The ASTRI* project.
Prototype status and future plans for a dual mirror small Cherenkov telescope mini-array

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on behalf of the ASTRI Collaboration

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* Astrofisica con Specchi a Tecnologia Replicante Italiana

The ASTRI Prototype Program

The ASTRI Program is an Italian "**Progetto Bandiera**" (Flagship Project) funded by the Ministry of Education, University and Research (MIUR) for a total amount of **8 M€** to develop the **"replica" technology for mirrors and new sensors for VHE astrophysics.**

The main **goal** is the realization, ***within the CTA framework***, of an **end-to-end prototype of the CTA SST** to be tested under field conditions.

INAF is in charge of the design of the mirrors and the camera, development of the software and other related activities. The telescope structure is designed by external firms.

INAF contributes with about **24 FTE/year** to the project, and received to cover the costs **3 M€** for **2011** and **2 M€** for **2012**. Reviews are foreseen by MIUR in order to allocate, on an annual basis, the budget according to the following scheme: **2013 (2 M€)**, and **2014 (1 M€).**

The ASTRI Collaboration

Principal Investigator **G. Pareschi**

Co-PIs	O. Catalano & S. Vercellone
Program Manager	M. Fiorini
System Engineer	A. Argan

INAF Institutions

- IASF Milano
- IASF Bologna
- IASF Palermo
- OA Brera
- OA Padova
- OA Torino
- OA Bologna
- OA Arcetri
- OA Roma
- INAF HQ Roma
- OA Capodimonte
- OA Catania

