ASTRI Astrofisica con Specchi a Tecnologia Replicante Italiana

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

NORTH-WEST UNIVERSITY YUNIBESITI YA BOKONE-BOPHIRIMA NOORDWES-UNIVERSITEIT

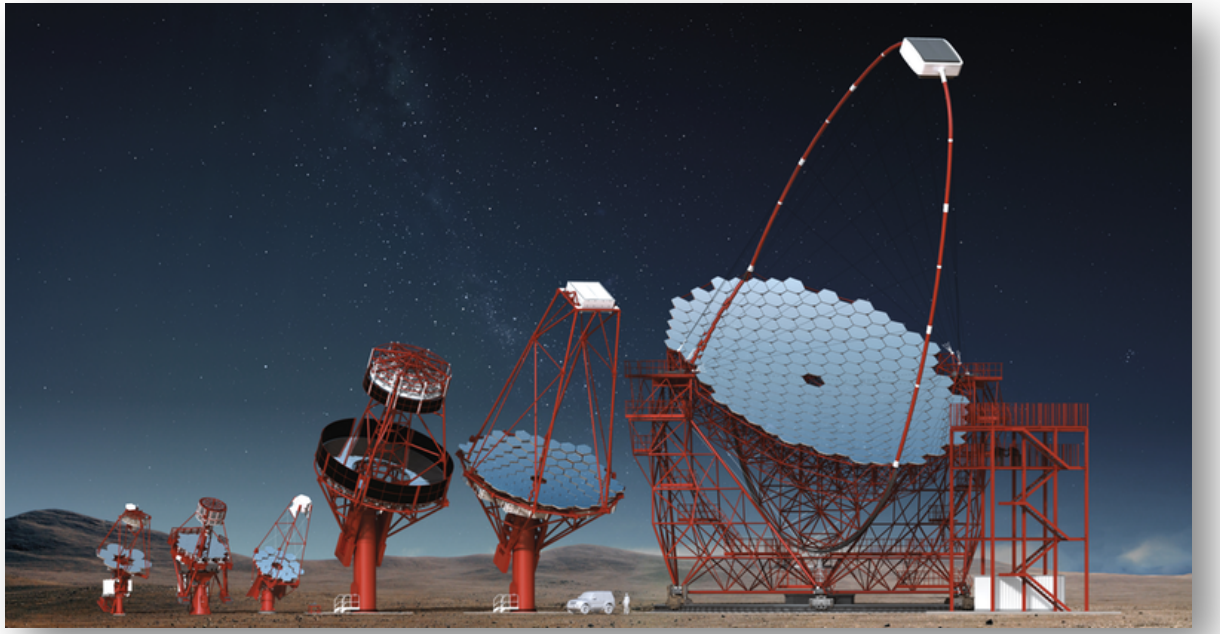
Universidade de São Paulo

MIUR

The "ASTRI Project"

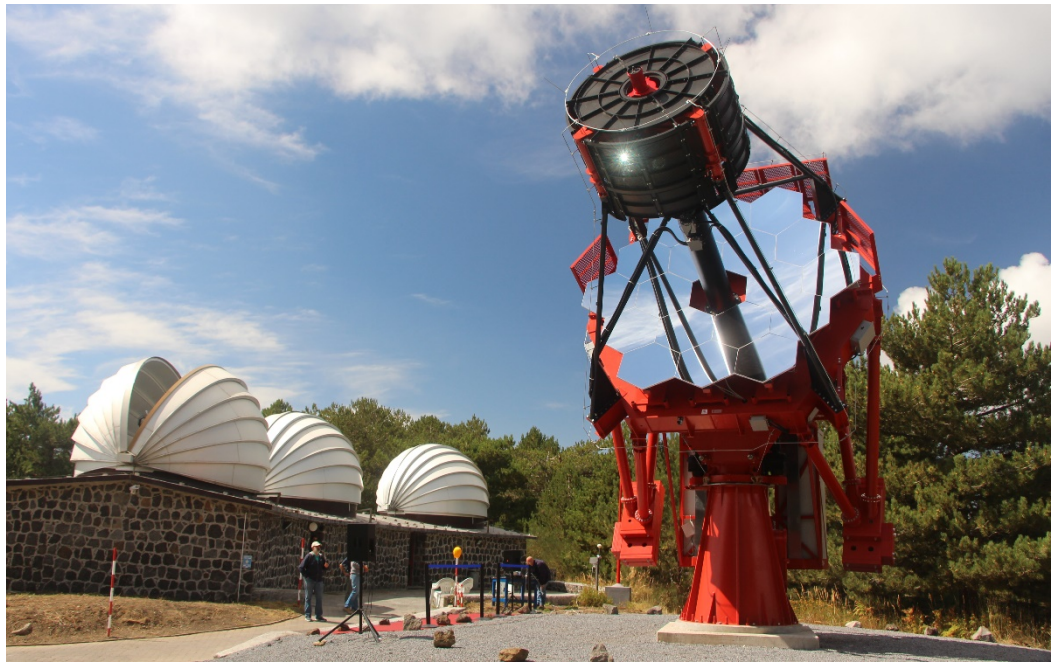
Enrico Giro – INAF

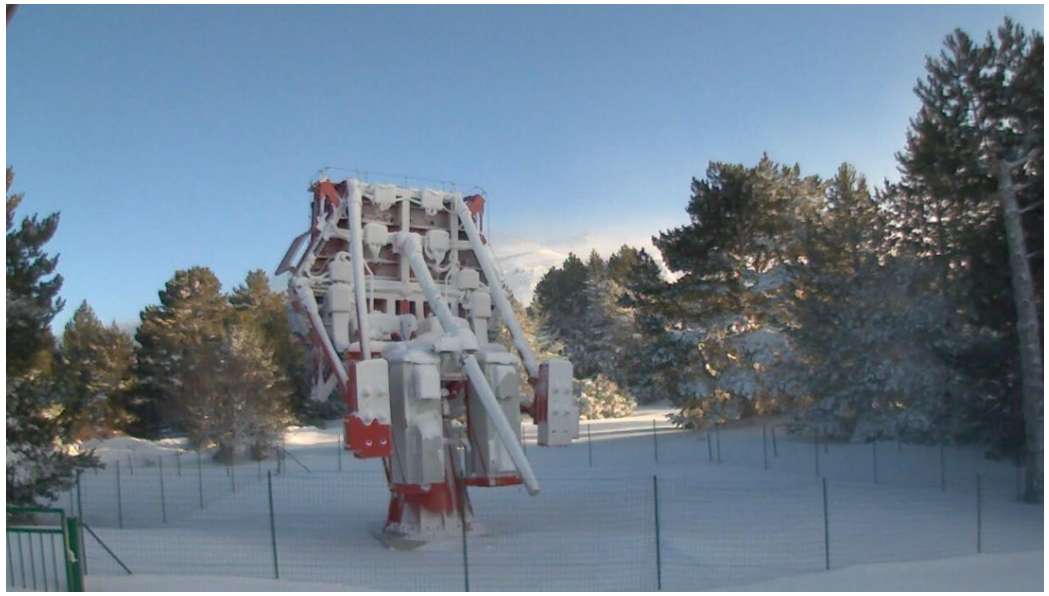
Industrial Opportunities Days, IOD - Napoli June 6-7 2019



ASTRI: Outline of the talk

- ASTRI Program
  - Why ASTRI
  - Organization & Funding
- ASTRI Prototype
  - The prototype in a nutshell
  - Highlights on performances of prototype
- ASTRI mini array
  - Production activities
- ASTRI & CTAO



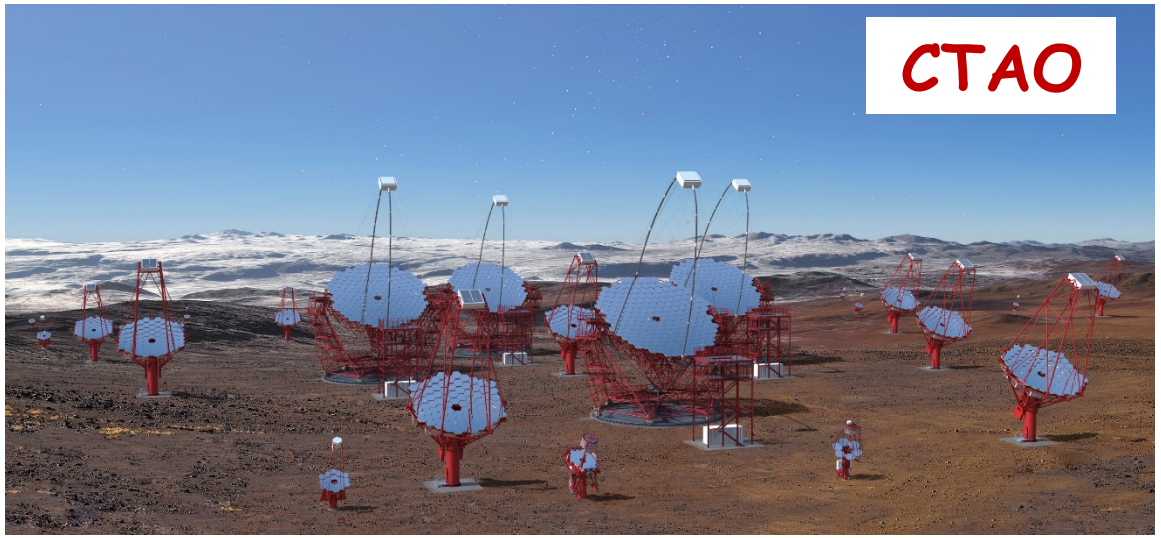


ASTRI: aim of the program

Prototype

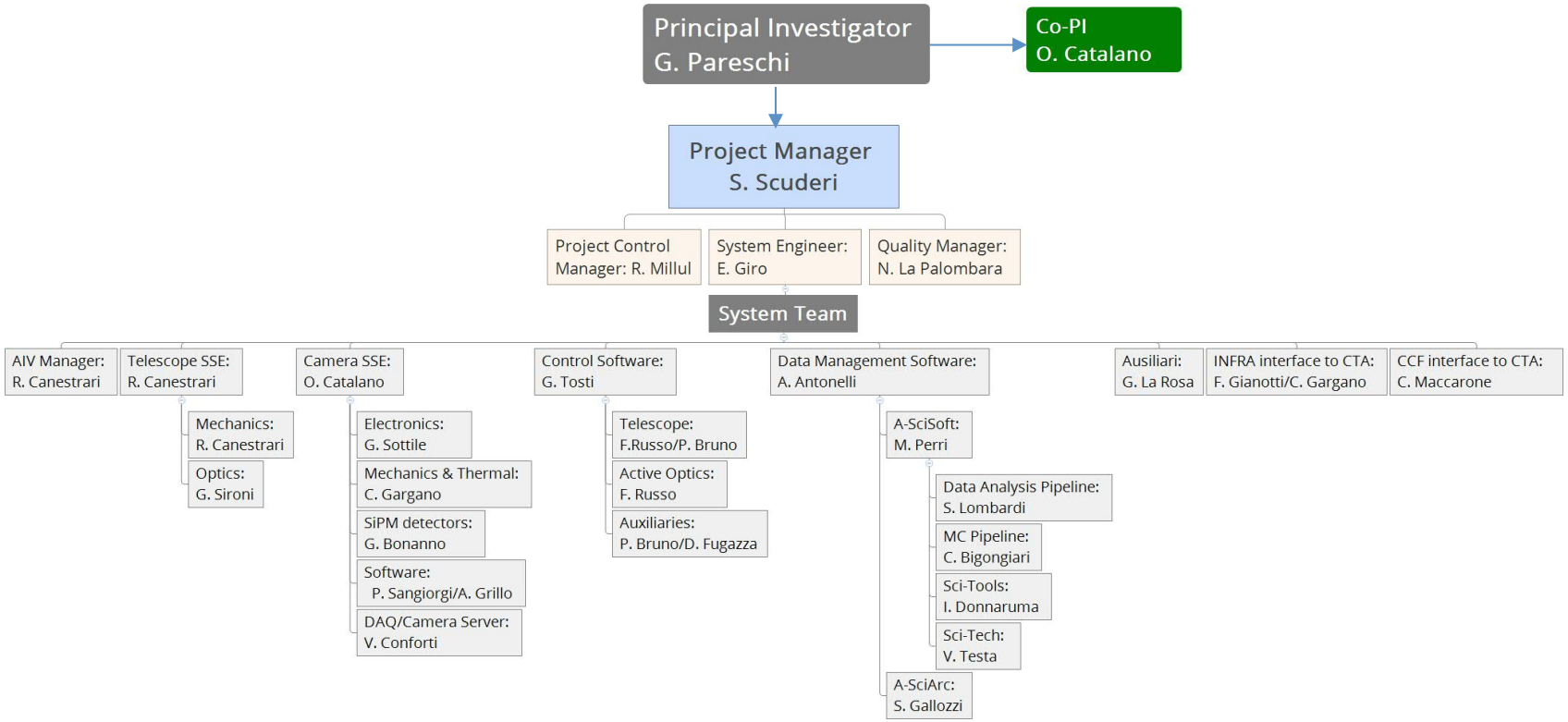
- E2E approach → astrophysical observations
- Test the stereoscopic imaging capabilities
- Test array trigger system
- Test array control system

