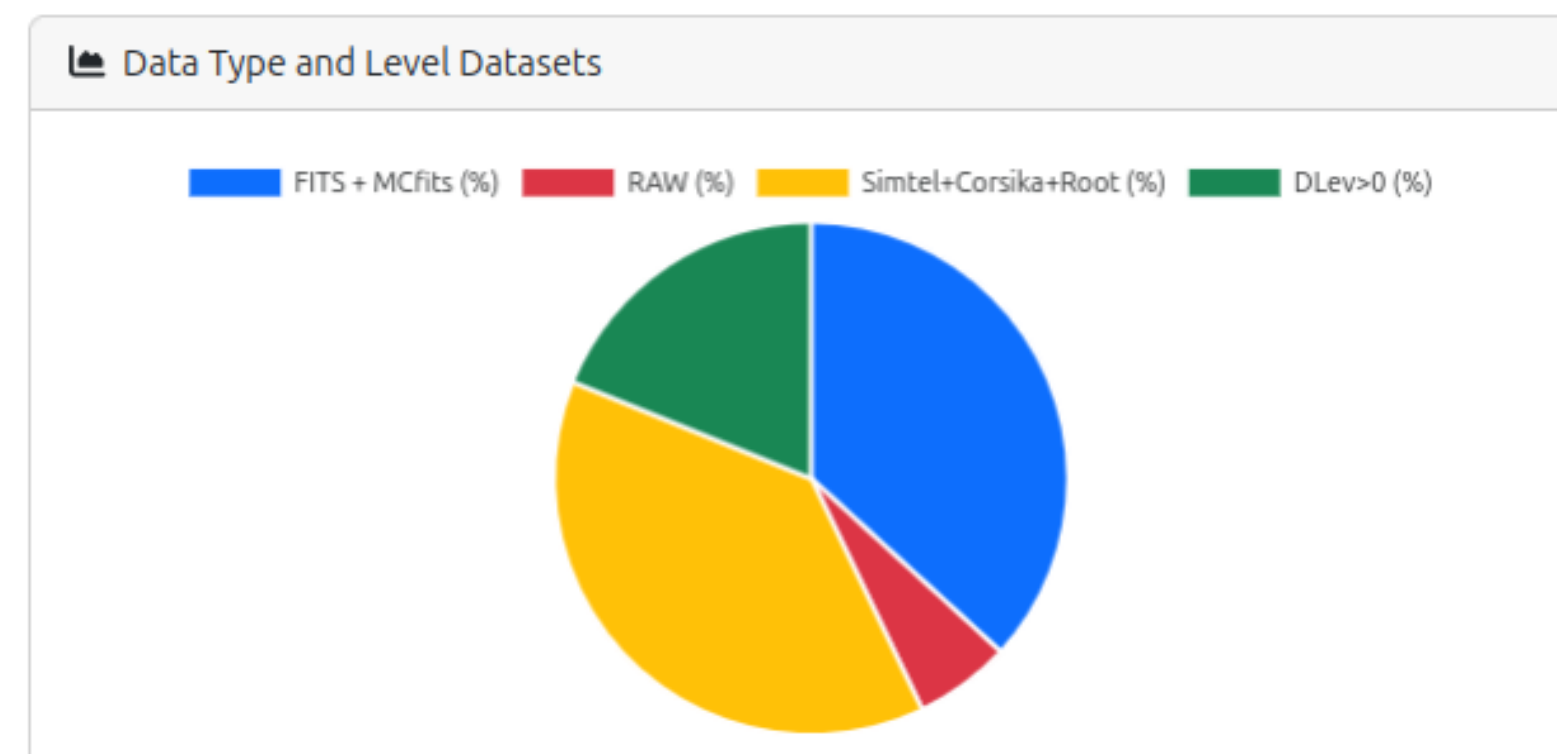
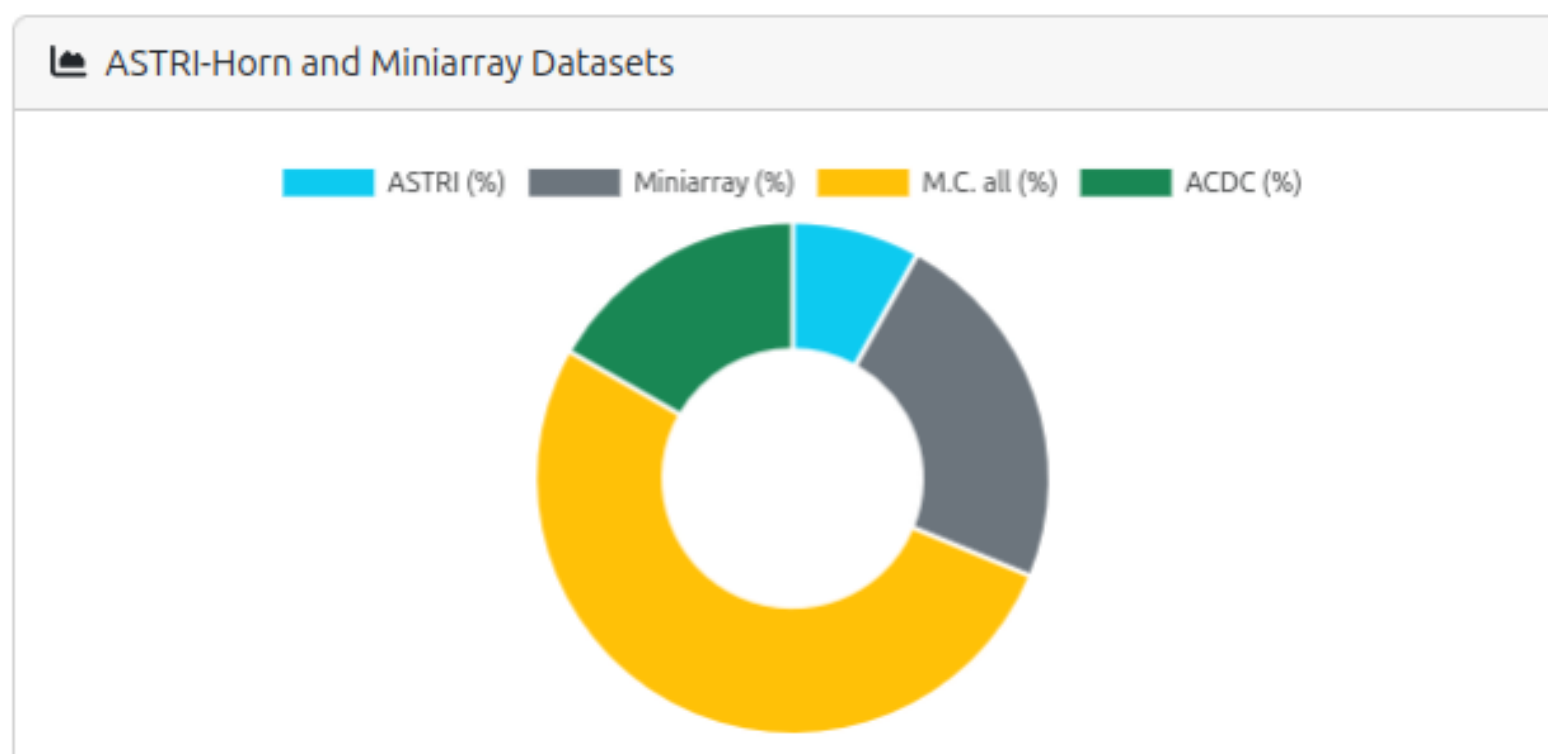
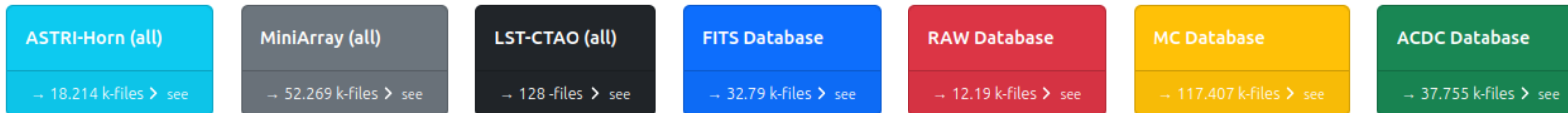
The onsite ICT supports the full remote operation of the Array

ASTRI Mini Array – Archive & Offsite Data Analysis and Simulations (OAR)



ASTRI & Miniarray Archive System - AMAS

AMAS-LDAP / AMAS-P.H.S. / **AMAS-Gateway** / LST-CTAO-Gateway



Simulation and Data Analysis

See Casaburo and La Parola talks

The ARCHIVE automatically:

1. takes RAW data from TEIDE
2. performs pre-reduction (DL0fits + calibs SEB/scitech)
3. execute Pipeline (DL0→DL3)
4. performs Quality Check
5. save, Backup & Replica for all data products
6. save logs, alert and notify

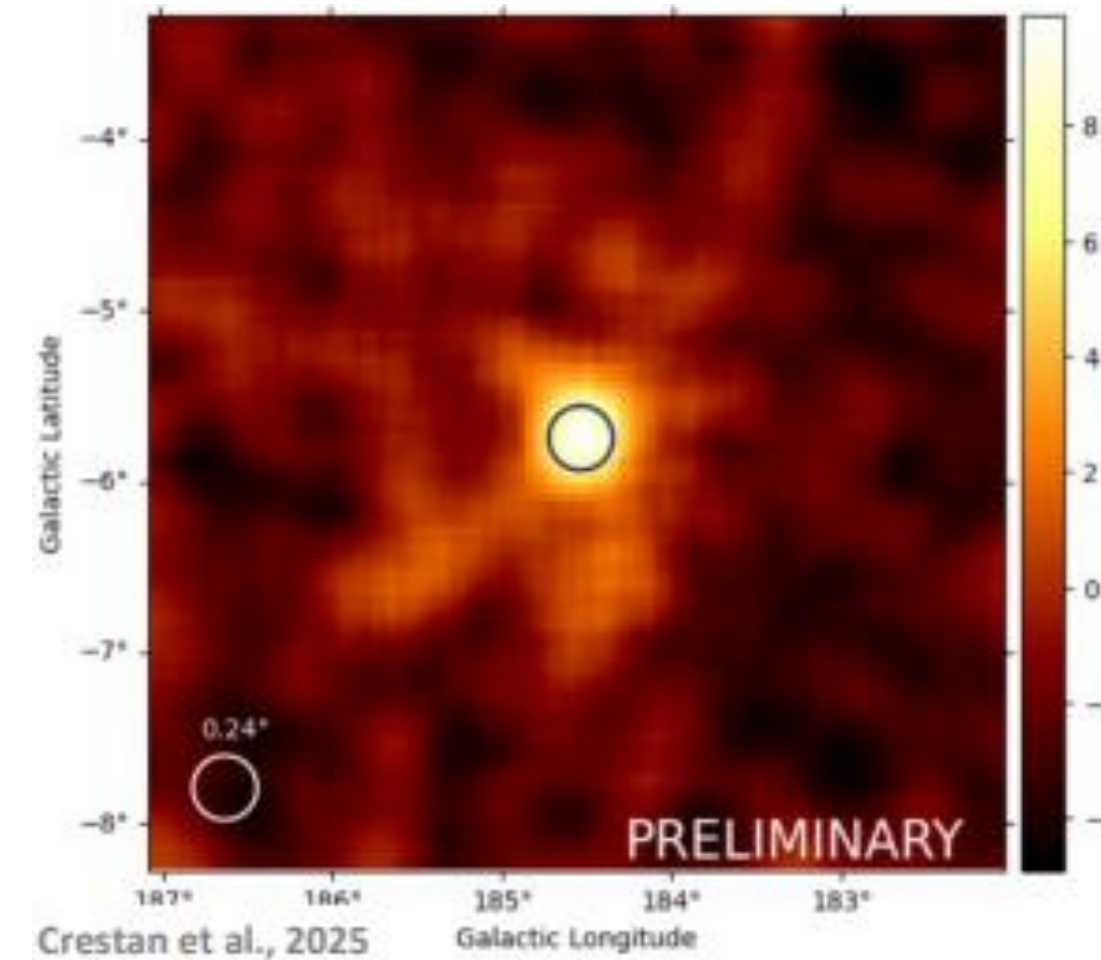
2025 Statistics (11/2025)

- 290k interactions
- 101k files processed (~10TB)