University Partners

- Univer. of Padova
- Univer. of Perugia

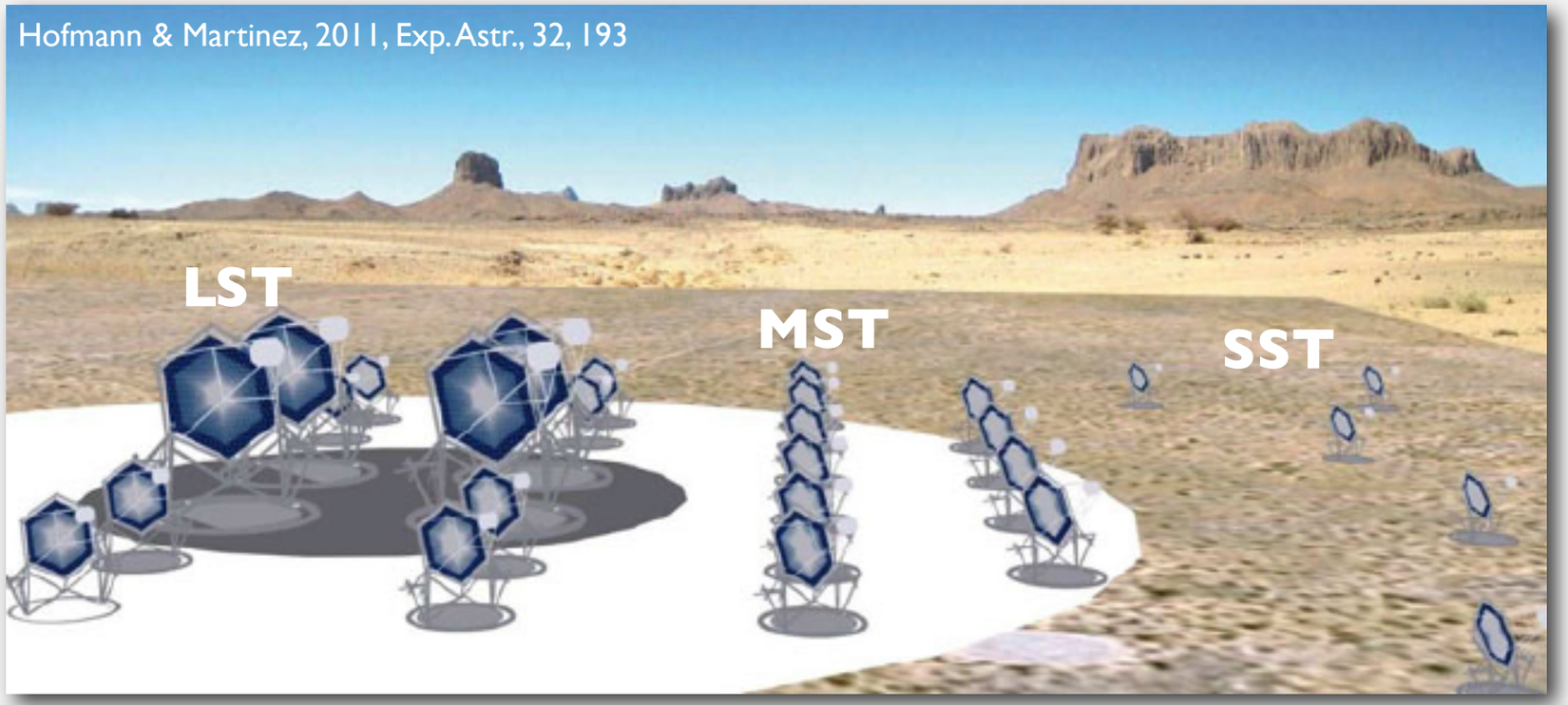
CTA and the ASTRI Program

The ASTRI Program is strictly linked to the CTA concept.

CTA plans the construction of several tens of telescopes divided in 3 kinds of configurations, in order to cover the energy range from a tens of GeV (Large Size Telescope, **LST**), to a tens of TeV (Medium Size Telescope, **MST**), and up to 100 TeV (Small Size Telescope, **SST**).

On CTA, see W. Hofmann talk tomorrow + several posters in P4 Section.

Within this framework, INAF is involved in the realization of an end-to-end SST prototype.