- Demonstrator to validate the novel technology for Cherenkov telescopes and in particular for CTA (see F. Dazzi presentation)
- Training facility for telescope and maintenance operations.
- Test bench for the implementation of new HW and SW.
- E2E approach validated through astrophysical Cherenkov observations



Possible contribution to the production of a number of SST telescopes for CTA south site

ASTRI: General Organization



Industrial Contribution

Telescope
- EIE
- Galbiati

Optics
- Media Lario
- Flabeg
- ZAOT

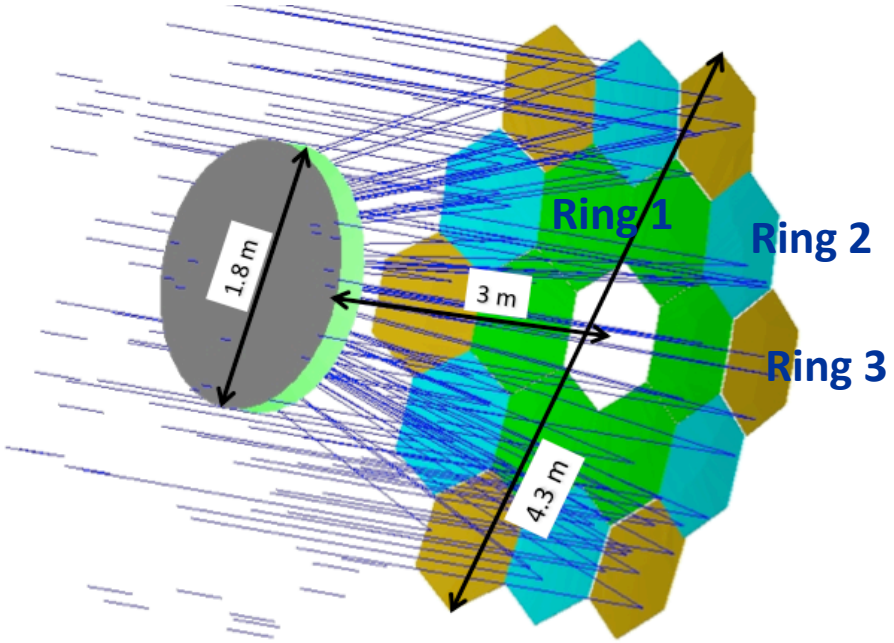
Cherenkov Camera
- Hamamatsu
- Weeroc
- Mindway
- Novasys
- Thermacore
- TMA

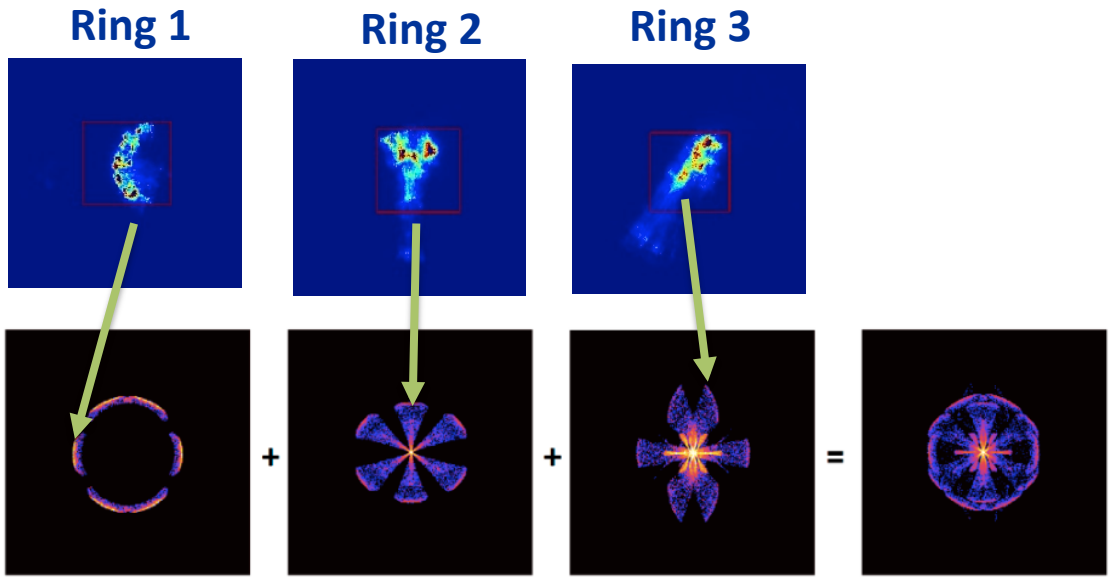
- **Prototype**: funds from MIUR through Flagship project and PRIN (~ 9 M€)
- **Mini-array**: Dedicated funds from MISE – "Astronomia Industriale" (10 M€), and international partners in particular Universidade de Sao Paulo – Brazil, (1.8 M€) and North Western University – South Africa (0.3 M€)
- **CTAO**: funds from MIUR (50 M€)

ASTRI in a nutshell : Structure Assembly

Mechanical Structure	
Dimensions & Mass	
Height of the Telescope (pointing horizontally & vertically)	7.5 m & 8.6 m
Radius of free area for Az. Movements	5.3 m
Total Mass of the prototype	19000 kg
Tracking & Pointing	
Driver Encoder Precision	2 arcsec
Tracking Precision	<0.1°
Pointing Precision After Calibration	5 arcsec
Servo Control	
Motors & Drivers	SEW
PLC	Beckhoff
Encoders	Heidenhain

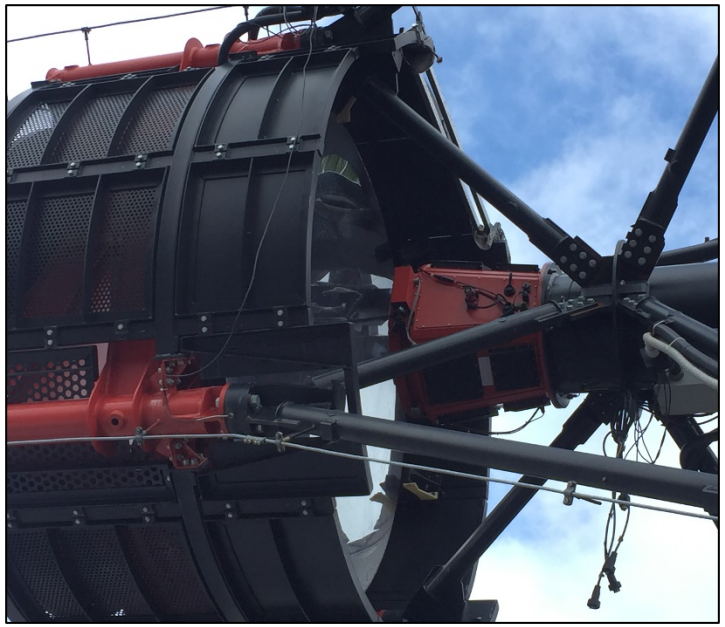
ASTRI in a nutshell : Optics

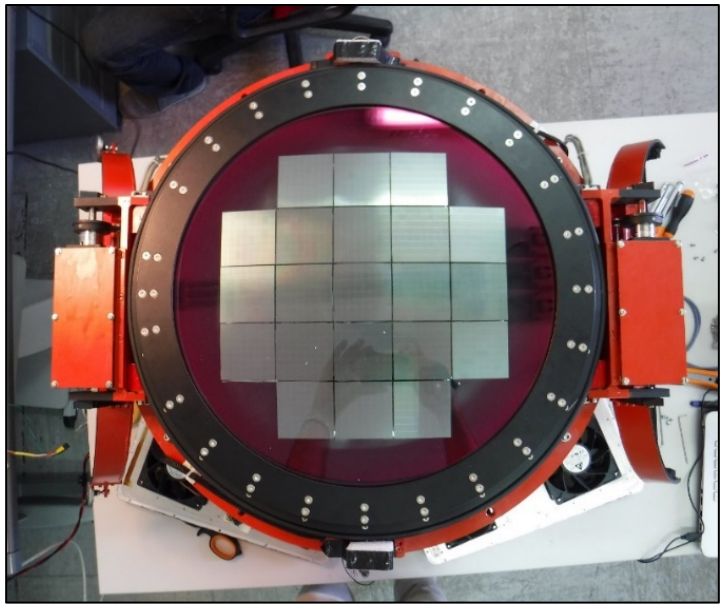




Optics	
Optical Configuration	Schwarzschild-Couder
Average effective collecting area	5 m^2
Focal Length	2.2 m
Aperture	4.3 m
f/#	0.5
FOV	10.5° (8.2° prototype)
PSF (@ 100 % of FOV diameter)	0.19°
Primary Mirror (segmented)	
Diameter	4.306 m
Number of segments	18
Size of a segment	850 mm (face-to-face)
Nominal Radius of Curvature Ring 1,2,3	8.52, 9.87, 12.54 m
Technology	Cold Slumping
Coating	Al+SiO_2
Micro-roughness (RMS, 0.1 - 200 mm spatial wavelength range)	< 2 nm
Secondary Mirror (monolithic)	
Diameter	1.8 m
Technolgy	Hot Slumping
Coating	Al+SiO_2