ASTRI Mini-Array: Current Status



**ASTRI1 Full operational since
autumn 2024**



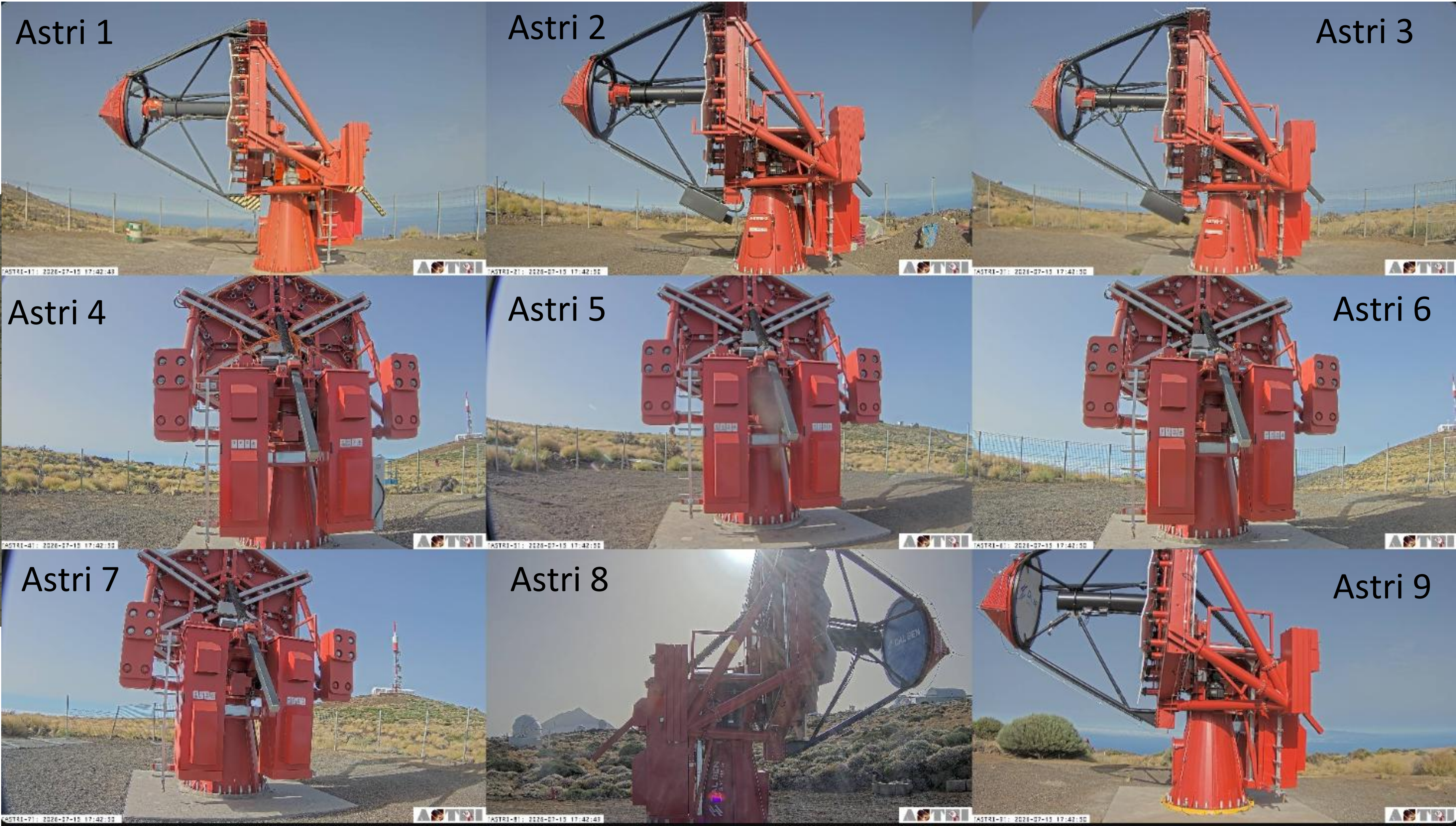
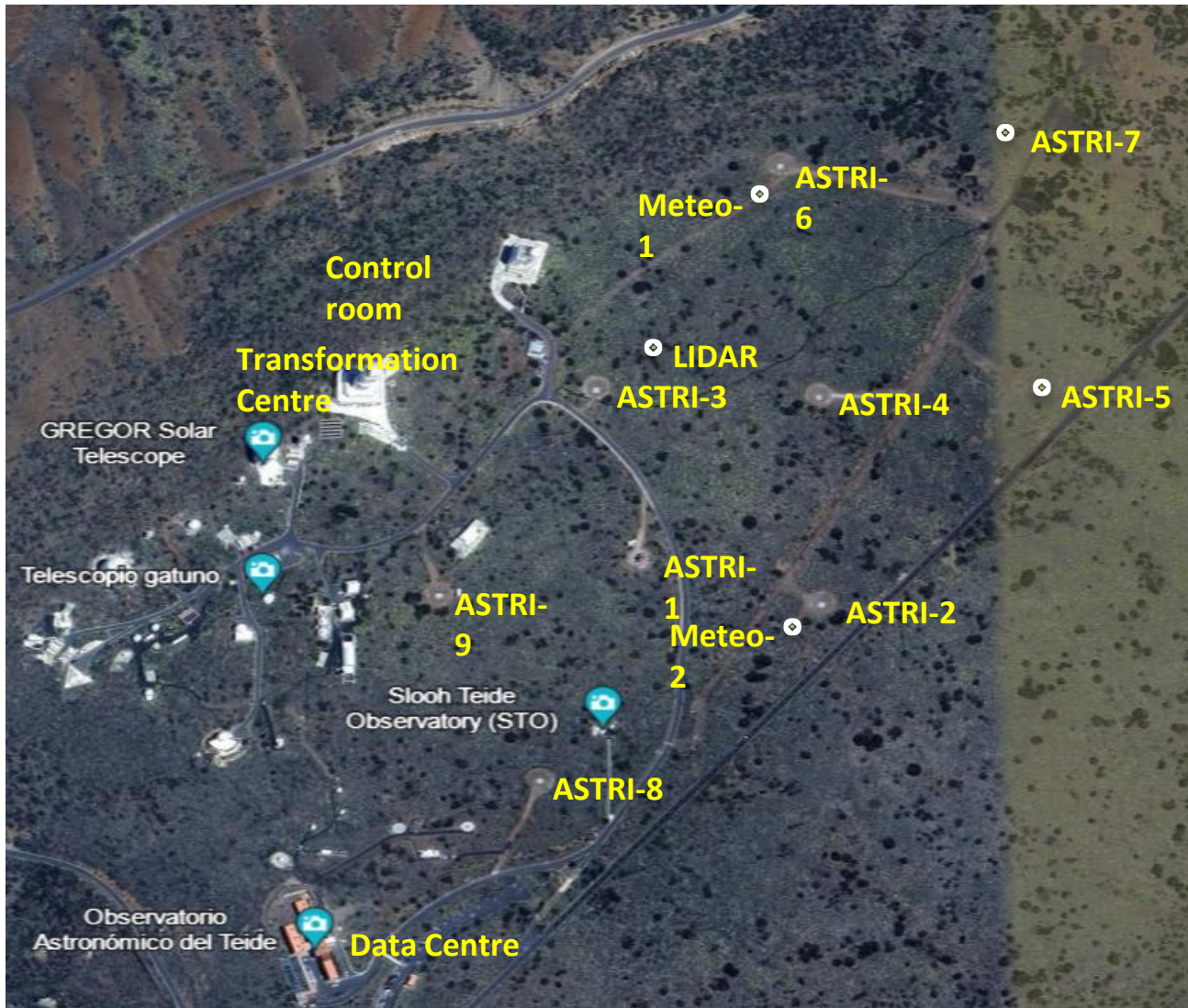
Crab detection during commissioning:
Nov 2024- Feb 2025



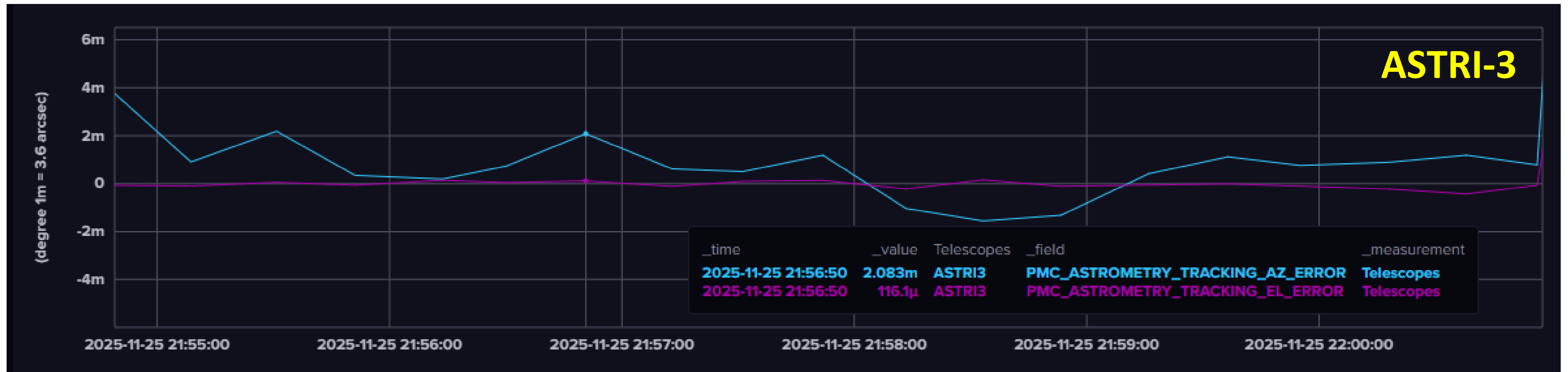
ASTRI Mini-Array: Current Status



Installation of the
9 telescopes completed!



ASTRI Mini-Array: ASTRI-2 to 9 Commissioning

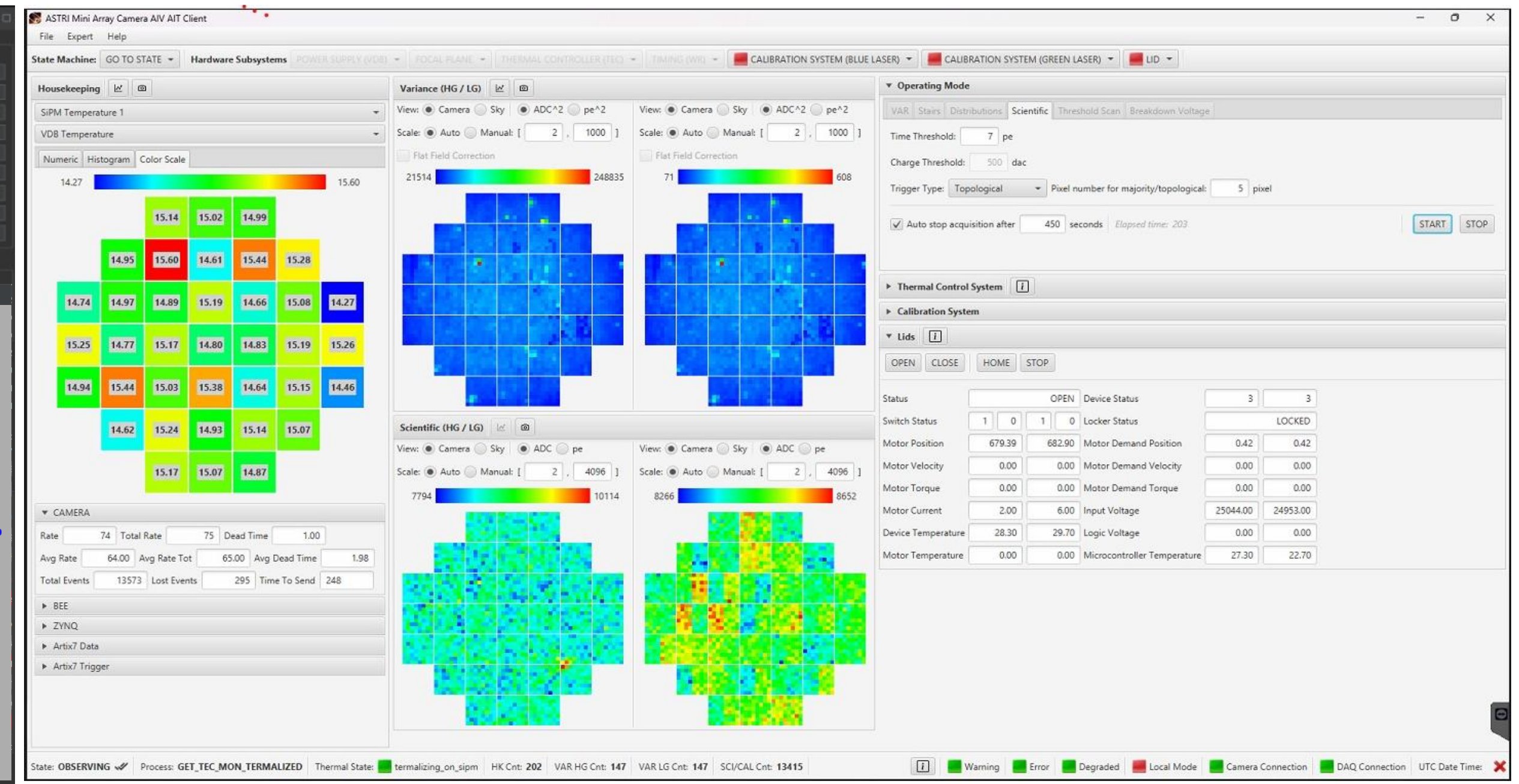
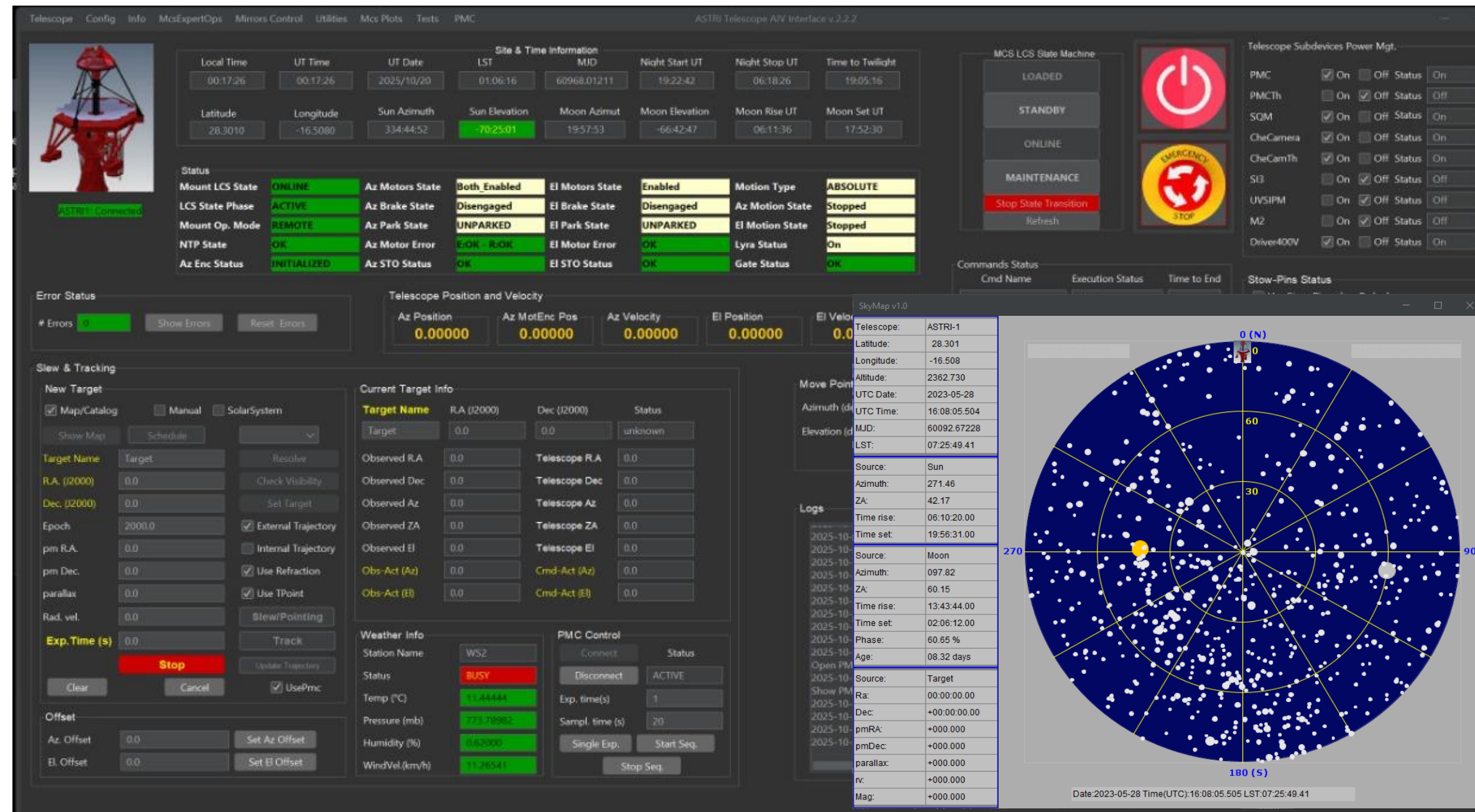