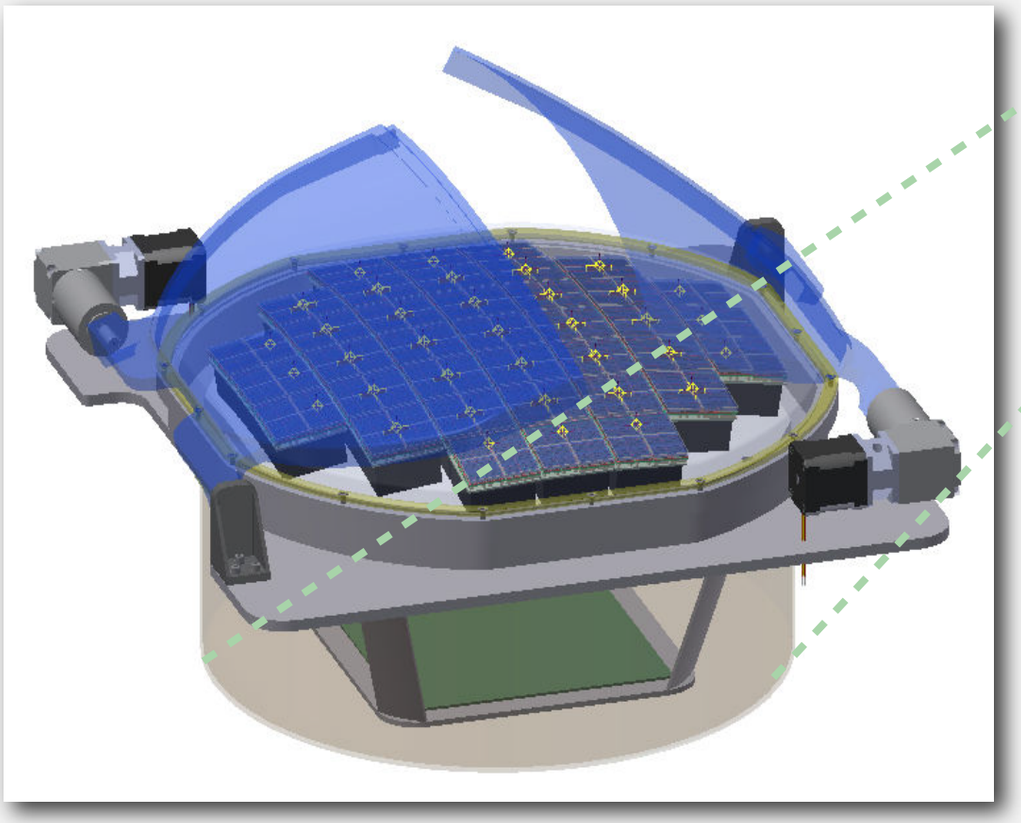


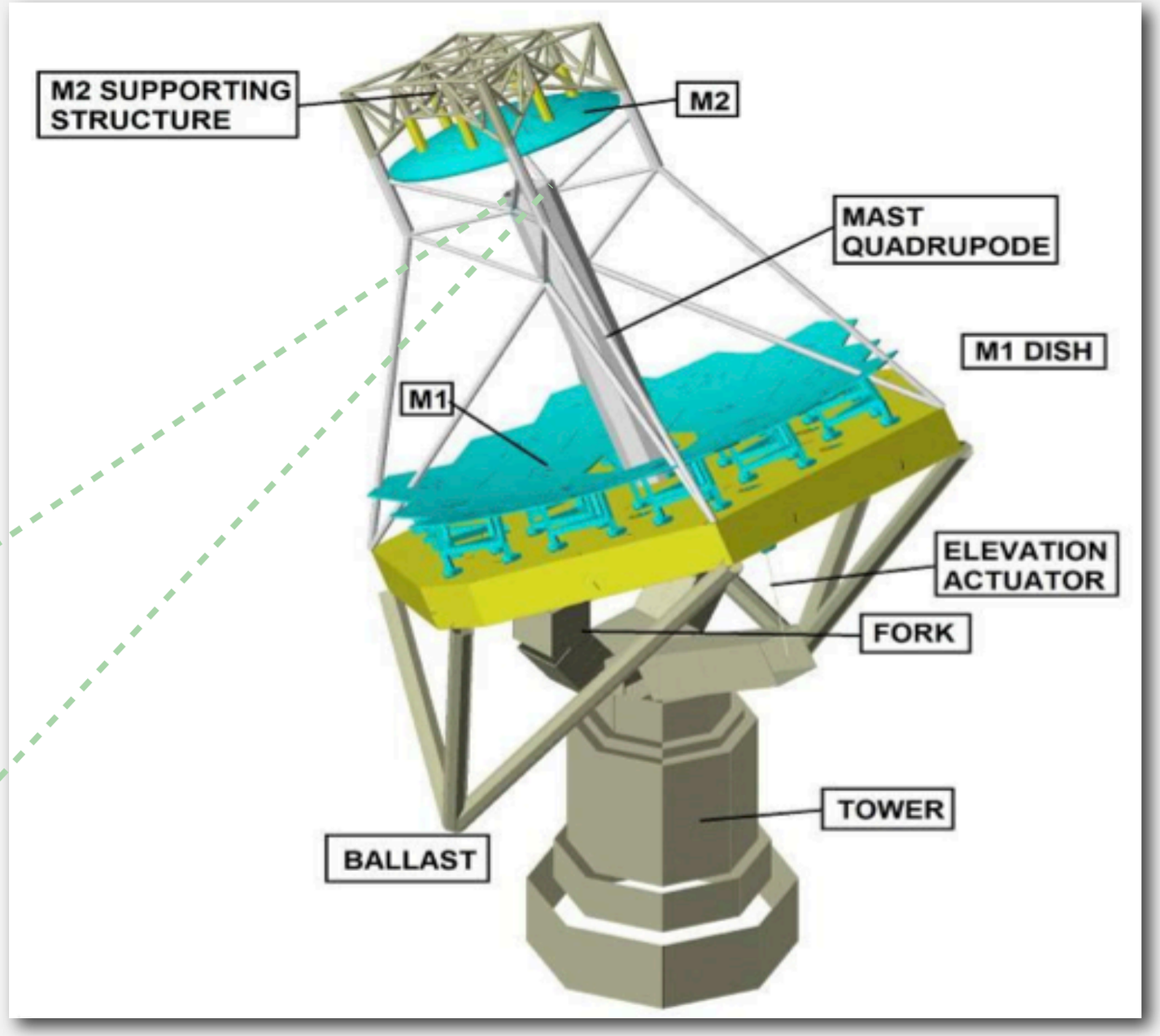
The Dual Mirror SST (SST-2M) Concept

ASTRI SST-2M concept:

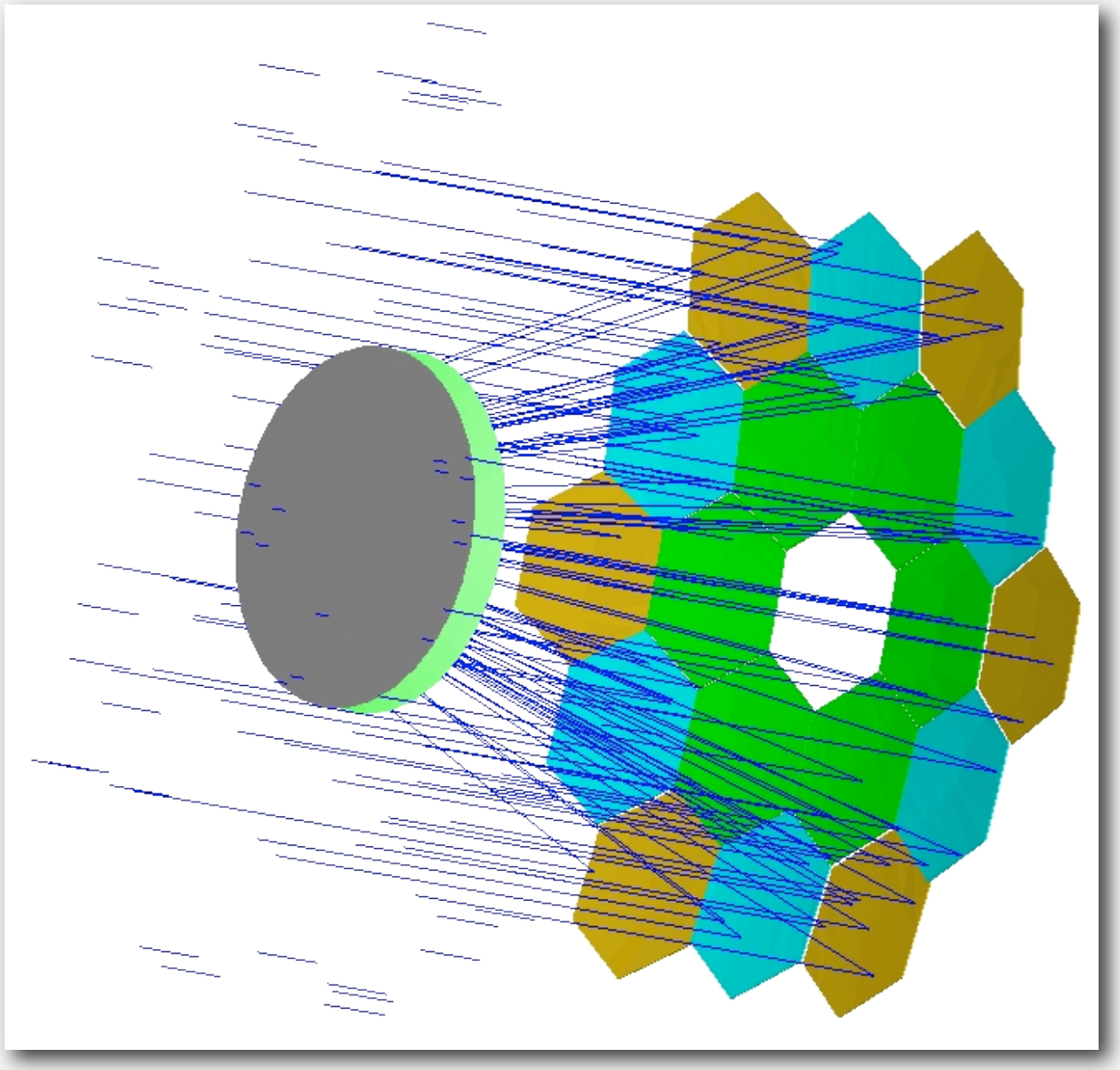
a large (9.6°) field of view dual-mirror (Schwarschild-Couder) telescope;

a light (~50 kg) and compact (~50x50x50 cm^3) camera based on Hamamatsu Si-PMTs.