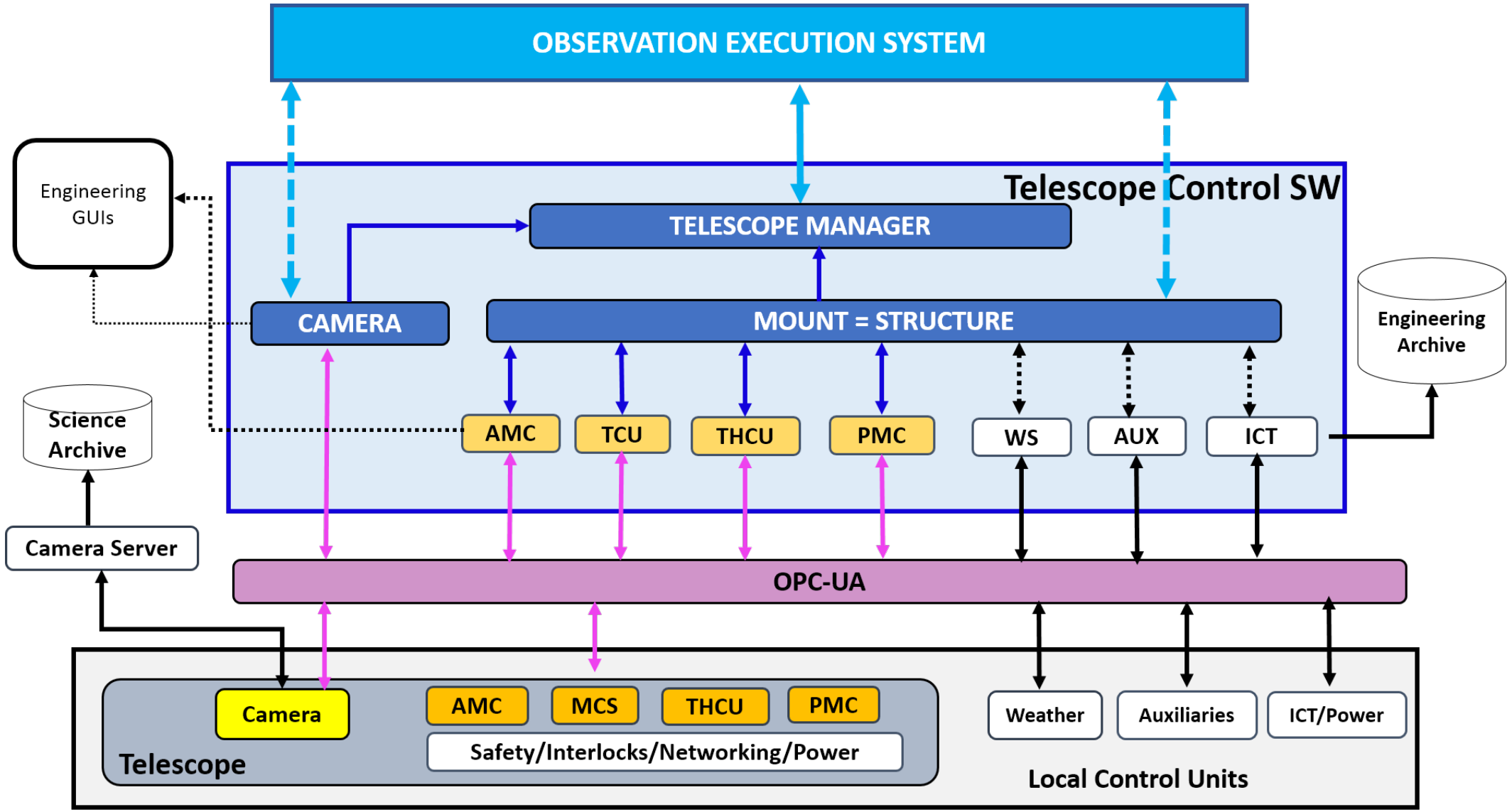
ASTRI in a nutshell: Cherenkov Camera



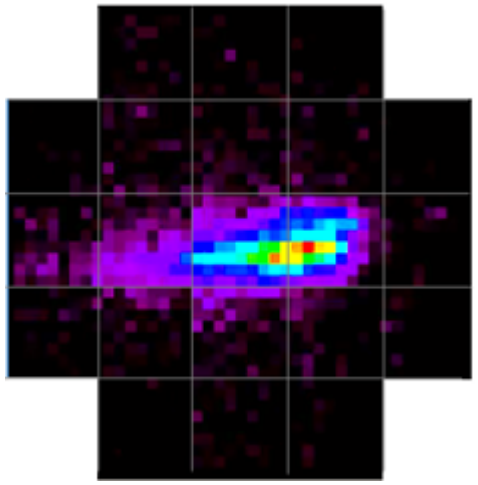


Cherenkov Camera	
Camera opening Angle	70°
Sensors	SiPM (Hamamatsu LCT5)
Number of Pixels	2368 (1344 protoype)
Pixel size	7x7 mm
Pixel rate	4kH Hz
Dynamical range	1 – 2000 (1350 prototype) pe^-/pixel
Photon Detection Efficiency	> 35% @ 400nm
FoV	10.5° (8.2° prototype)
Weight	73 kg
Dimensions	0.52m x 0.66m x 0.56m
Power consumption	0.65 kW

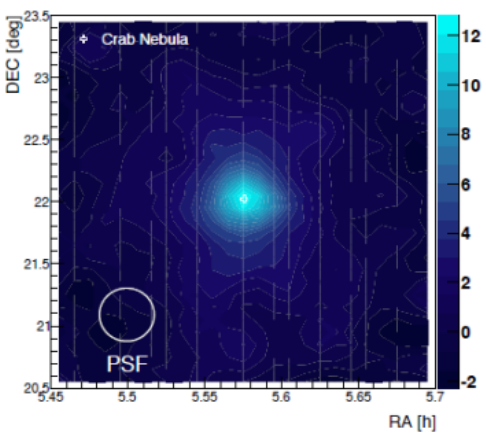
ASTRI in a nutshell: Control Software

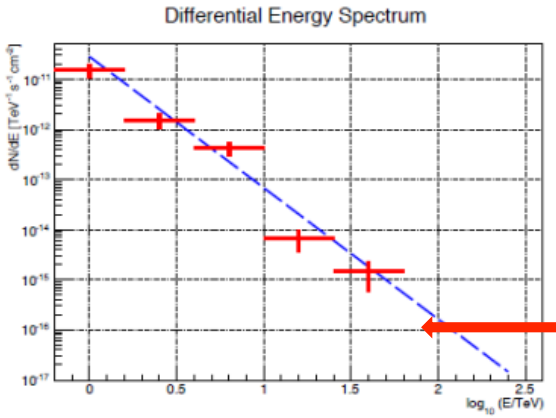


A-SciSoft is a dedicated software package for data reconstruction and scientific analysis The software perform data reduction (from DL0 up to DL4) for ***real-like ASTRI SST-2M prototype data***

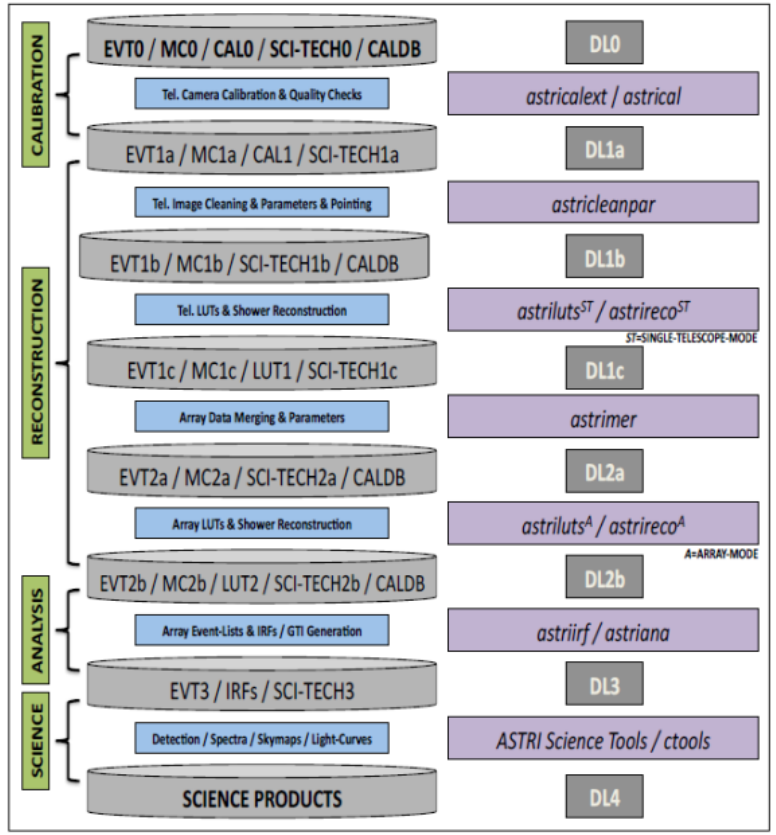


Raw Data





Science Products

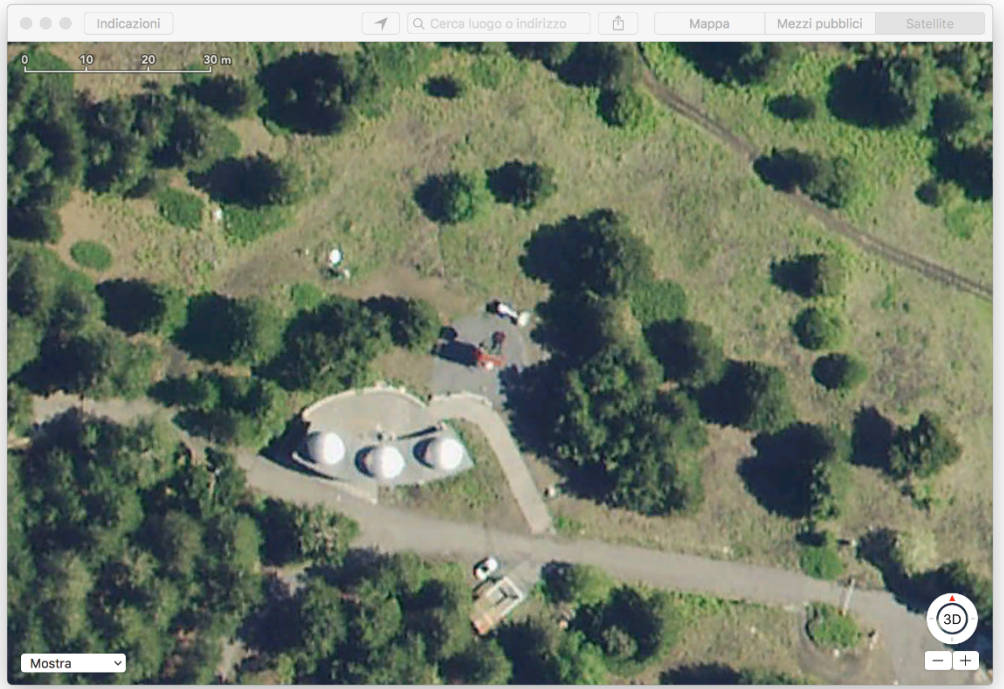


Breakdown stages; Basic components; Executable modules; I/O Data level.