- Validation tests of the telescopes cover all the functionalities associated to their subsystems and integrated system
- Positioning and tracking → complete tuning of the motion control loop
- Procedures assessed on ASTRI-3 to be applied to all other telescopes
- All tests, telescope pointing model and mirror alignment performed on ASTRI-2 and ASTRI-3
- Partial tests performed on telescopes ASTRI-4 to 9

ASTRI Mini-Array : ASTRI-2 to 9 commissioning



AIT/V Engineering GUIs were developed to control telescopes and cameras and monitor all main parameters

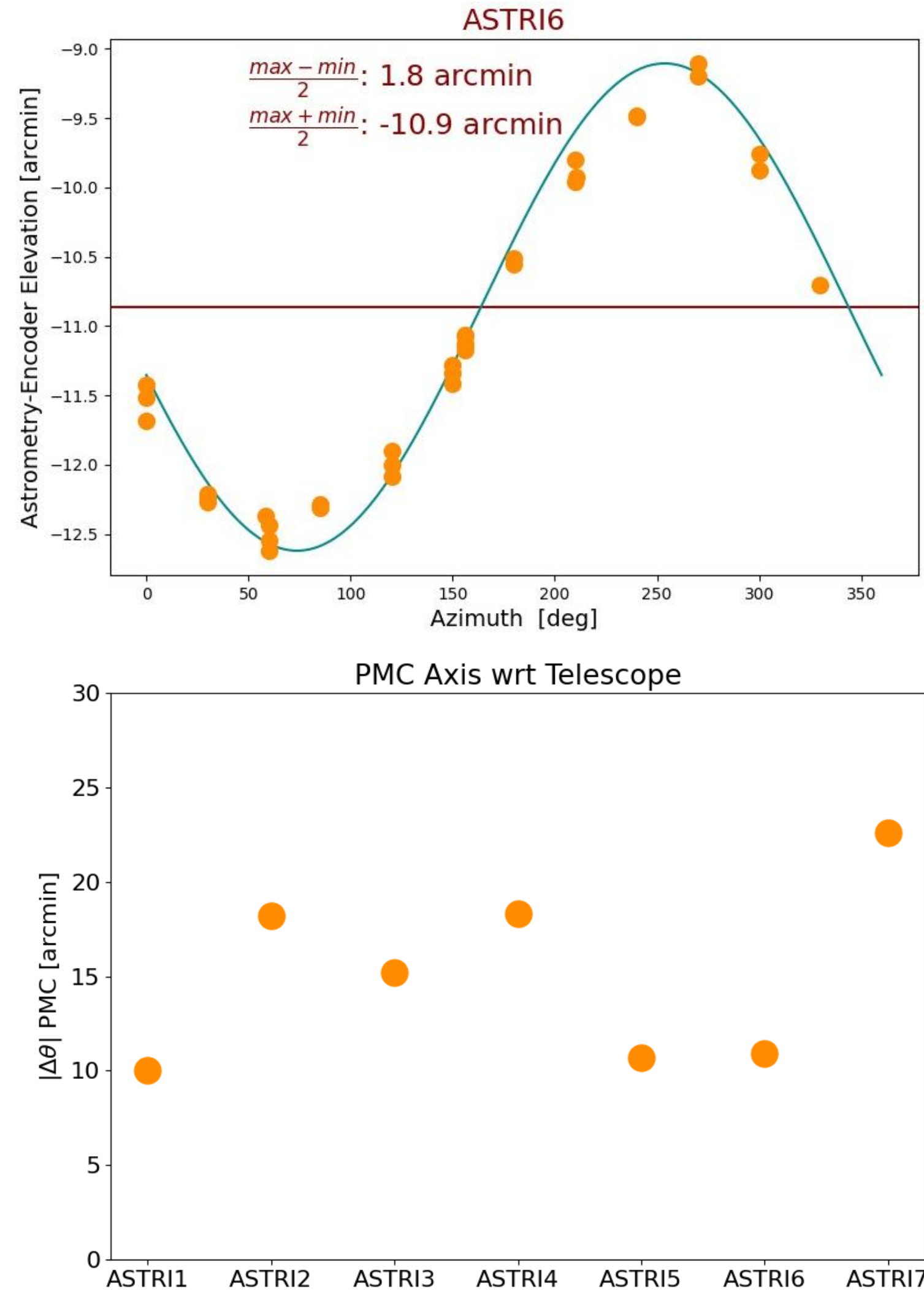


- Kinematical parameters of all telescopes to allow them to reach the same position of the sky all at the same time
- Compare positioning and tracking of all telescopes to reach the same accuracy.
- Autoguider with use of the Pointing Monitor Camera
- Pointing Model tools;
- M1 & M2 integrated control for their alignments

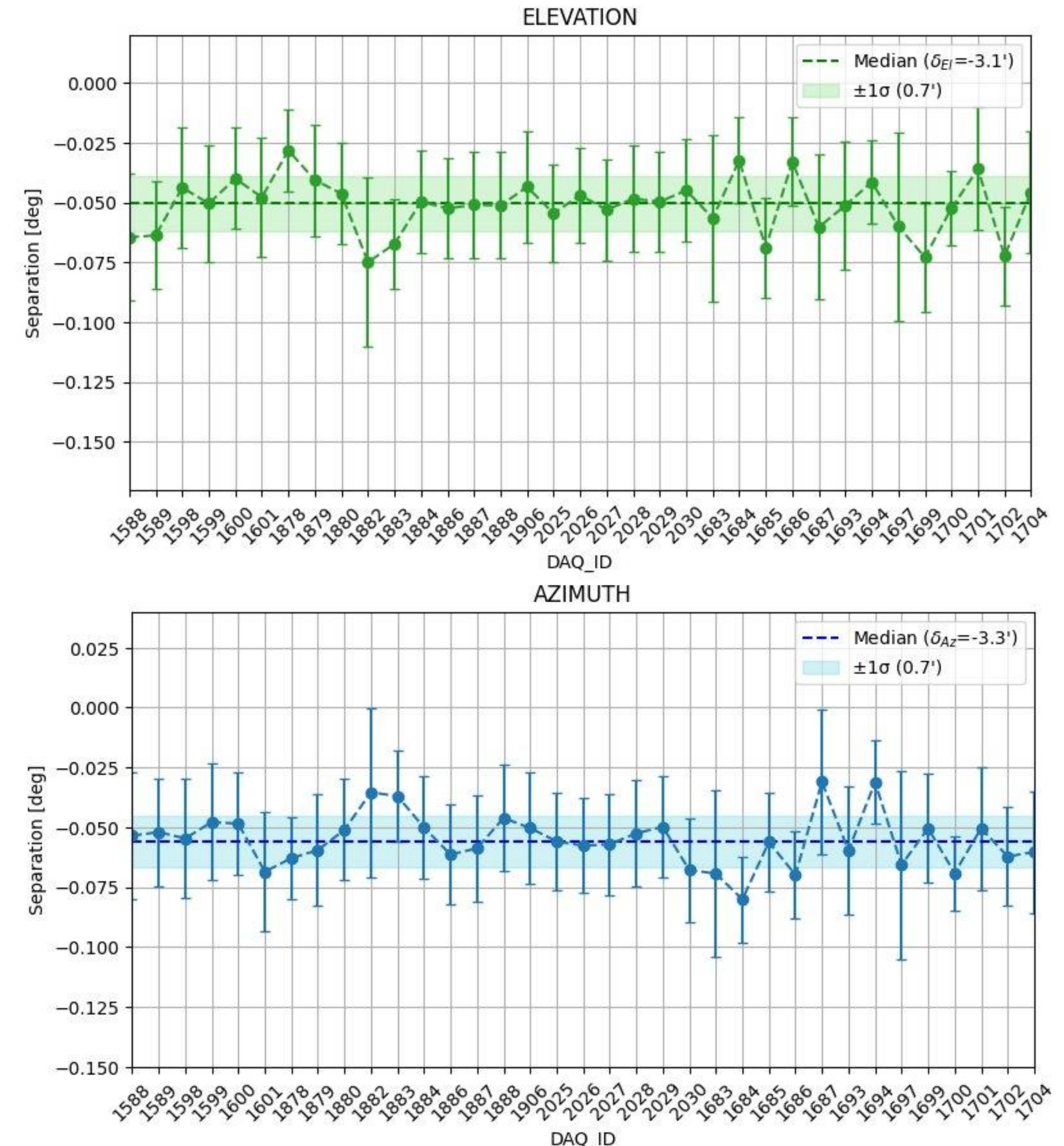
- Selection of the available cameras
- Control all camera subsystems
- Slow-control operations through an OPC-UA interface
- Camera parameters monitoring