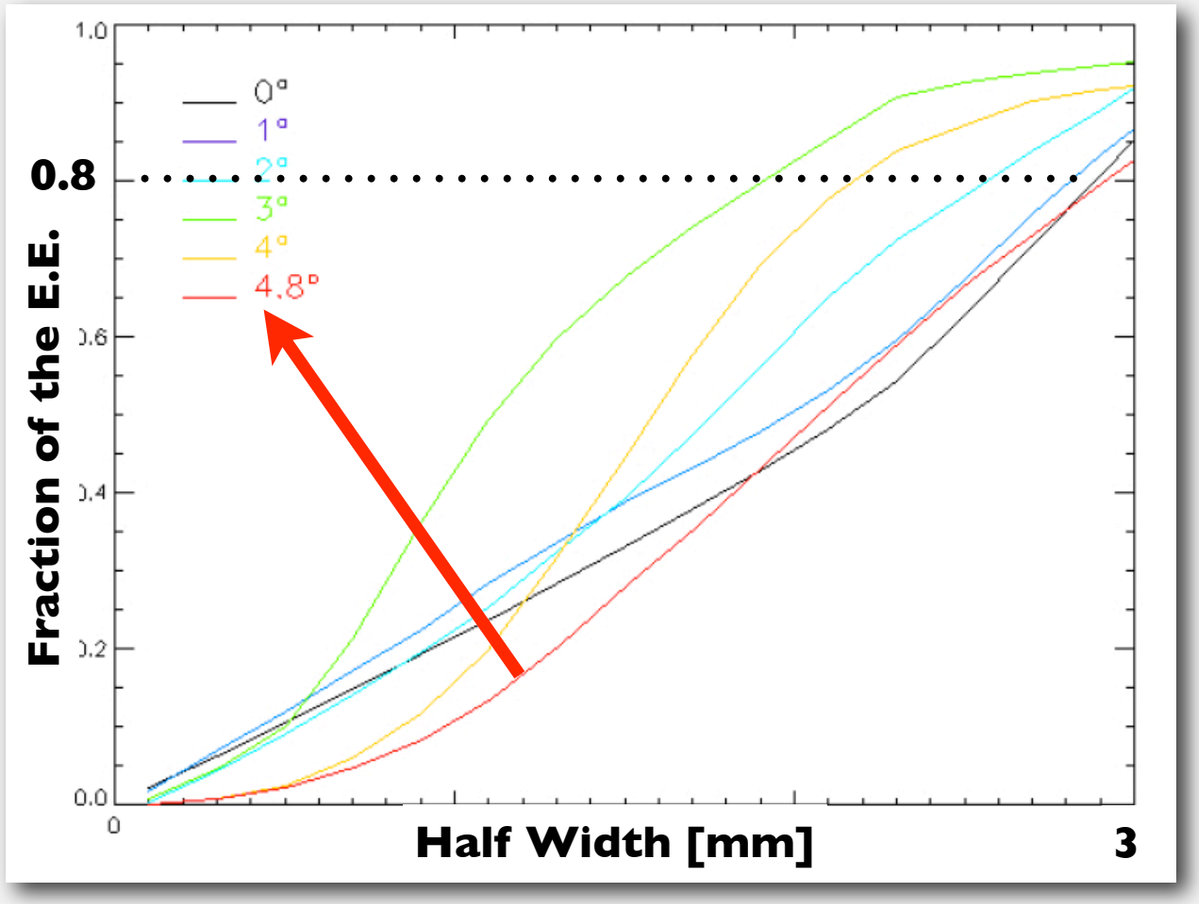




The ASTRI SST-2M Optical design



The optical system is a Schwarzschild-Couder configuration.



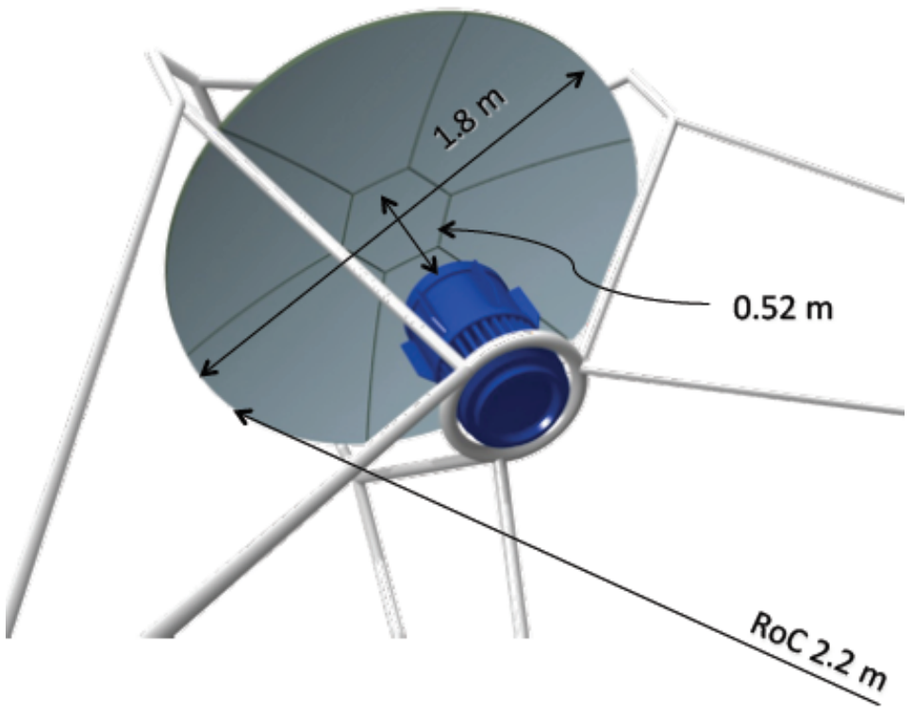
Fraction of the *Enclosed Energy*:
the design optimization has been done in such a way the amount of energy contained within 2x2 physical pixels (6.2mm logical pixel) is not less than 80% along the entire field angle.