ASTRI Scientific Software

- can handle real and MC data for both prototype and mini-array
- follows the general CTA design and data model scheme defined in CTA Data Management
- is developed for on-line/on-site/ off-site data reduction pipelines
- manages FITS data from DL0 to DL4 (`cfitsio`/`CCfits` libraries) (for mini-array, DL0 in RAW format)
- can run on x86 / ARM CPUs & NVIDIA GPUs
- is developed in independent software modules linked by pipelines written in Python
- uses CTA Science Tools

ASTRI Prototype: Inauguration



24th September 2014

Inauguration of the prototype @ INAF-Catania mountain station in Serra La Nave placed at 1725 meters on the Etna volcano

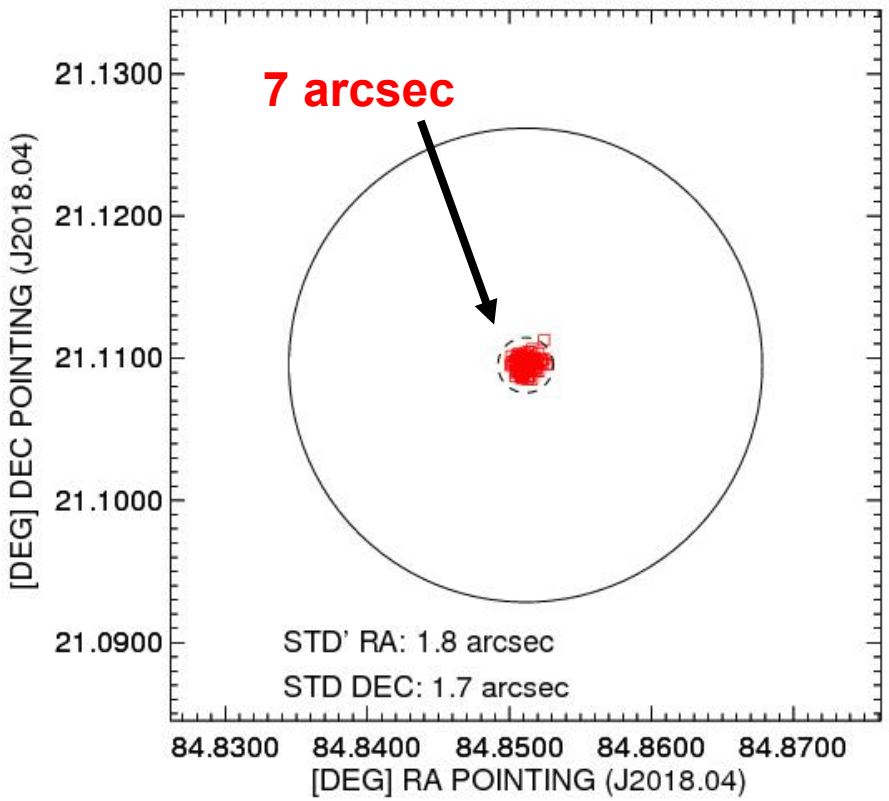
ASTRI Prototype: Dedication to Horn D'Arturo

10th of November 2018

Dedication of ASTRI prototype telescope to Guido Horn D'Arturo → ASTRI – HORN telescope

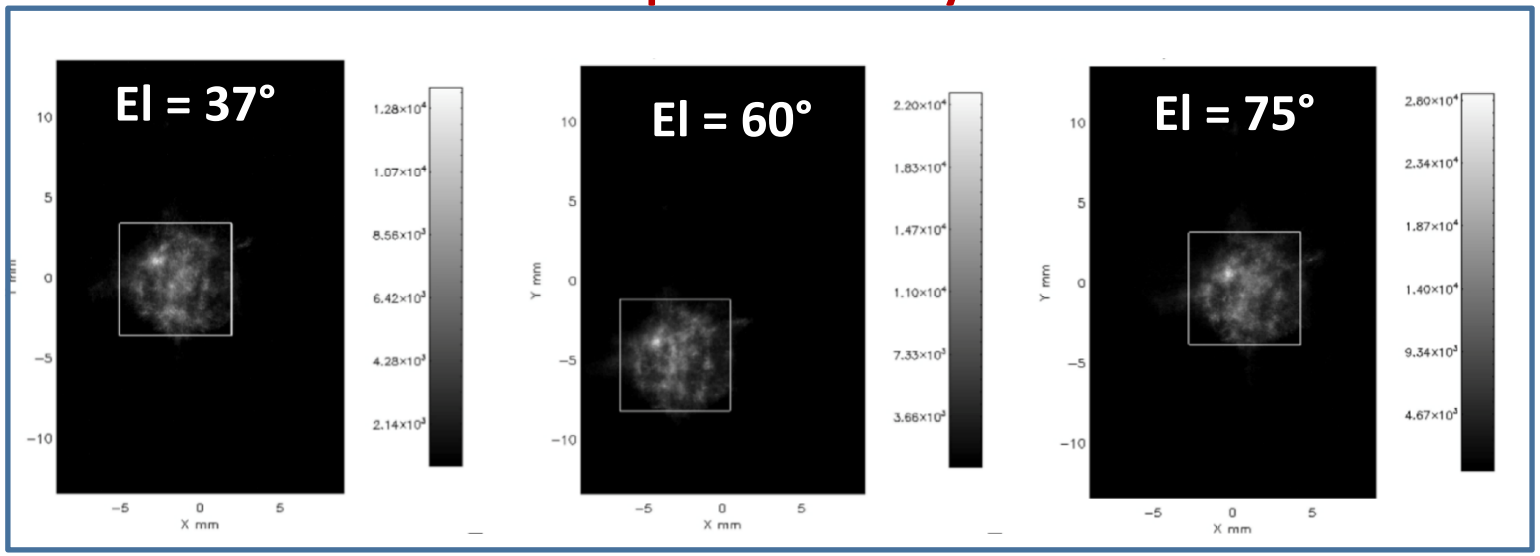
ASTRI – HORN: Telescope Performances

Pointing accuracy

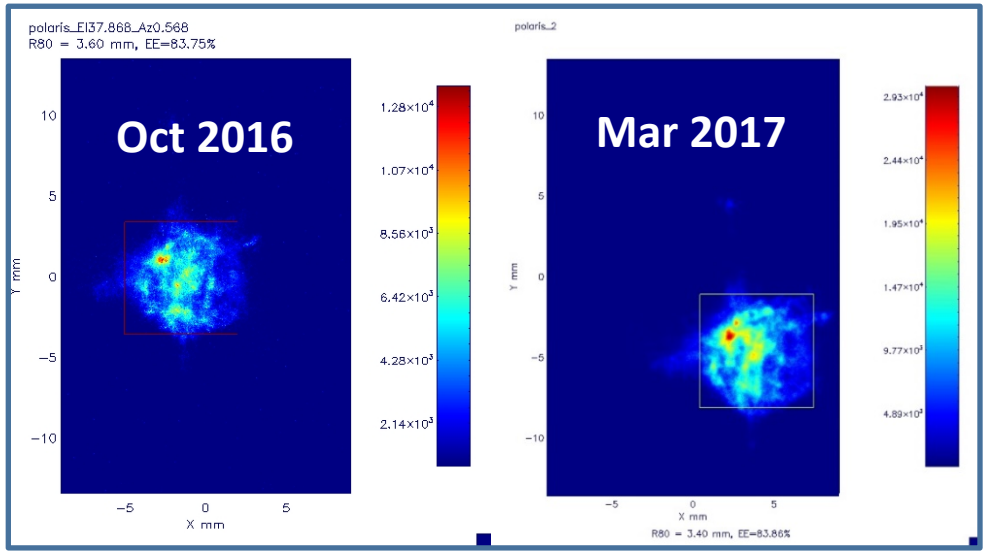


- CTA post calibration astrometric accuracy: 7”
- CTA online astrometric accuracy: 1’

PSF Spatial Stability

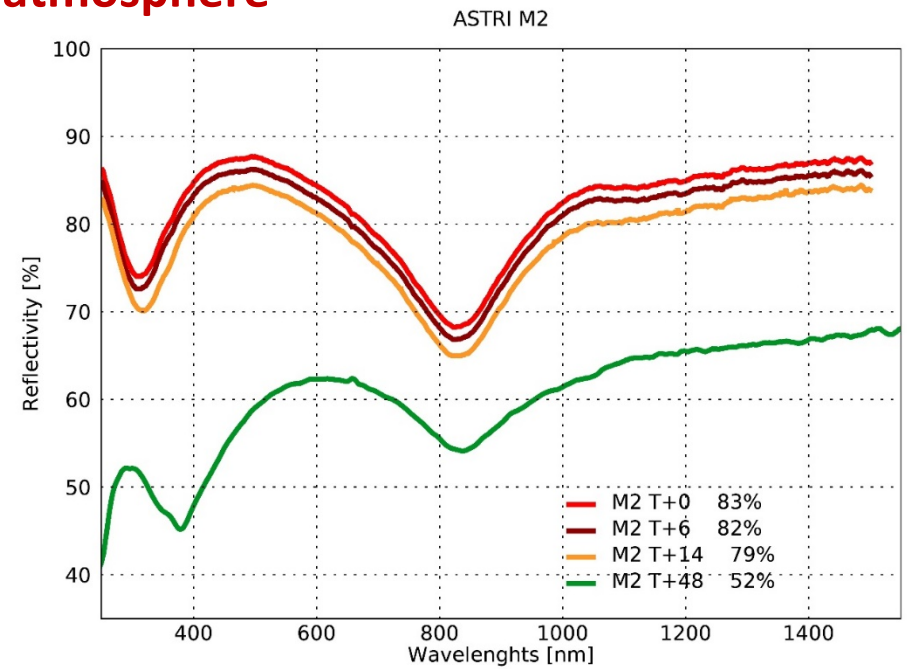


PSF Temporal Stability

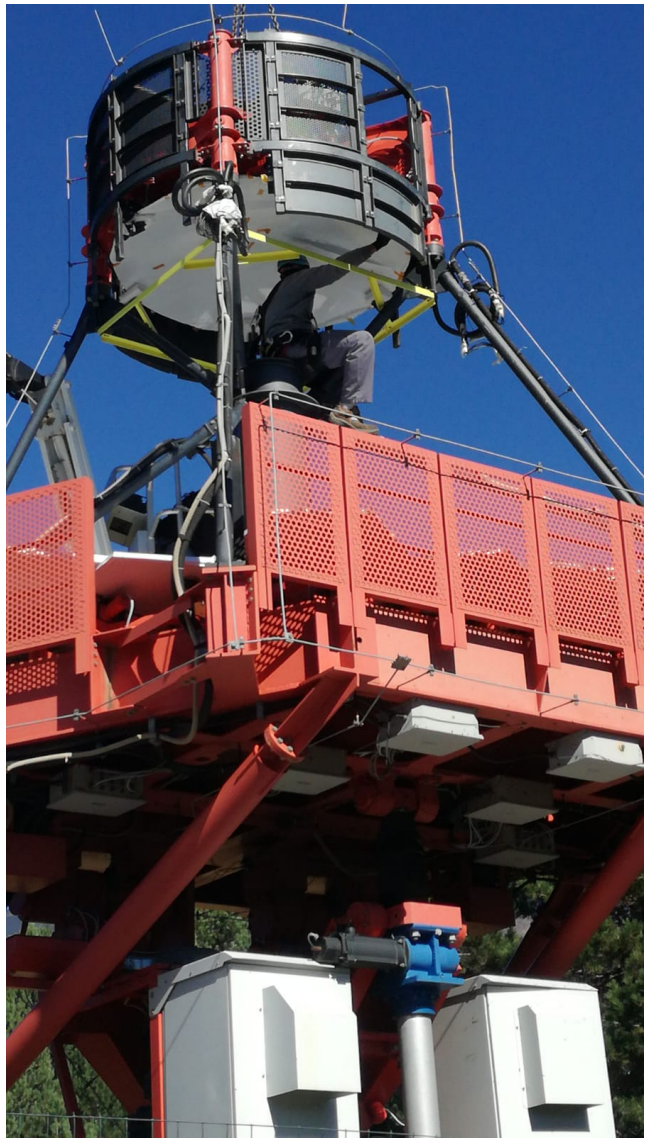


No active mirror control is necessary for normal operations → Tool for Assembly, Integration, Validation (AIV) and maintenance activities