ASTRI Mini-Array: Telescope calibrations

Alignment between PMC and Telescopes

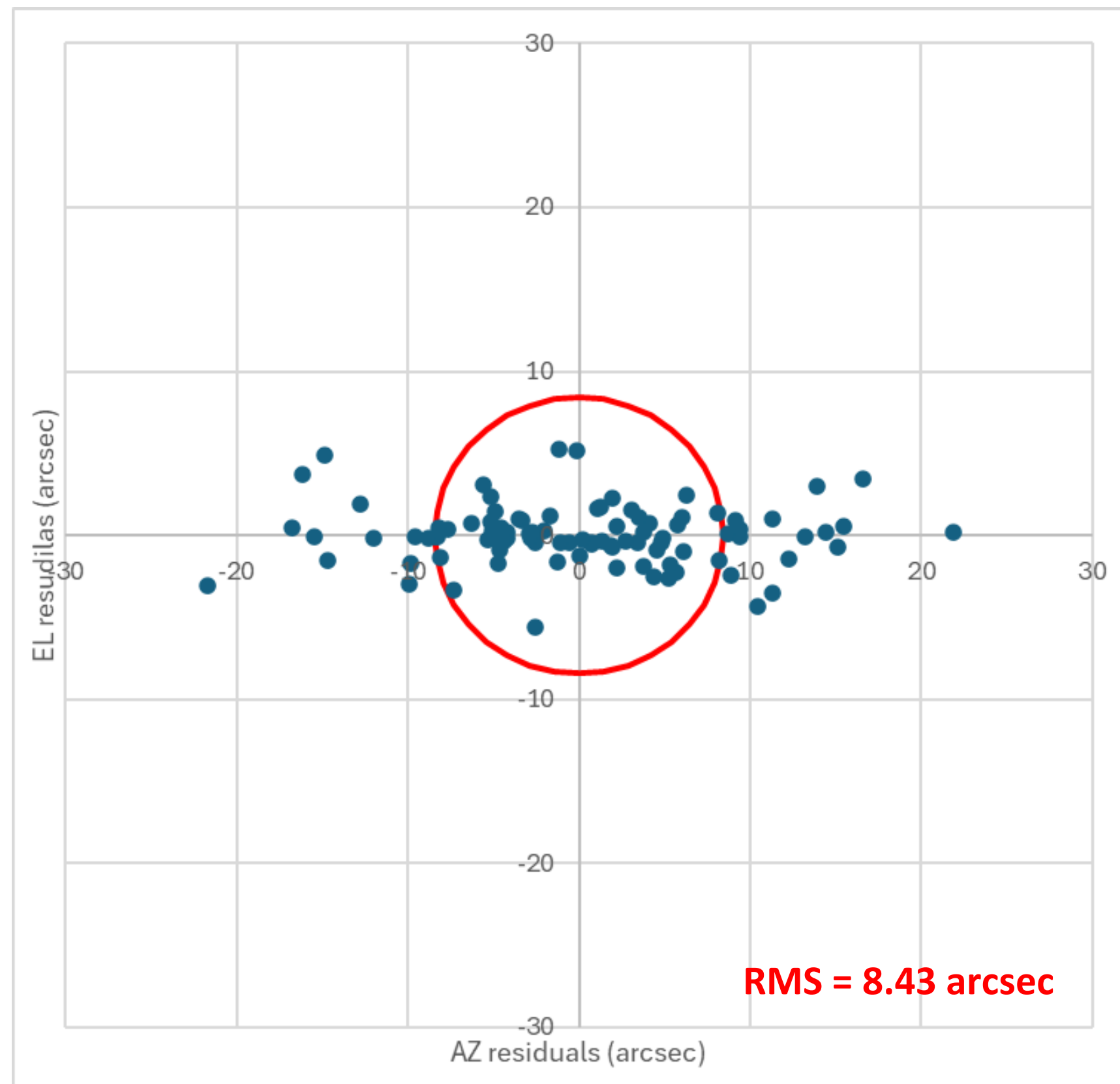


Offset between PMC and Cherenkov Camera (ASTRI1)

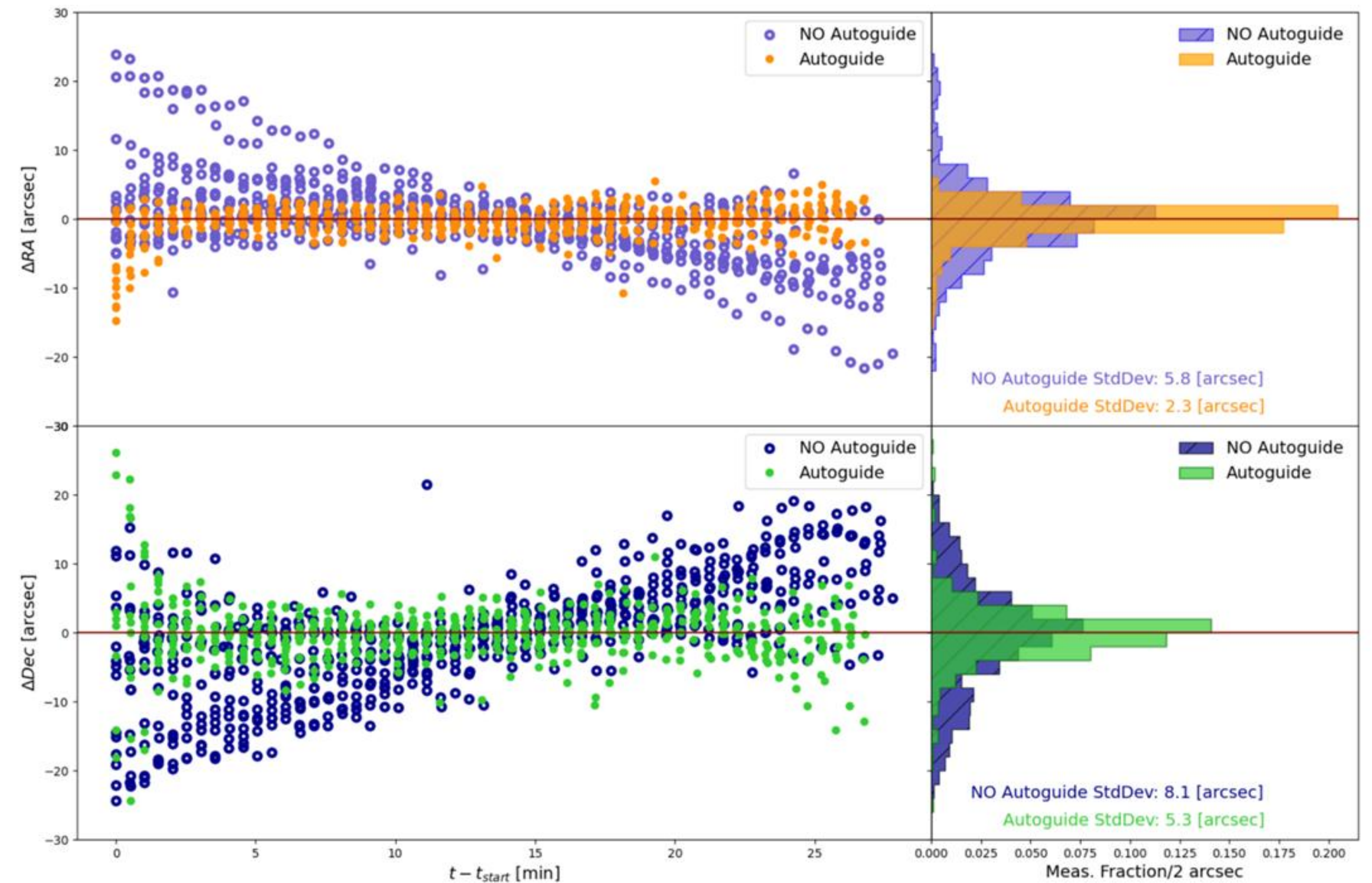


ASTRI Mini-Array: Pointing & tracking

Pointing model – ASTRI-6

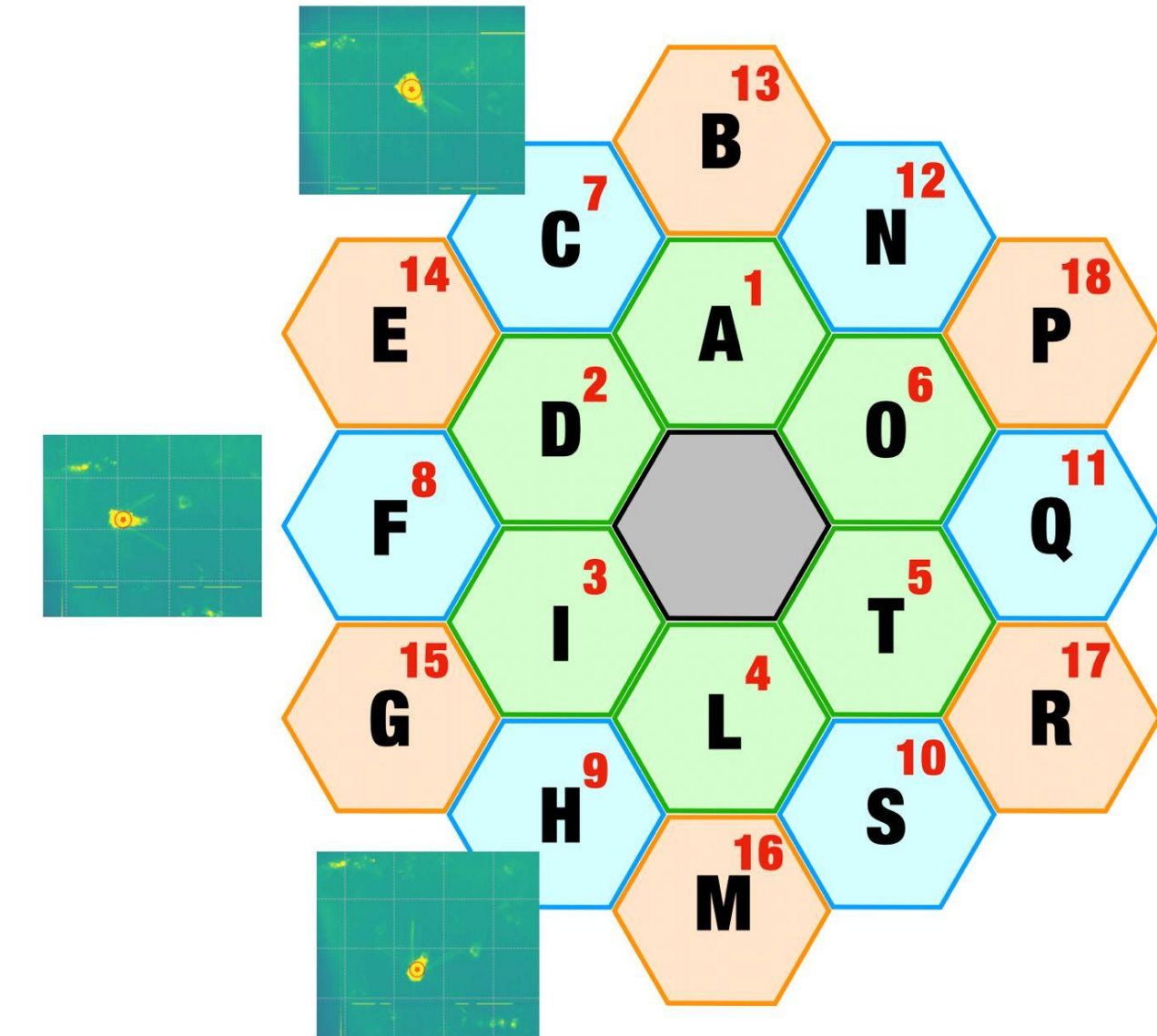
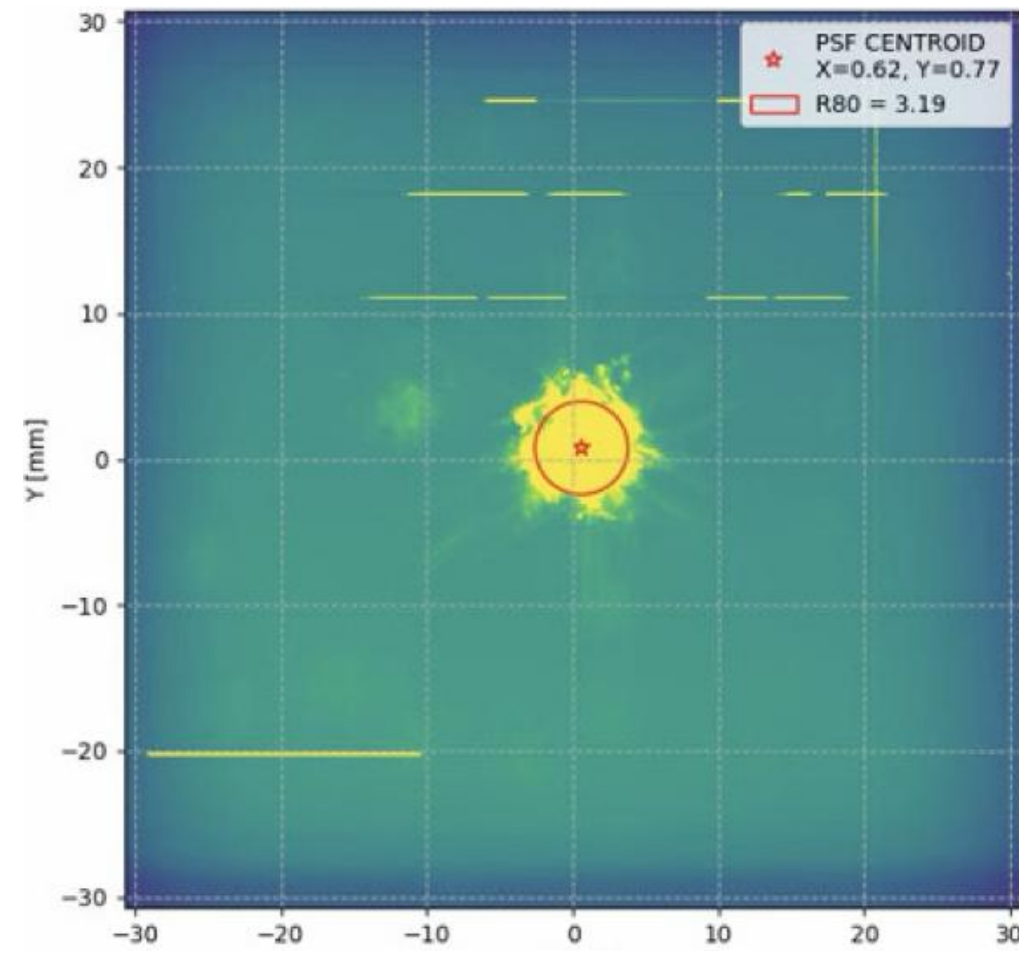