The ASTRI Prototype Mirrors

Mirrors' main characteristics:

- **Primary Mirror diameter:** 4.3 m (tessellated)
- **Secondary Mirror diameter:** 1.8 m (monolithic)
- **F#:** 0.5
- **Equivalent focal length:** 2150 mm
- **Corrected FoV diameter**: 9.6°

The ASTRI Prototype Mirrors

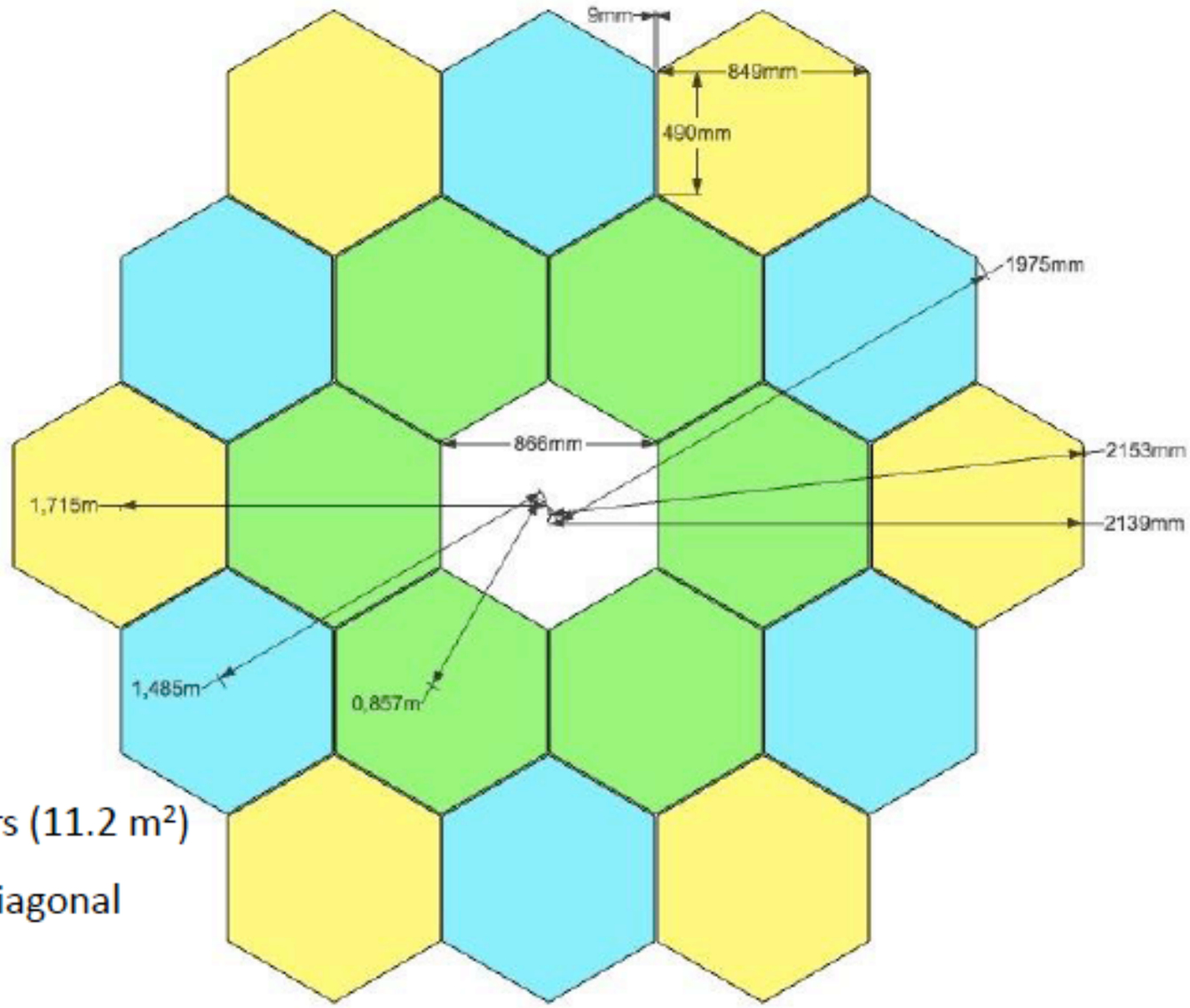


Secondary mirror (M2)