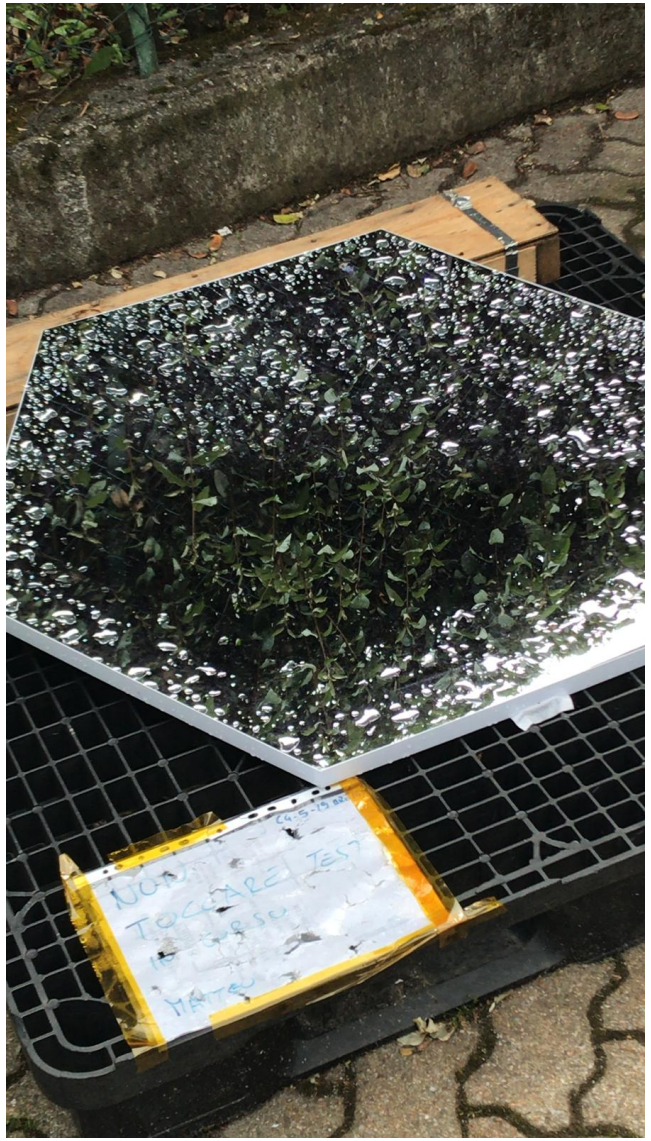
Ageing faster than expected → Etna aggressive atmosphere



Changing M2 Mirror



Looking for a protective coating

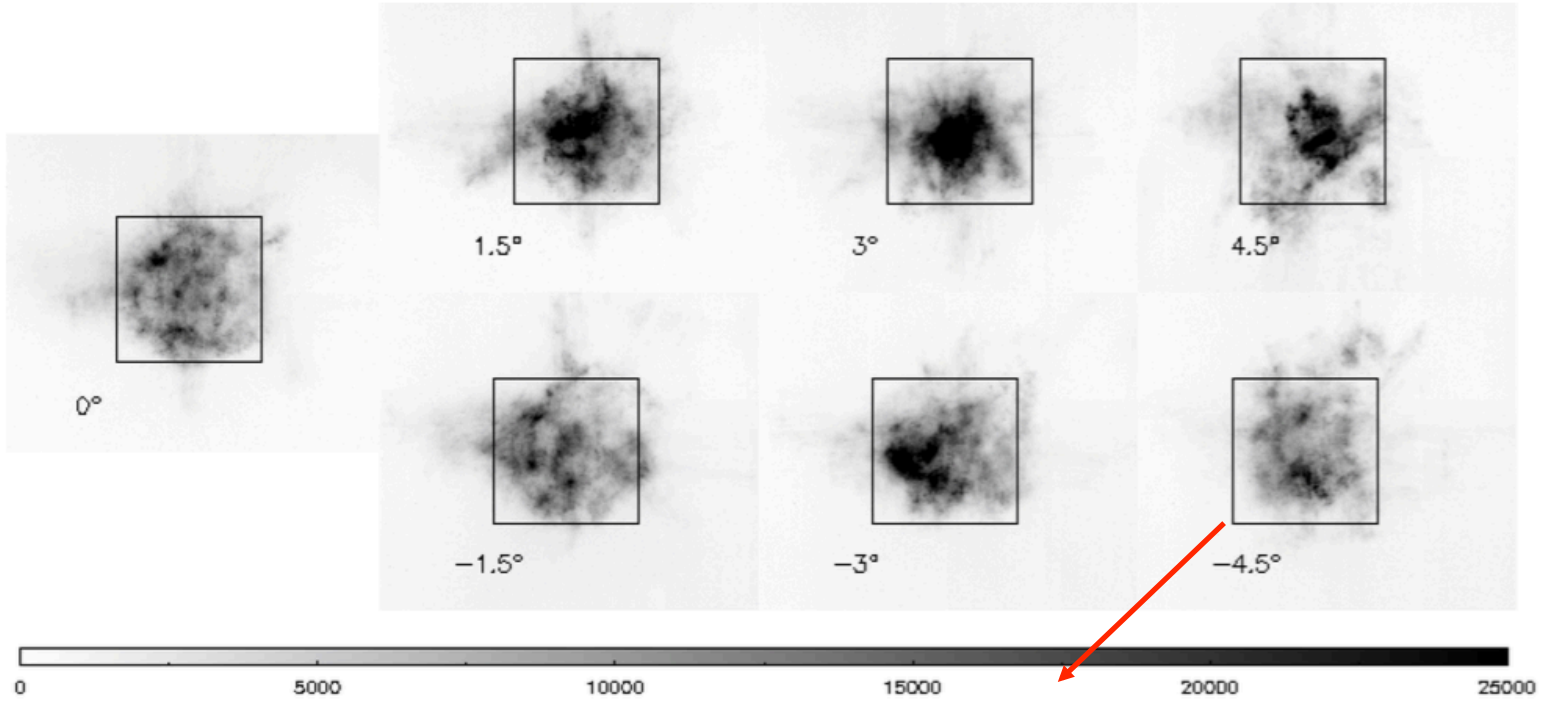


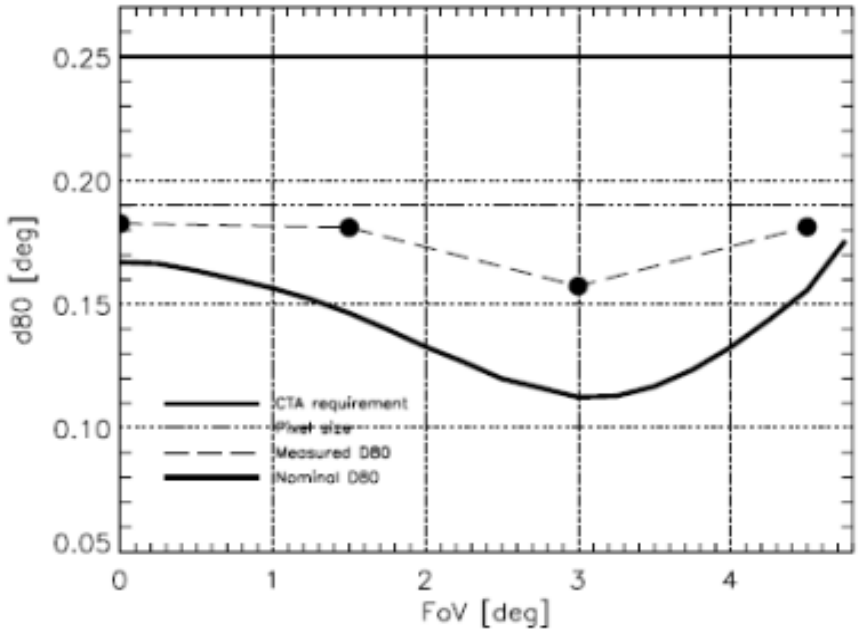
ASTRI – HORN: PSF across the field of view

Astronomy & Astrophysics manuscript no. a˙a˙paper˙optical˙quality˙ver3˙arXiv
September 28, 2017

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

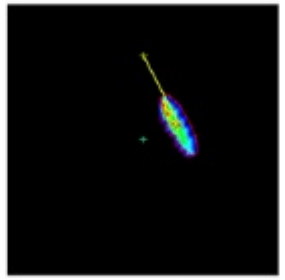
E. Giro[1,2], R. Canestrari[2], G. Sironi[2], E. Antolini[3], P. Conconi[2], C.E. Fermino[4], C. Gargano[5], G. Rodeghiero[1,6], F. Russo[7], S. Scuderi[8], G. Tosti[3], V. Vassiliev[9], and G. Pareschi[2]

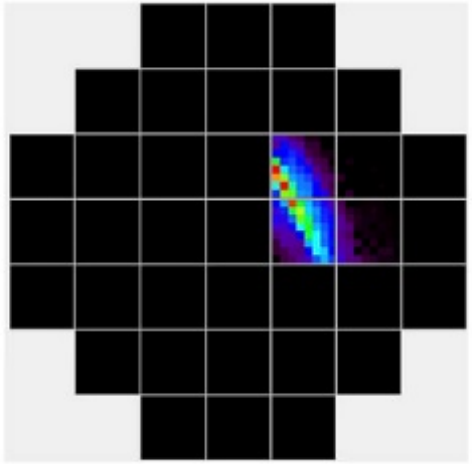




FoV position (deg)	D80 (mm)
4.5	6.72
3.0	6.32
1.5	7.28
0.0	6.86
-1.5	6.32
-3.0	5.50
-4.5	6.90

SiPM pixel linear dimension: 7 mm → 11.2 arcmin





25th of May 2017

First Cherenkov light with the ASTRI camera

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cta cherenkov telescope array

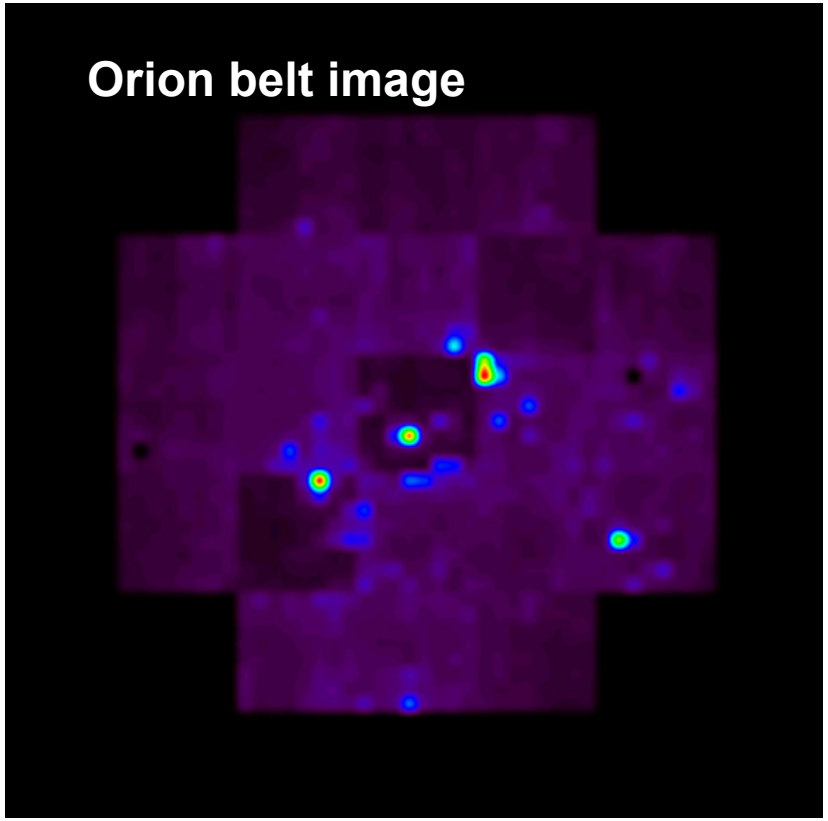
Press Release

CTA Prototype Telescope, ASTRI, Achieves First Light

Download full release: 2 MB / PDF

During the nights of 25 and 26 May, the camera of the ASTRI telescope prototype (pictured to the left) recorded its first ever Cherenkov light while undergoing testing at the astronomical site of Serra La Nave (Mount Etna) in Sicily managed by INAF-Catania. This comes not long after its optical validation was achieved in November 2016 (read story here). This accomplishment was the first optical demonstration for astronomical telescopes using the novel Schwarzschild Couder dual-mirror design. The ASTRI telescope is a proposed Small-Sized Telescope design for the Cherenkov Telescope Array (CTA).