Tracking – ASTRI-1

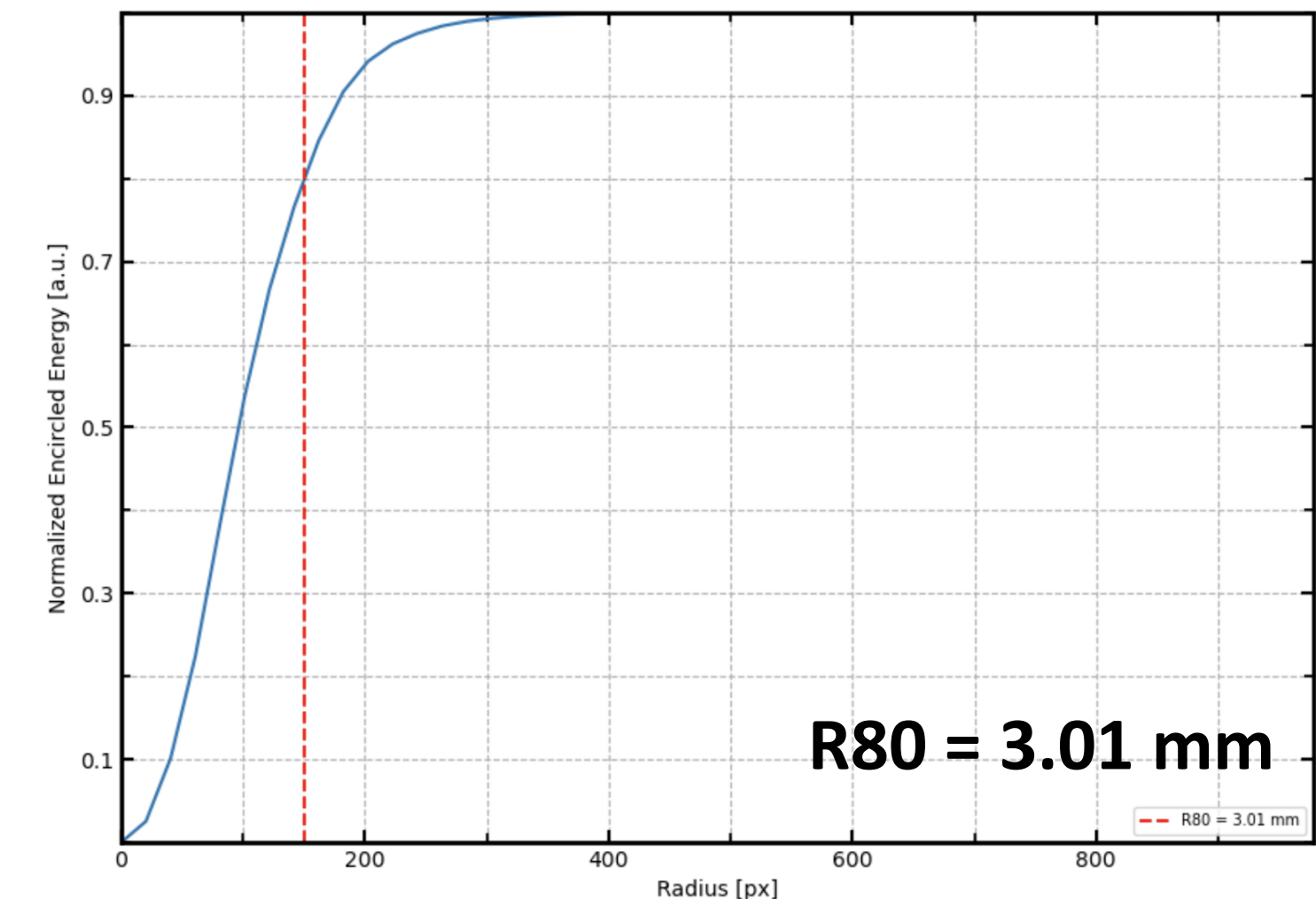
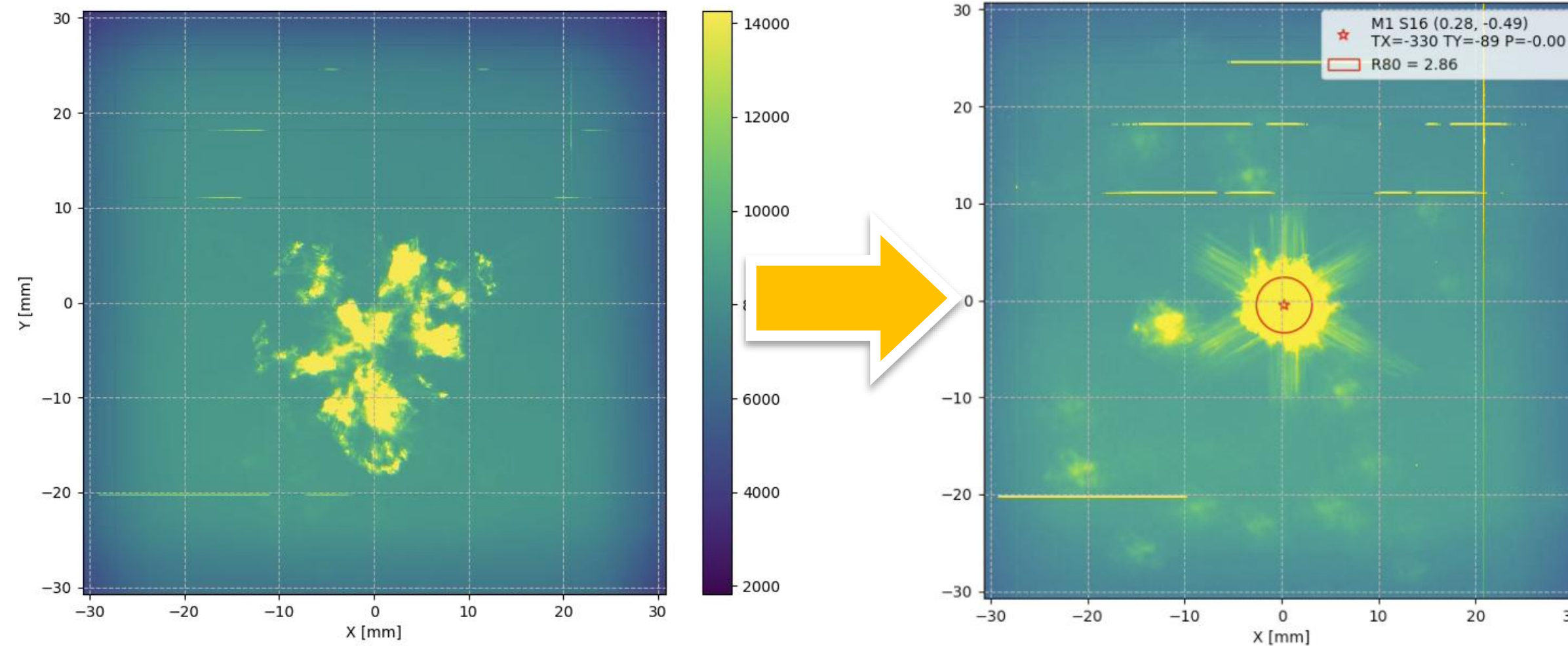


ASTRI Mini-Array: Mirrors Alignment

ASTRI-2

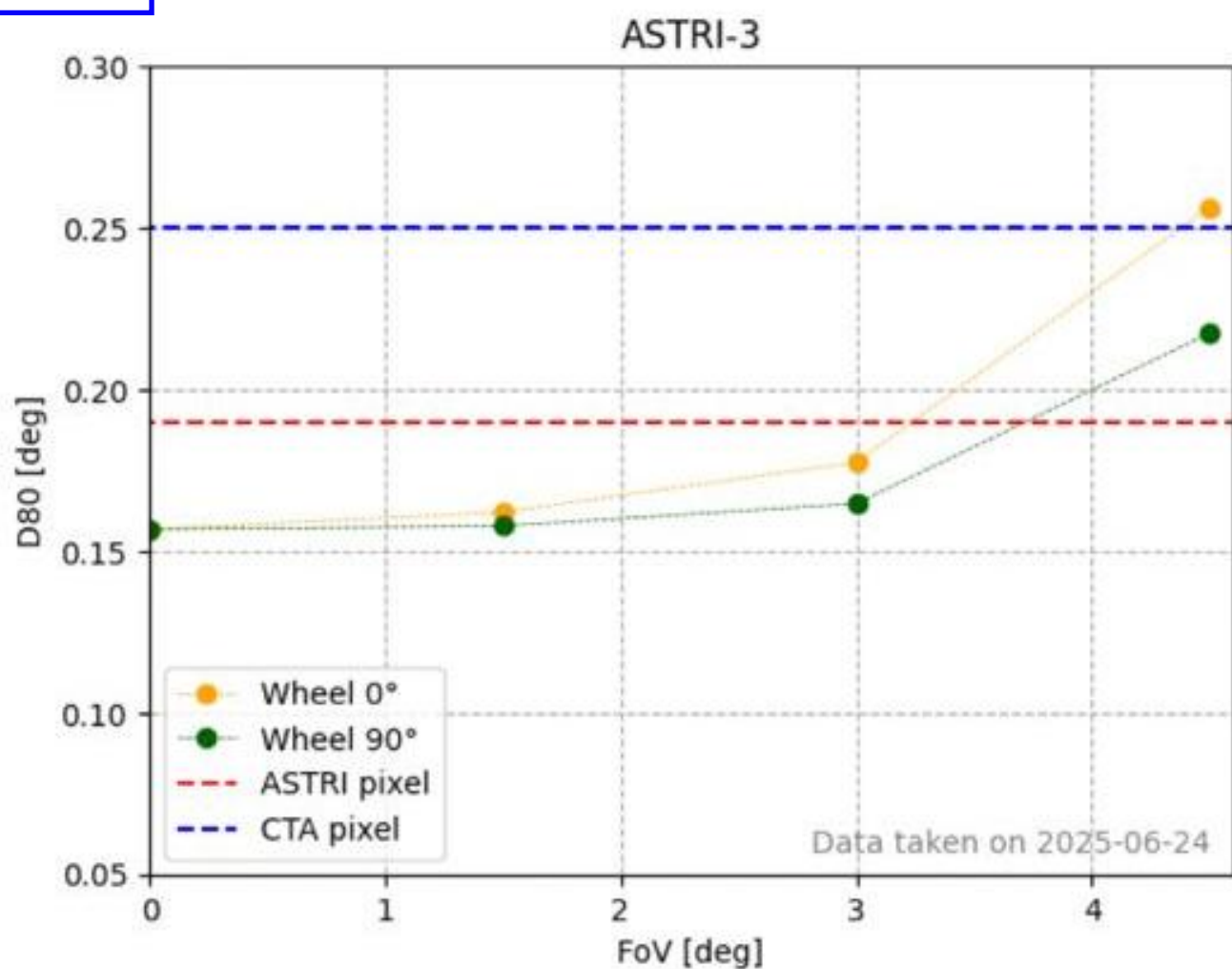
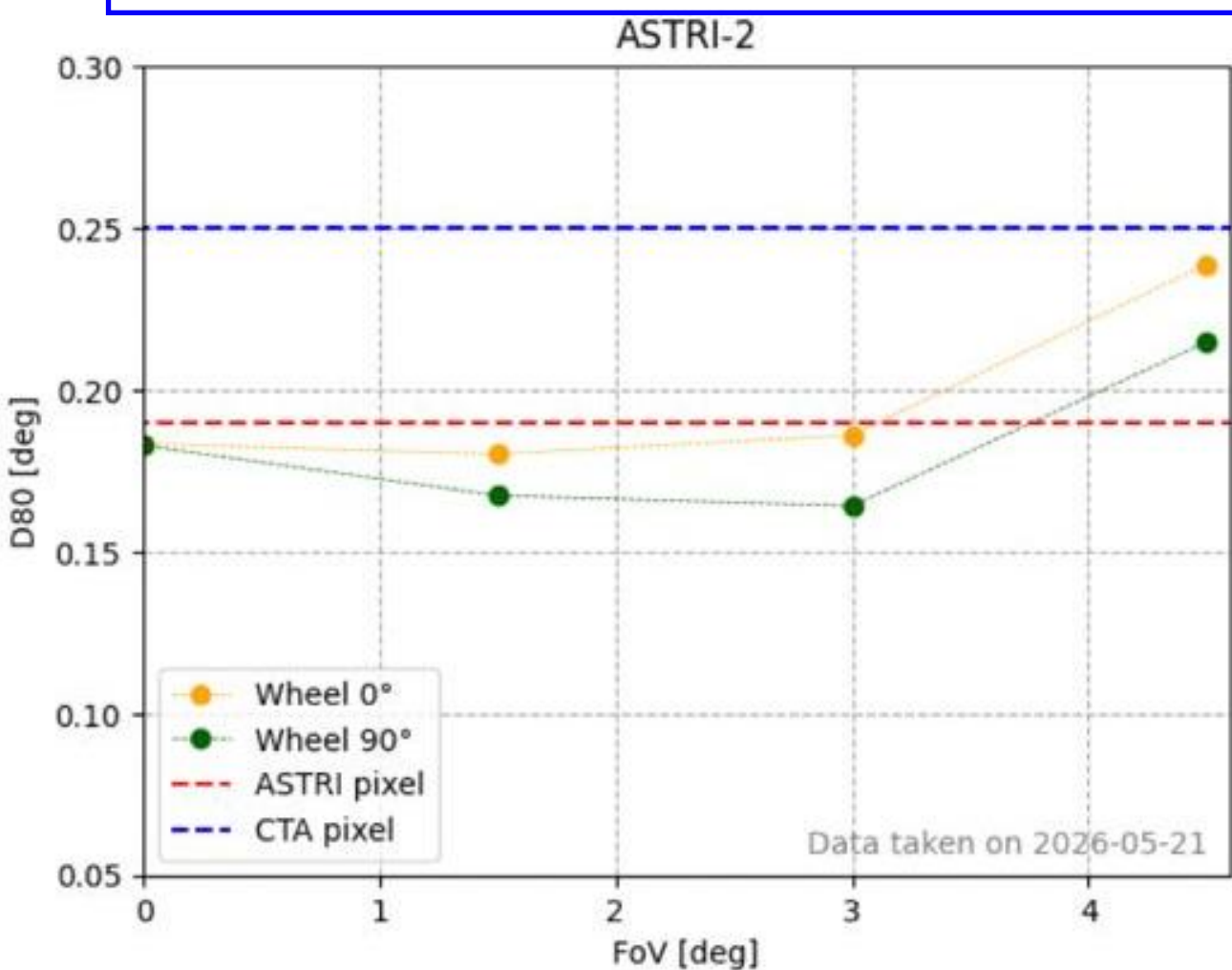
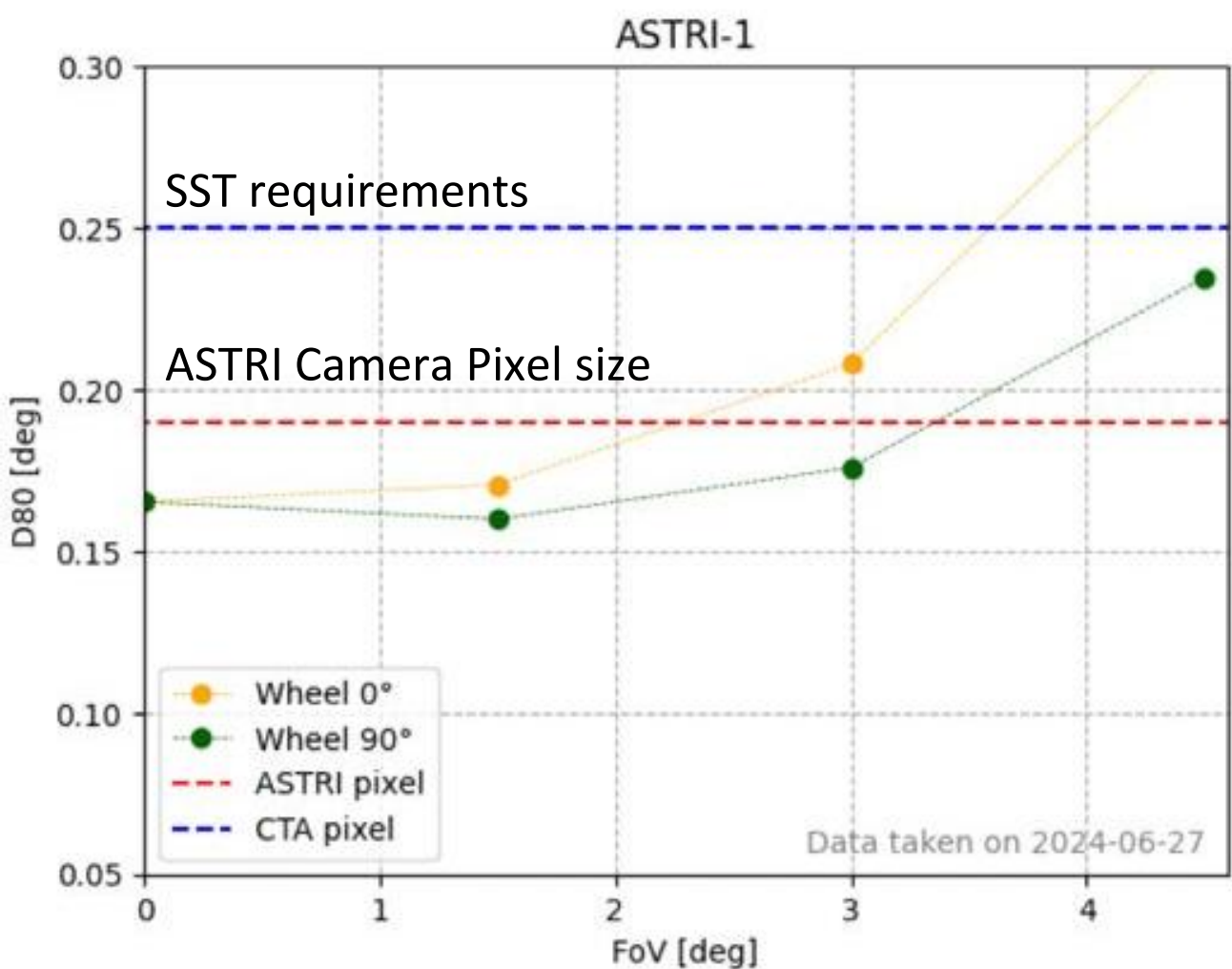