Monolithic

Supporting structure may allocate sectors

3 actuators: tip-tilt and piston for alignment and focussing purposes



Primary mirror (M1)

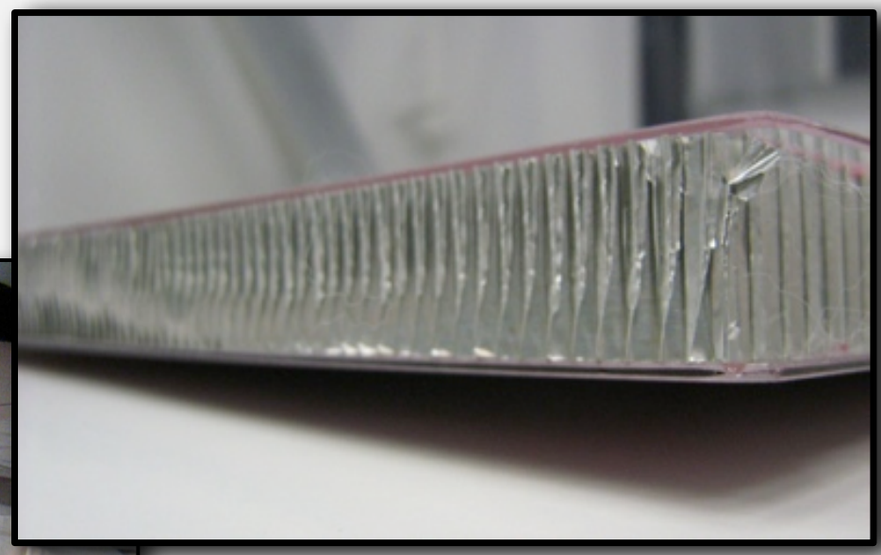
18 hexagonal shaped mirrors (11.2 m^2)

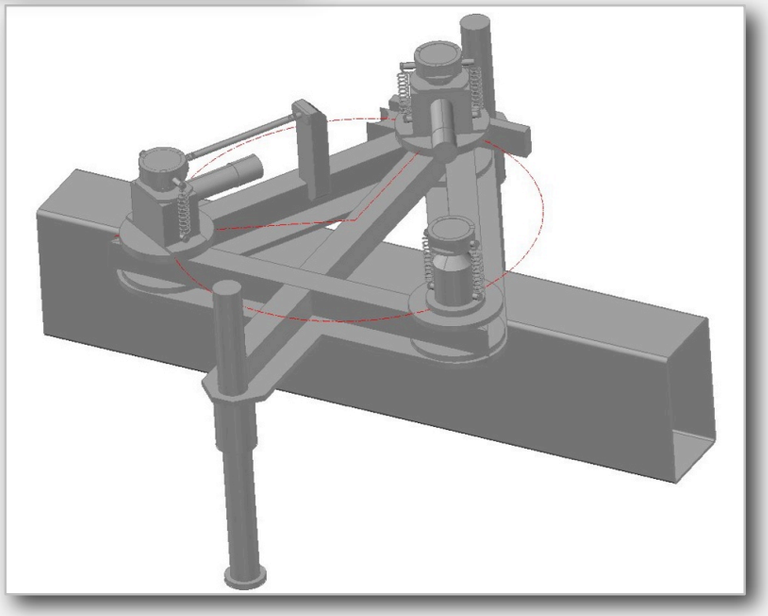
850 mm face-to-face, 1 m diagonal

3 types of segments

2 actuators + 1 fixed point: tip-tilt corrections for alignment purposes

The Prototype Primary Mirror (M1)