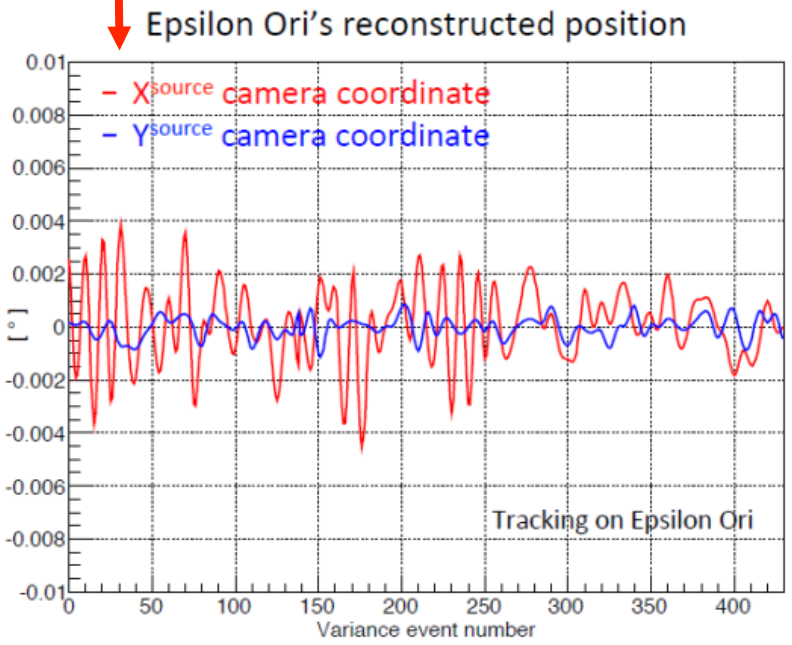
Although the camera was not fully configured, the ASTRI team was still able to capture its first Cherenkov light and produce beautiful images of the showers generated by cosmic rays in the Earth's atmosphere. The image below shows one of the events captured by the team. This information will allow scientists to reconstruct the direction of gamma-ray photons emitted from celestial sources (indicated by the yellow line on the image on the left). The camera is based on novel SiPM small pixel sensors (7 mm x 7 mm) and CITIROC ASICS peak-finder front-end electronics. The camera was specifically designed to fit on the dual mirror ASTRI telescopes for covering a large field of view of 10^{o} x 10^{o}.

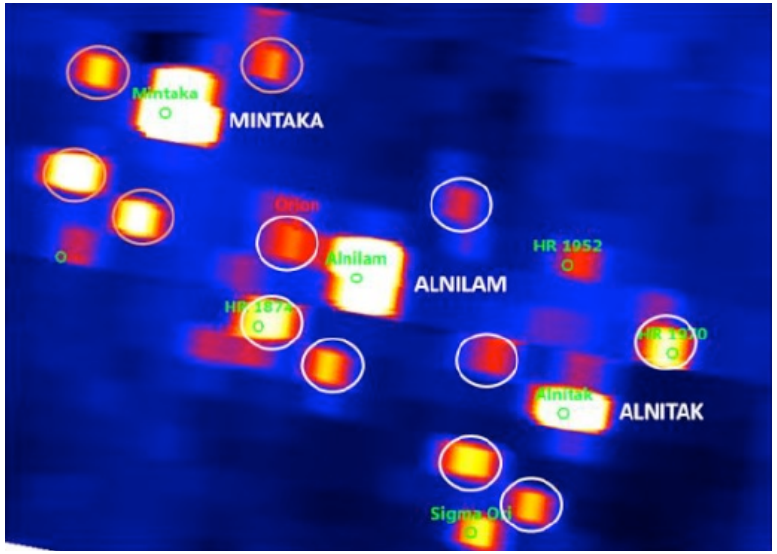


The acquisition of the variance data is done in parallel with the normal Cherenkov data acquisition

- **Measurement of Night Sky Background (NSB)**
- **Monitoring of the mirrors optical alignment**
- **Monitoring of telescope pointing accuracy**

The electric signal generated by each pixel not triggered is continuously sampled and the variance of the sequence of ADC values is proportional to the photon flux.

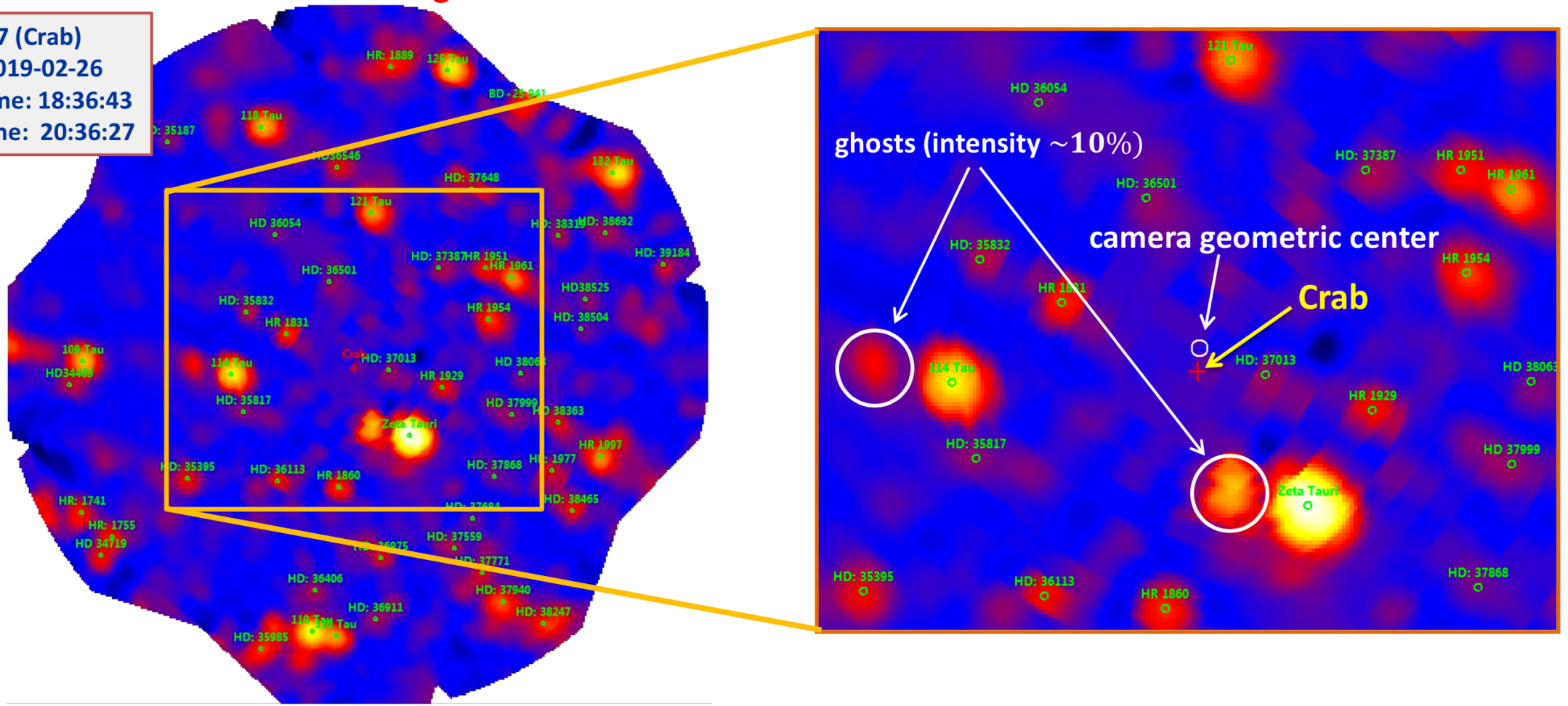




ASTRI – HORN: Telescope Performances with variance method

FoV of a "Crab tracking" observation

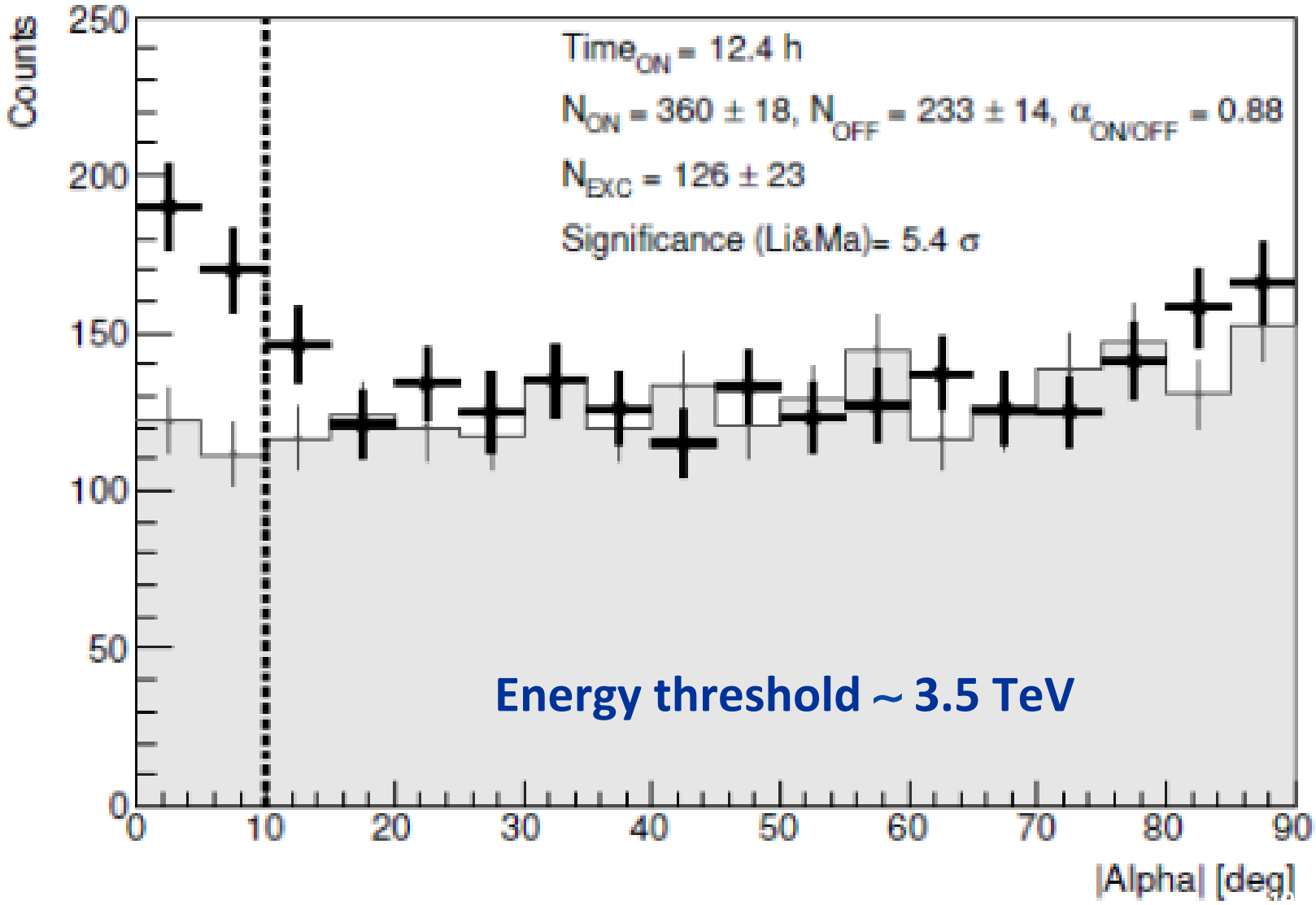
Run id: 1597 (Crab)
- Date: 2019-02-26
- Start time: 18:36:43
- Stop time: 20:36:27



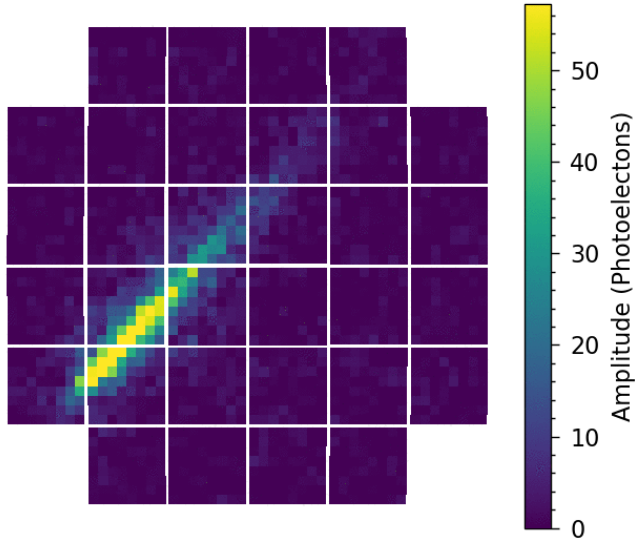
- **In the first skymap obtained from "variance" data acquired simultaneously to a scientific Crab tracking observations, a significant offset $(\sim 10')$ between the geometric center of the camera and expected Crab position is observed**

Observations between 5th and 11th december 2018

First detection of a Gamma Ray Source with a IACT dual-mirror telescope!!!