ASTRI-3

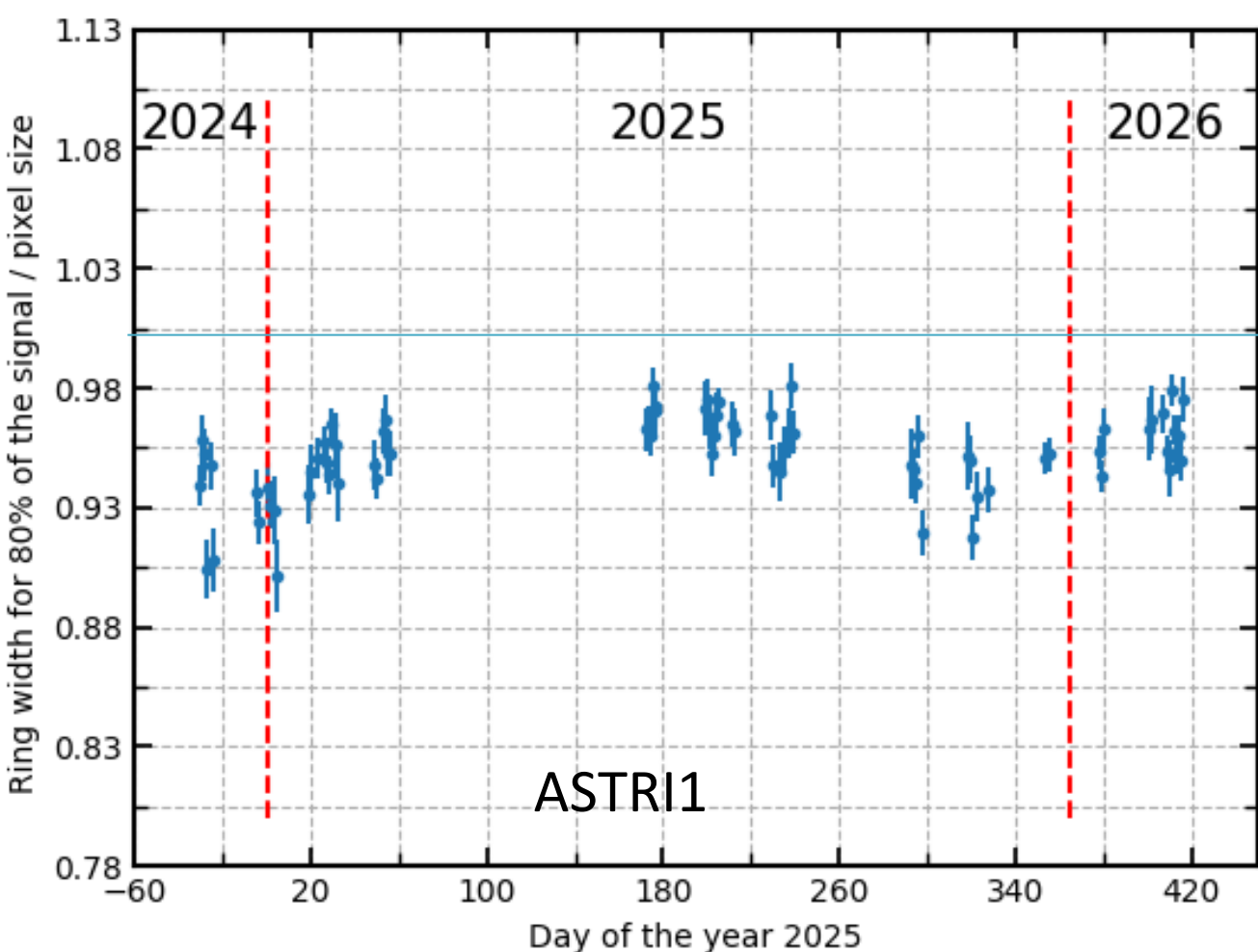


ASTRI Mini-Array: Monitor of Optical PSF

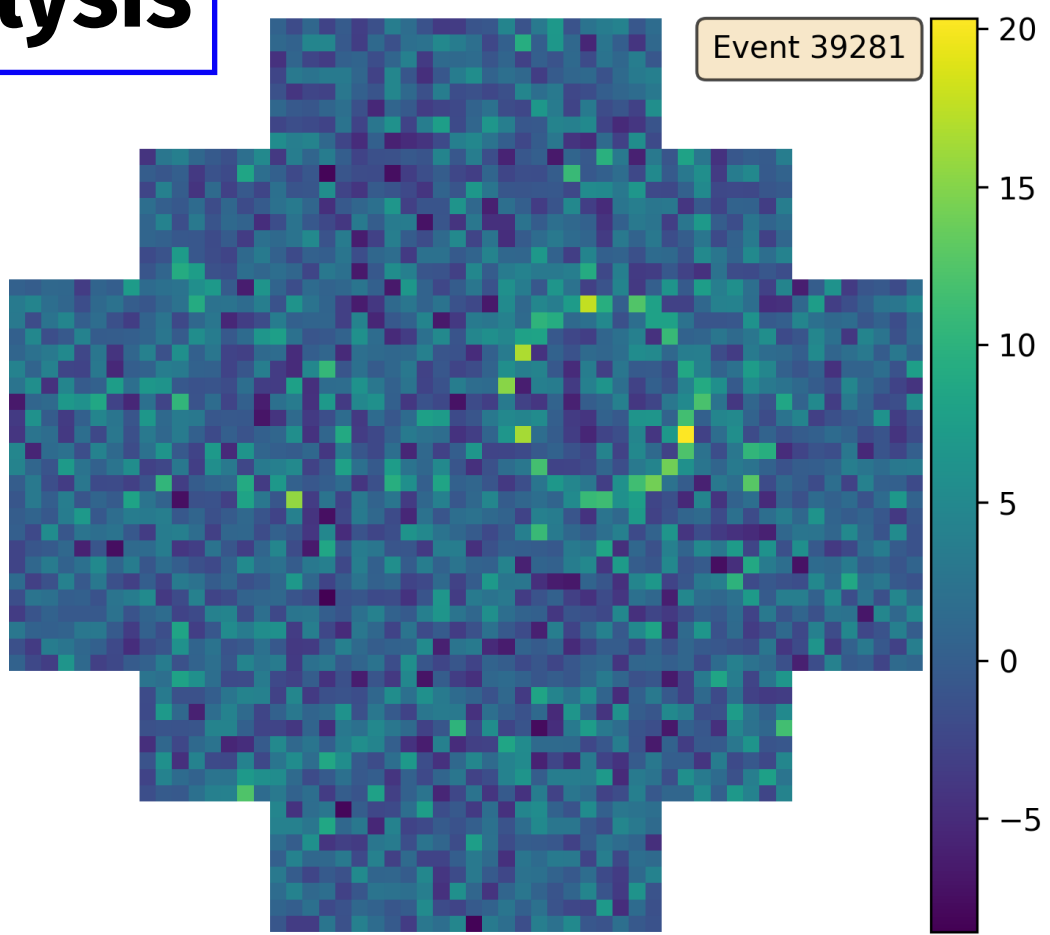
Optical Camera Measurements



Moun rings Analysis

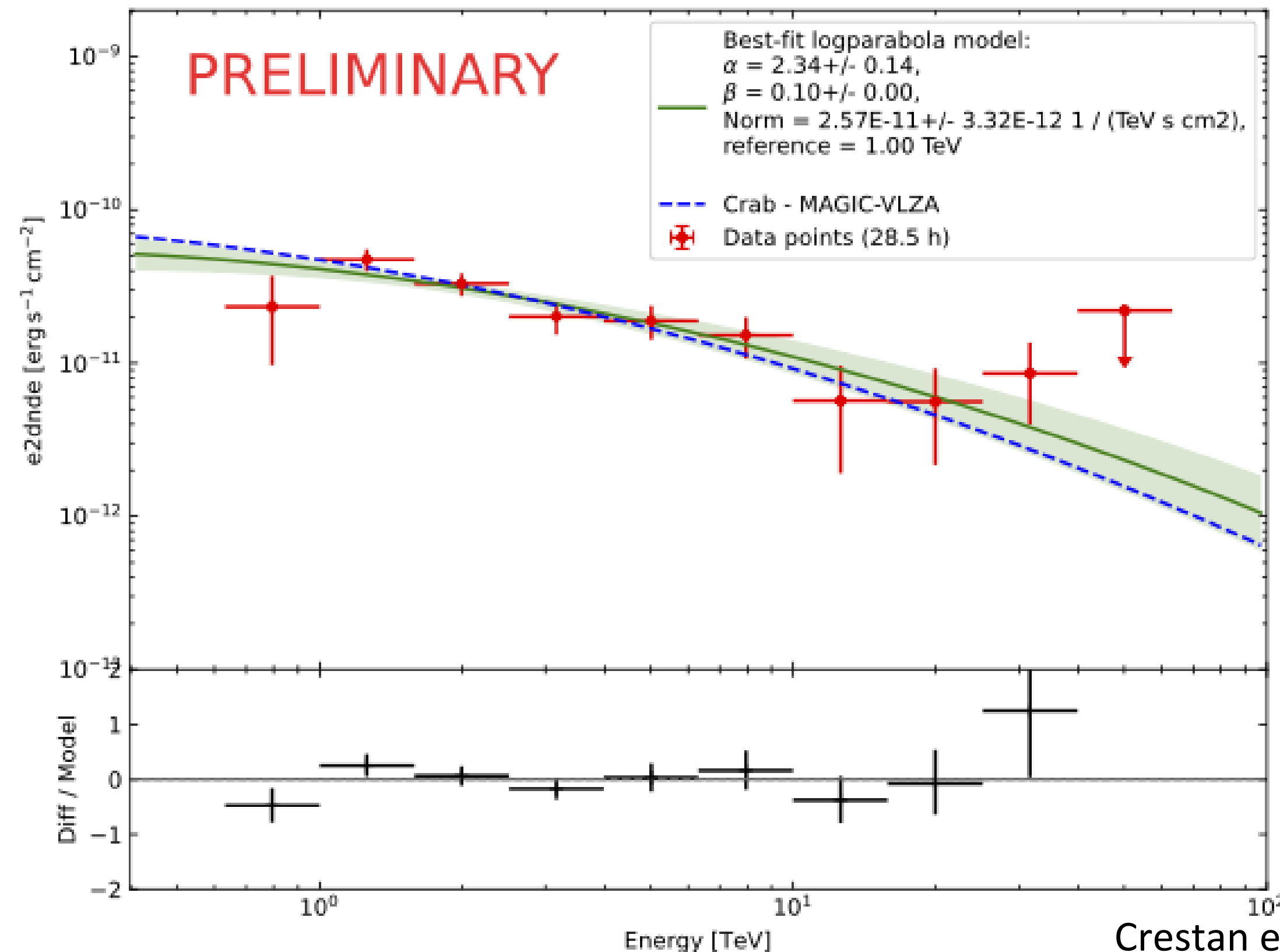


Mineo et al., 2026, SPIE, 14151-89



See Mineo's Talk

Crab (mono mode)