First Cherenkov light with CHEC-S camera



CHEC campaign

- From 29th of April to 10th of May at Serra La Nave with ASTRI – Horn telescope
- Enginering and calibration tests
- Observations of MRK 421, MRK 501, and BG 1553-113
- Next run in June

ASTRI mini-array: The next step of the program

ASTRI mini-array → Implementation of an array of 9 ASTRI SST-2M

- Commitment with the Italian government and international partners to build it
- Funds: dedicated funding outside the 50 M€ of the Italian contribution to CTA
- Site: any suitable location (contacts and discussions in progress)

- End to end: validation and commissioning of the array through Cherenkov astronomical observations
- In CTAO context:
  - Assessment of array trigger
  - Testing of array control software and general operations
  - Testing of AIV procedures on site (time, personnel, infrastructure, tools)
  - Testing of array performance against Montecarlo simulations
  - Testing of Implementation of the intensity interferometry capability

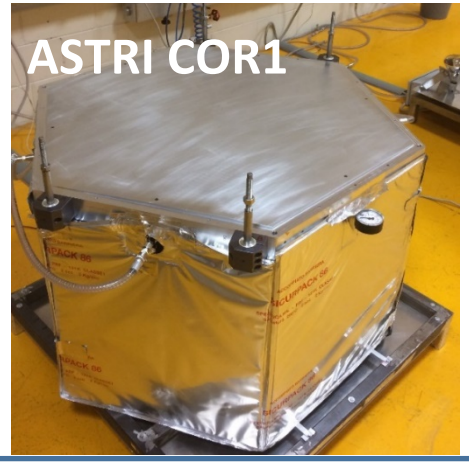
Procurement through industrial contracts

- **Optics**
  - Production of M1 (10 ASTRI & 2 MST) started in September 2017 → 2/3 ready
  - Production of 10 M2 mirrors completed
- **Structures**
  - Tender for 3 structures assigned and consolidation phase completed
  - Construction started
  - Tender for further six structures finalized and to be issued very soon
- **Camera Assembly**
  - Production of ASICs (CITIROC1A) started in March 2018 → ½ ready
  - Tender for SiPM closed -> Formal contract assignment two days ago to Hamamatsu Photonics
  - Tender Camera (mechanics, electronics, thermal) finalized and to be issued very soon

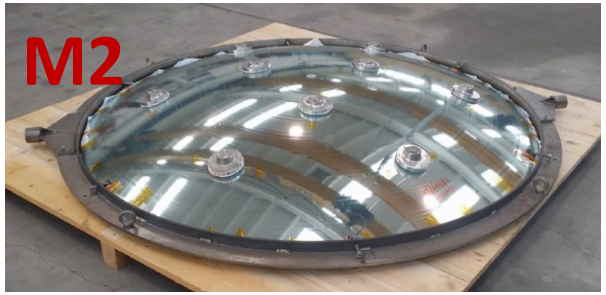
ASTRI mini-array: Optics procurement

Production Status

Mirror type	Bonded	Coated	Sealed	Finished	Packed	Delivered	Total
pSCT S1						10	10
pSCT S2						20	20
MST	14	10	1	13	15	112	165
ASTRI-COR1				7	22	1	30
ASTRI-COR2				1	24	41	66
ASTRI-COR3						66	66
Total	**14**	**10**	**1**	**21**	**61**	**250**	**357**



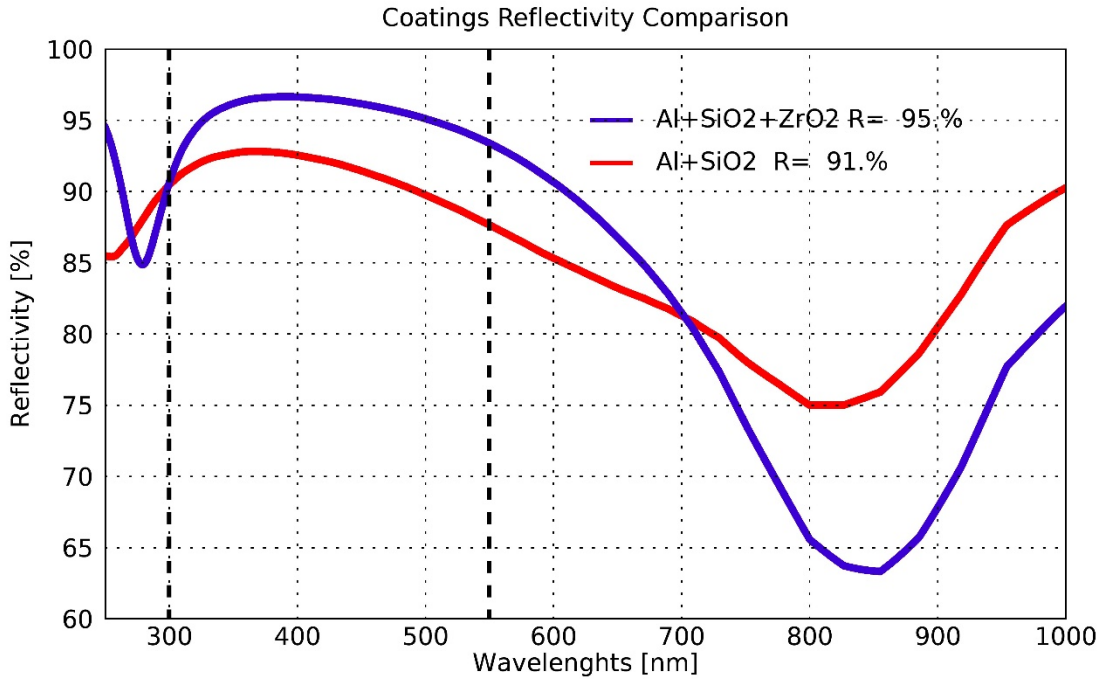
M1



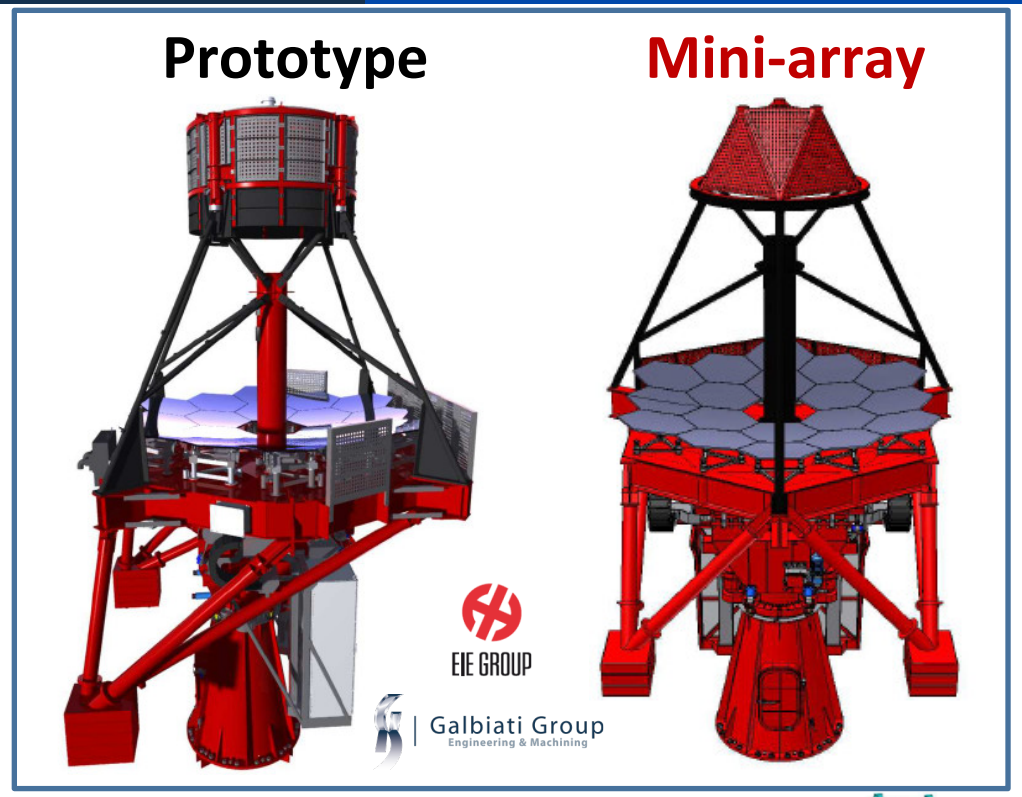
M2 production completed

Variations respect to prototype

- New coating → $Al+SiO_2+ZrO_2$
- M1 panels pads position

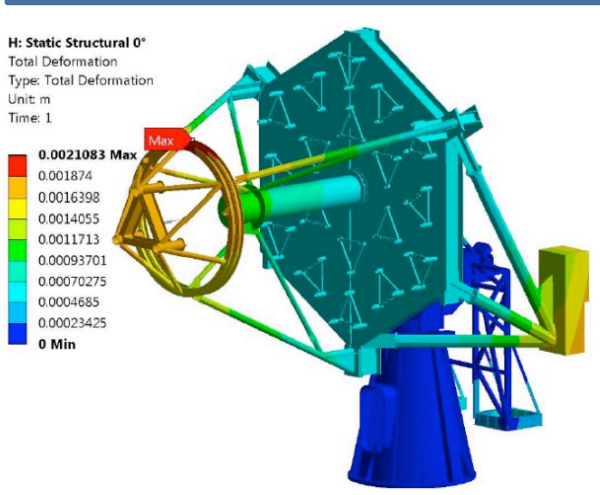


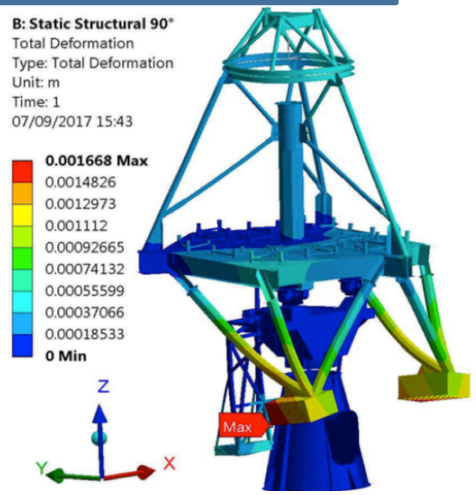
ASTRI mini-array: Structure procurement



Active Mirror Control simplification

- No need for AMC during operations
- No need refocusing telescope during operations
- AMC radially mounted for easier mirrors integration
- AMC mounted during AIV phase and for maintenance purposes



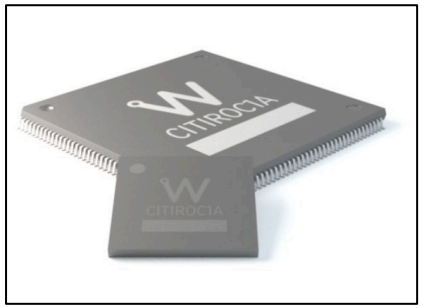


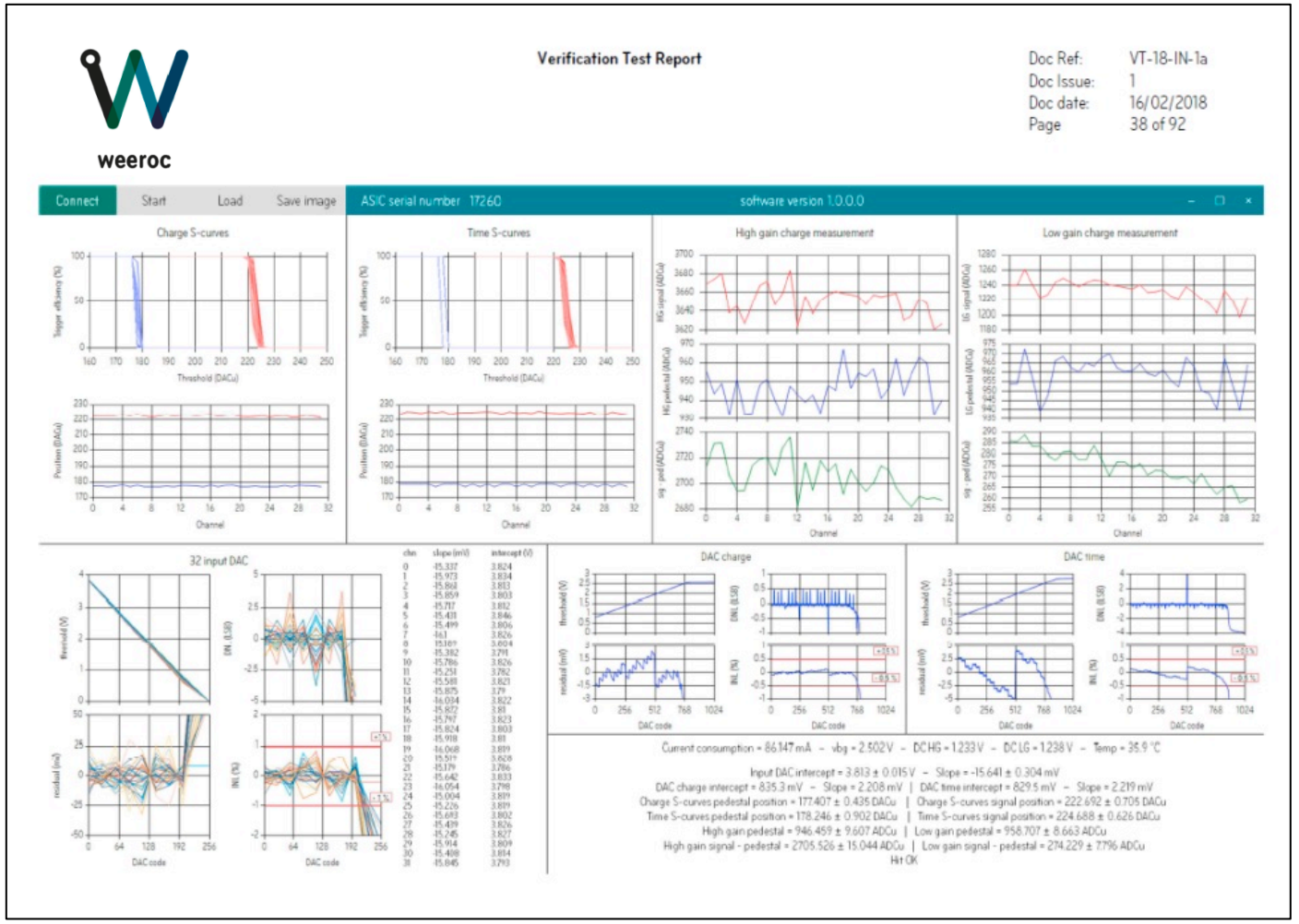
Mass reduction (25% → 16 Tons)

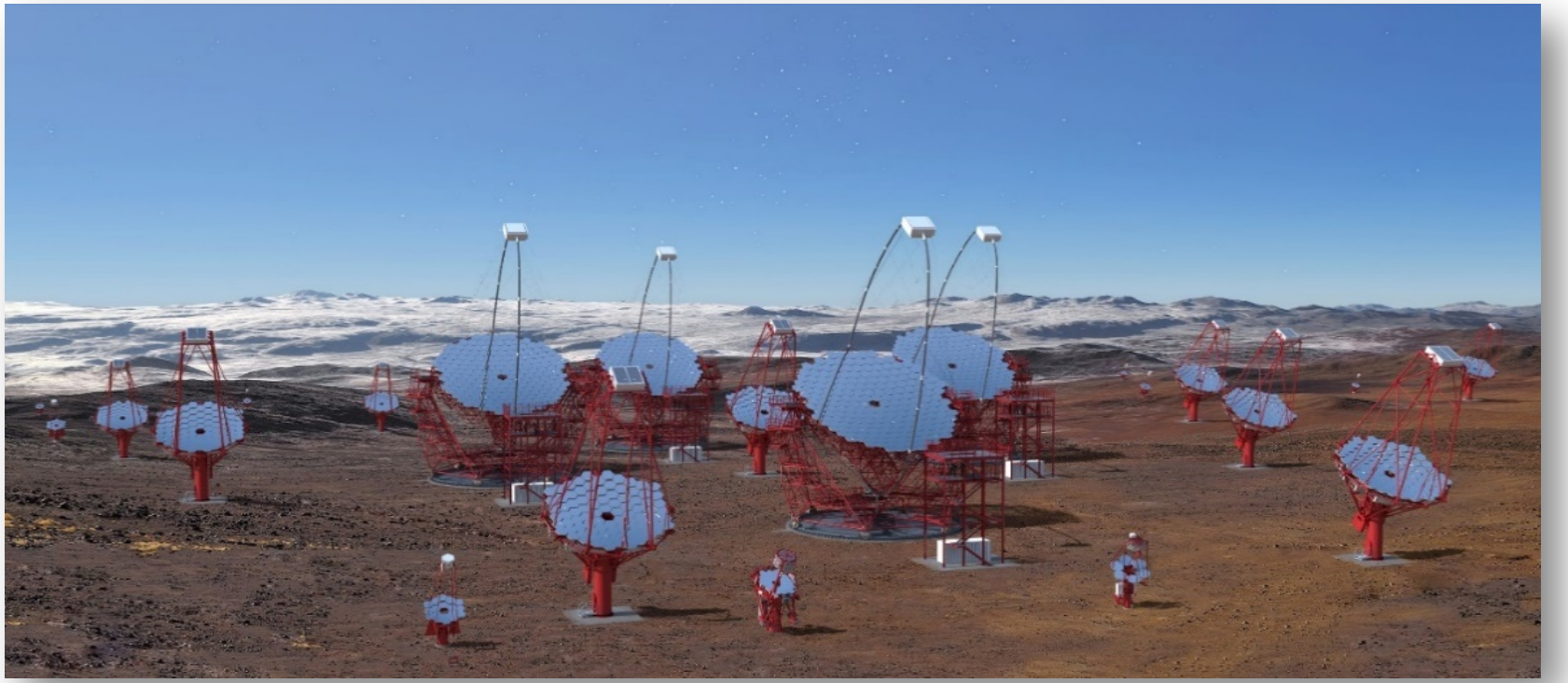
- Design consolidation of the dish and secondary support to maintain same stiffness lowering telescope weight
- M2 support structure modified
- Mast structure with only three legs
- Dish rotated for easier integration realized with commercial parts
- **FEA Analysis → The structure is able to support seismic loads, without suffering any damage (structural or permanent) that will prevent motion.**

ASTRI mini-array: Camera ASICs procurement

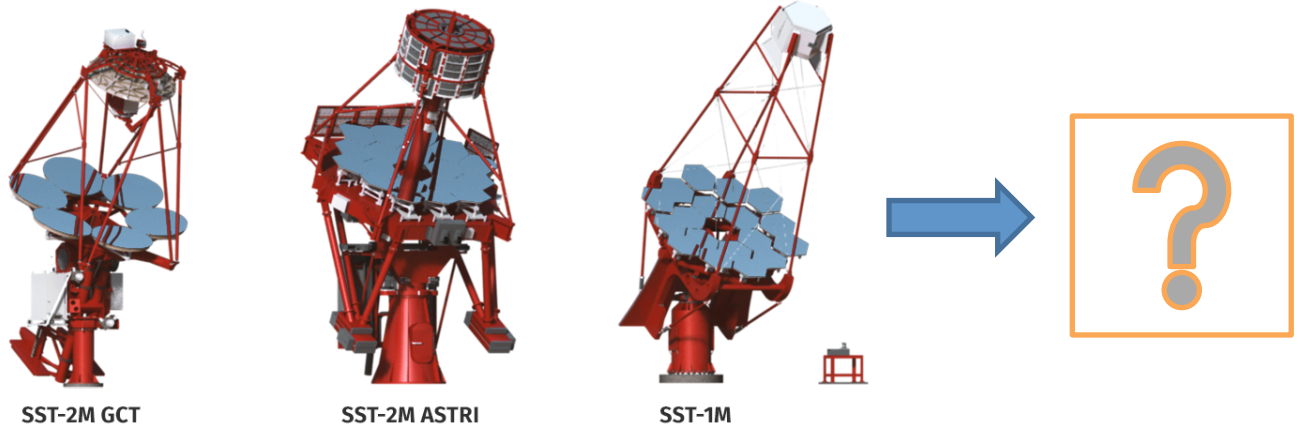
- Contract assigned to Weeroc
- KOM: 19th of June
- Production Plan Review: 1st of August 2018
- Qualification phase: completed March 2018
- First batch (485 CITIROC 1A) delivered end of October
- Final delivery late Spring 2019







Resolution of CTA council to implement only one SST design for CTAO



cherenkov telescope array

An SST-2M Implementation Concept

Response to the Request for Information

Version
1.2 (31-10-2018)

Editors
S. Scuderi
R. White

On Behalf of

The ASTRI Groups
Italy – INAF
Brazil
South Africa

The CHEC Groups
University of Adelaide
University of Amsterdam
Deutsches Elektronen-Synchrotron (DESY) Zeuthen
Durham University
Erlangen Centre for Astroparticle Physics (ECAP)
Max Planck Institut für Kernphysik (MPIK)
University of Leicester (UoL)
University of Liverpool
Nagoya University
University of Oxford

- The harmonization process started in May 2018
- CTAO management decided to review and evaluate current designs through an external panel
- Proposal submitted jointly with CHEC group in October
- Face-to-face meeting of the panel with the SST teams last March in Bologna
- CTAO is analyzing the report and will present its proposal to council

University groups Australia, Brazil, Germany, Italy, Japan, Netherlands, South Africa, UK


Grazie
Foto E. Marcuzzi EIE