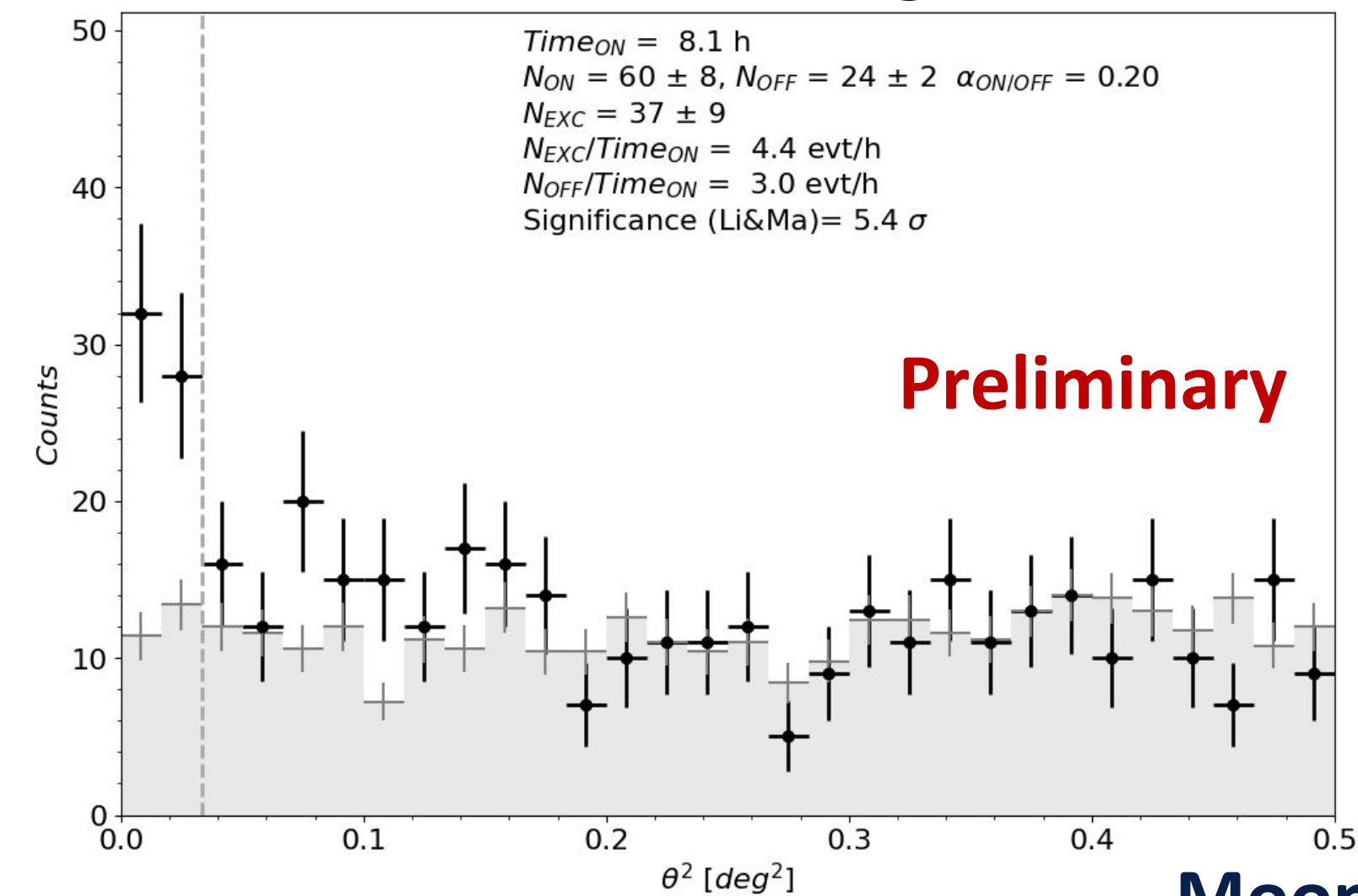


Crestan et al., 2025, PoS(ICRC2025), 617

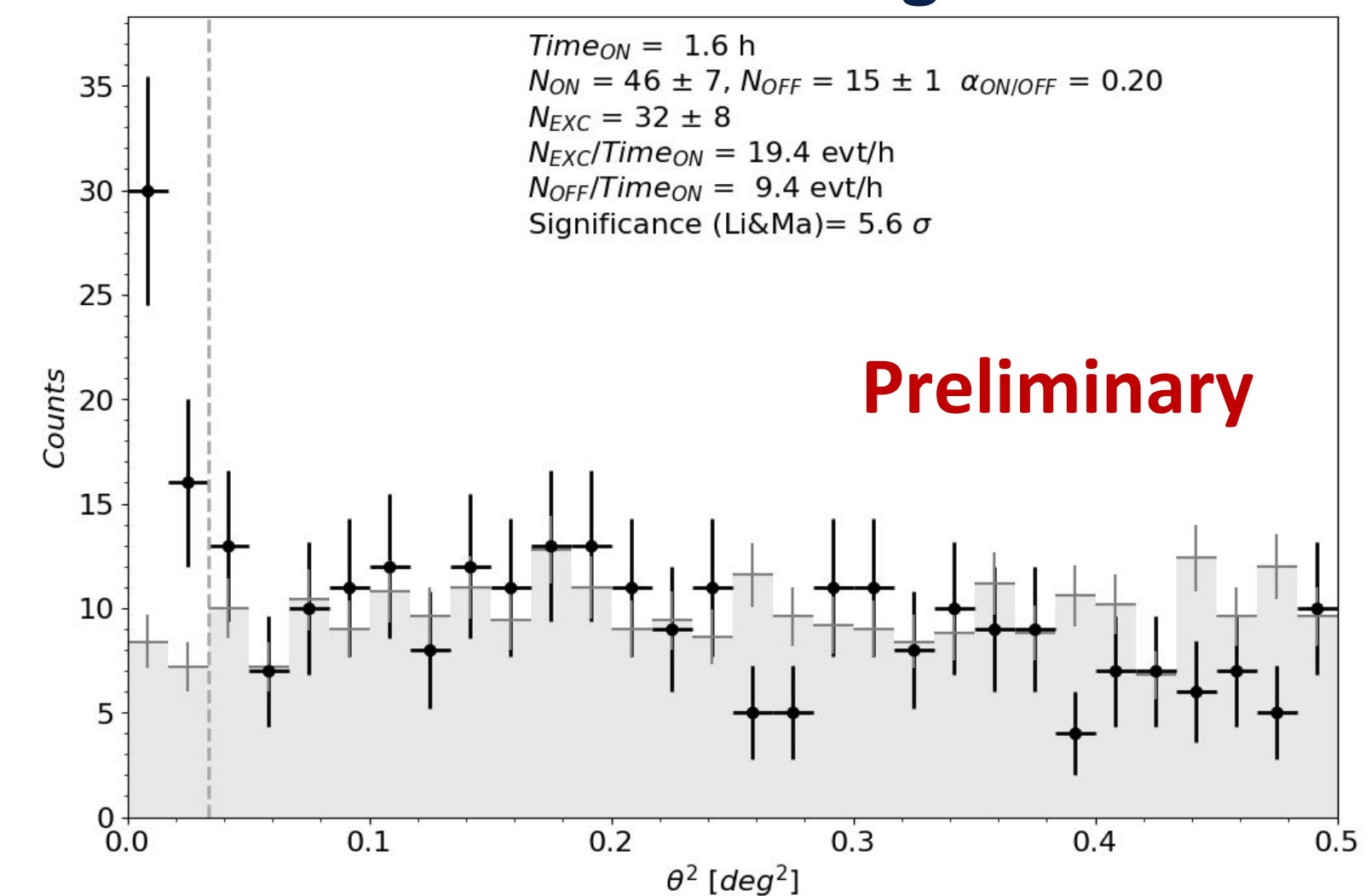
Lombardi et al., 2026, SPIE, 14155-100

See Vercellone's Talk

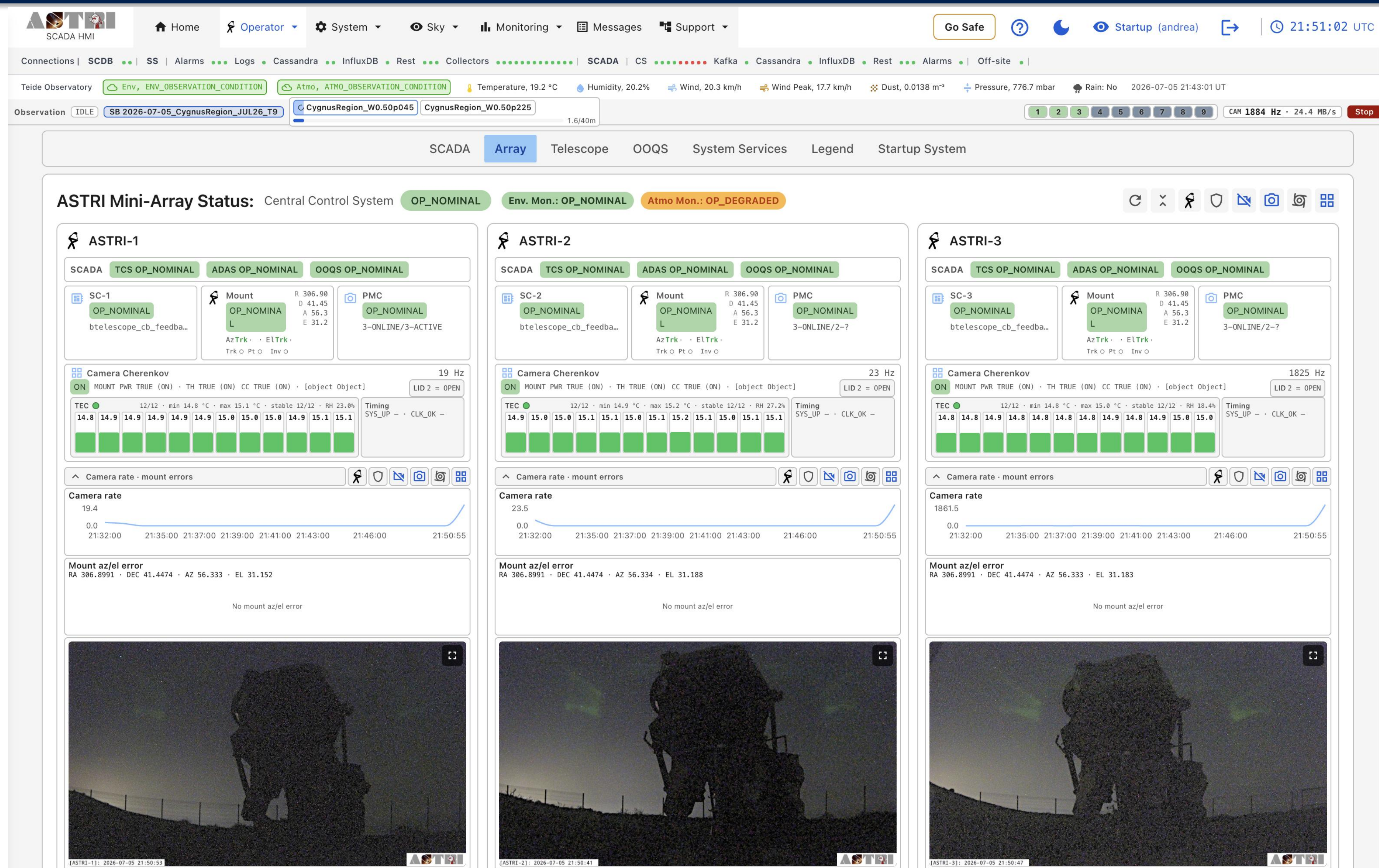
Off-axis offset angle 3.5°



Moon offset angle: 0.5°

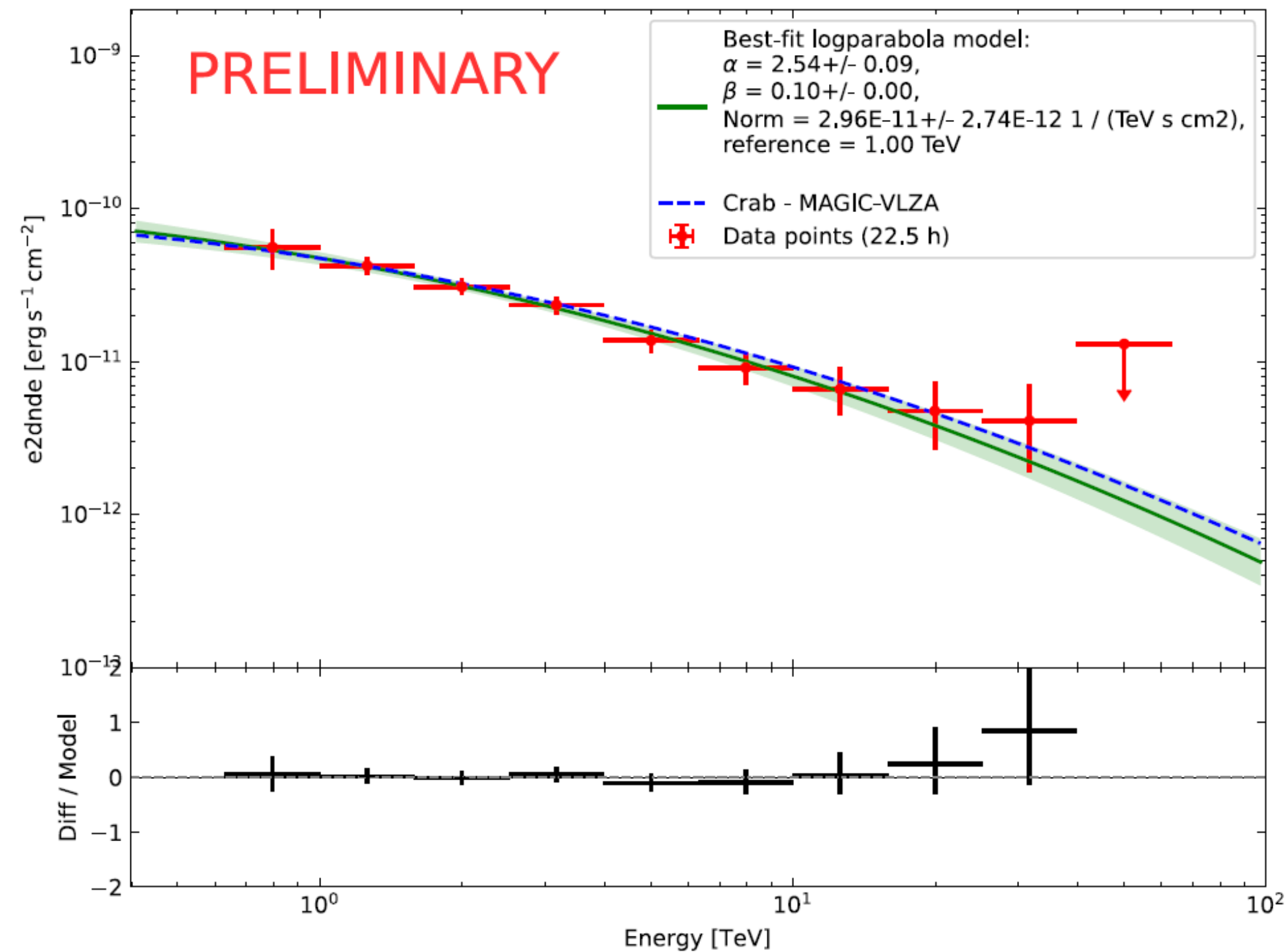


ASTRI Mini Array: Array Commissioning - ASTR1-3 integrated in SCADA

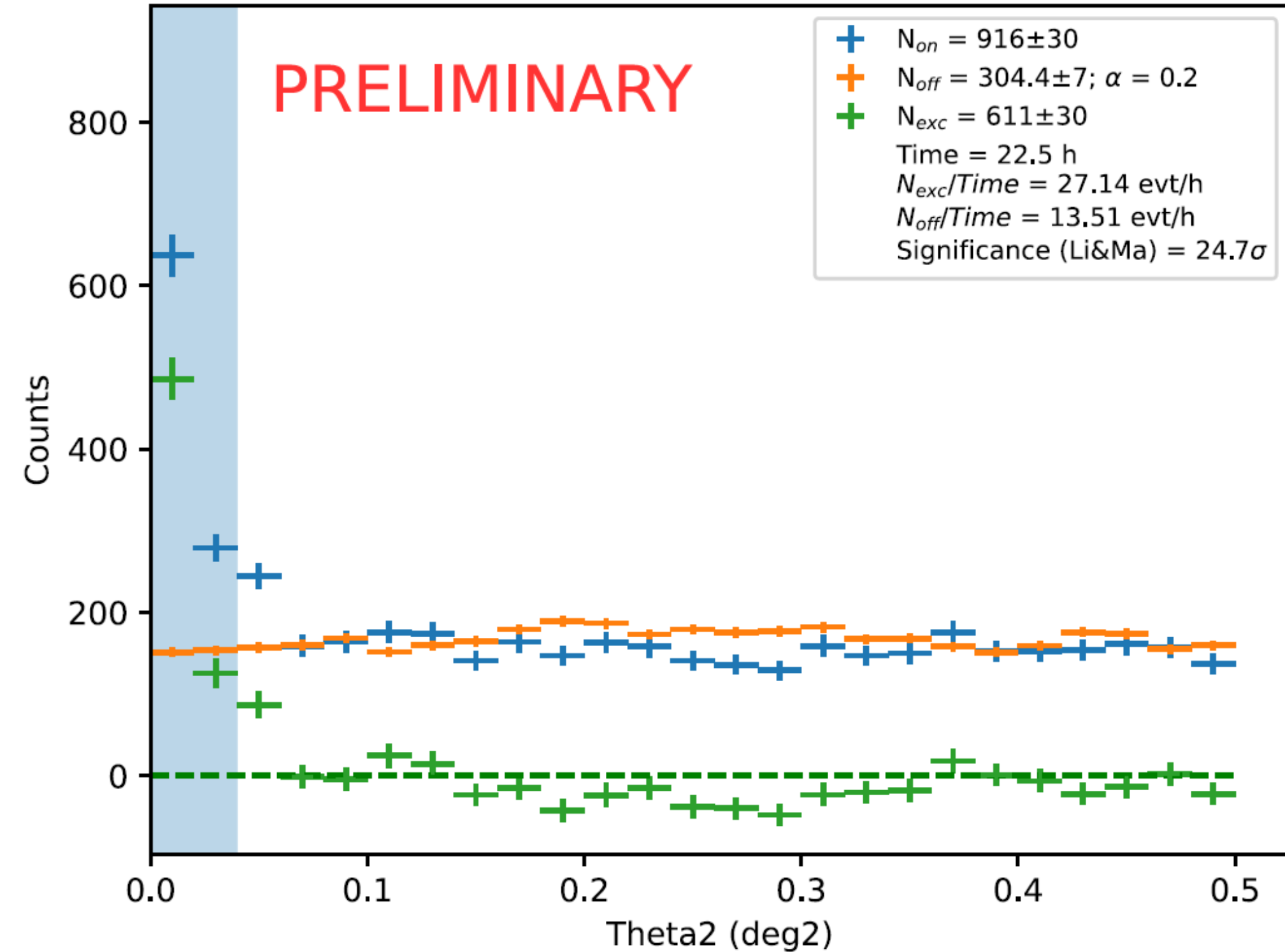


Array commissioning (Multiple telescopes)

ASTRI-1 & ASTRI-3 (stereo mode)



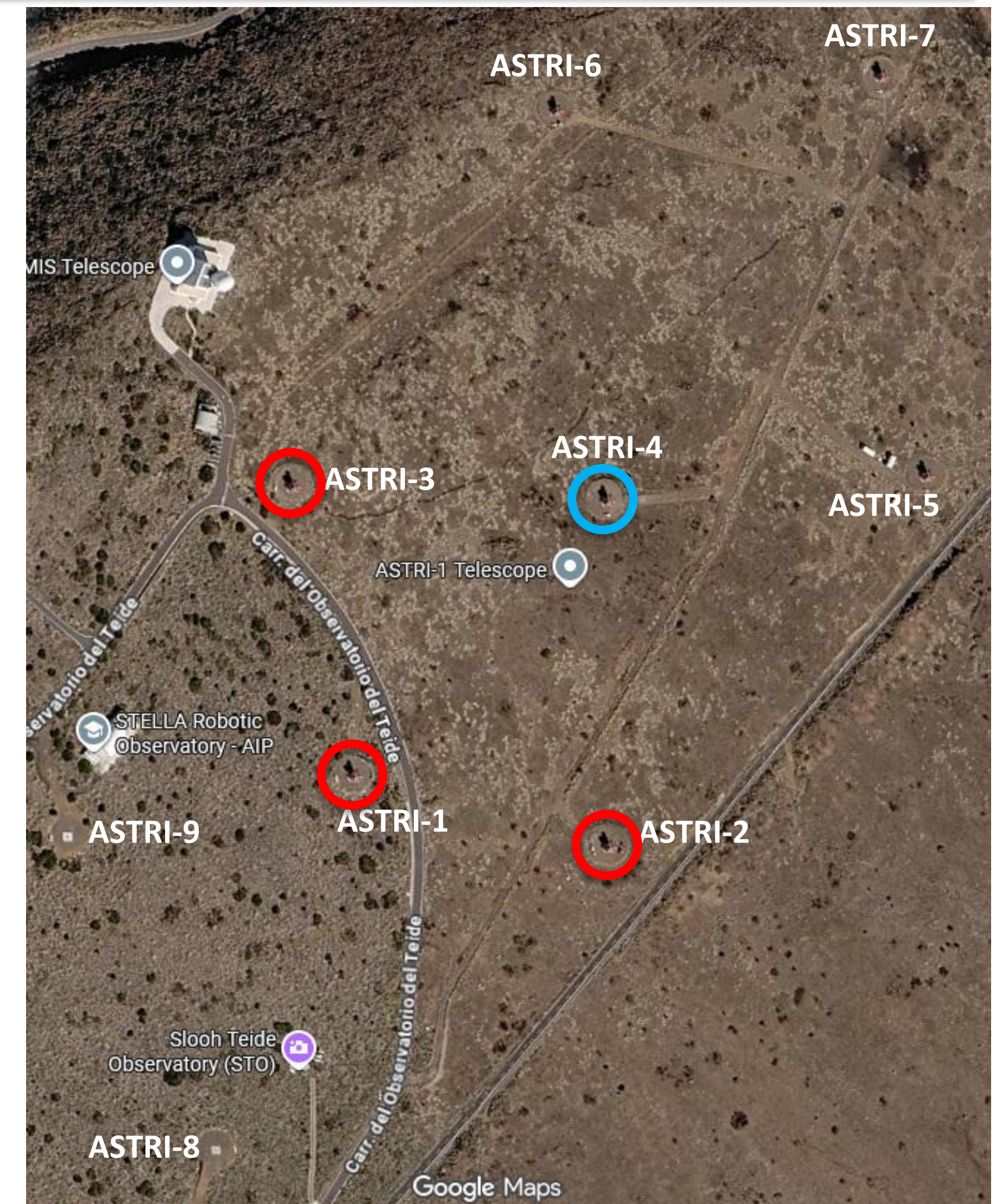
See Vercellone's Talk



Lombardi et al., 2026, SPIE, 14155-100

Summary of status of ASTRI Mini-Array

- **ASTRI-1** → Operational with Cherenkov camera
- **ASTRI-2** → Operational with Cherenkov camera
- **ASTRI-3** → Operational with Cherenkov camera
- **ASTRI-4** → Telescope tuning and mirrors alignment (🔧 July)
- **ASTRI-5** → Telescope tuning and mirrors alignment (🔧 September)
- **ASTRI-6** → Operational with SI3
- **ASTRI-7** → Telescope tuning and mirrors alignment (SI3)
- **ASTRI-8** → Integration @ Teide ongoing (🔧 end of the year)
- **ASTRI-9** → Integration @ Teide ongoing (🔧 end of the year)
- **Auxiliaries**
 - Weather stations operational
 - All sky camera not operational since Emilia storm
 - LIDAR ready for installation
 - Illuminator operational
- **ICT** → Operational
- **SCADA software** → Operational



ASTRI Mini-Array people



THANK YOU

Daniel Lopez/IAC