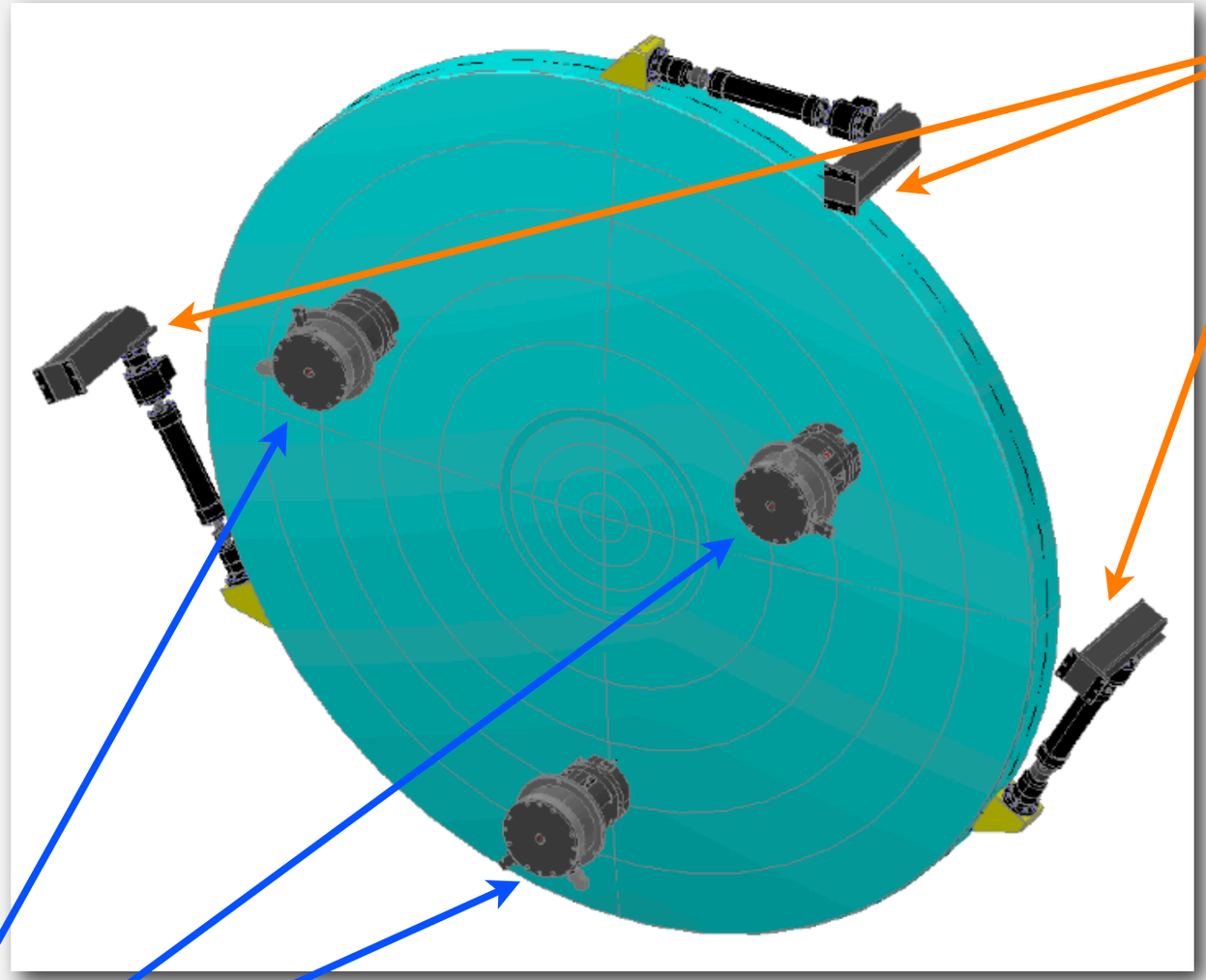




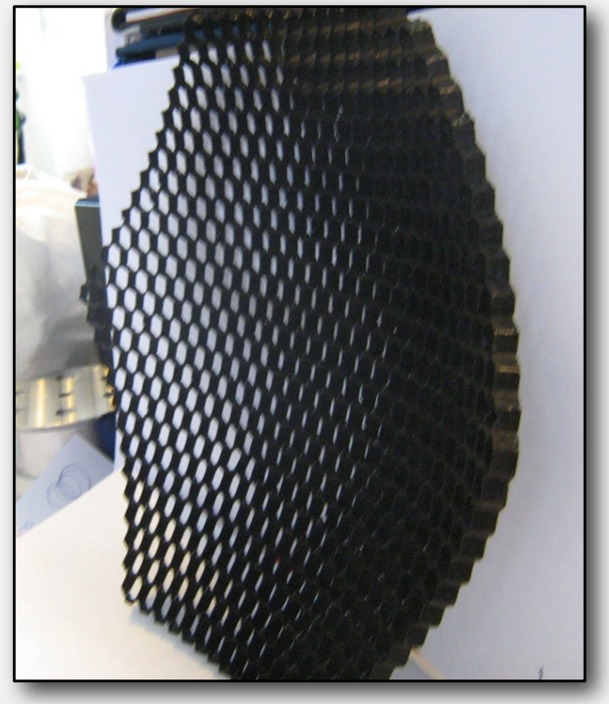
Procurement of the "raw" materials (hot slumped glass, honeycomb, glue), assembly and coating.

Triangle with mounting pins, 2 actuators, 1 fixed point, 1 tangential restrain, and the alignment system.

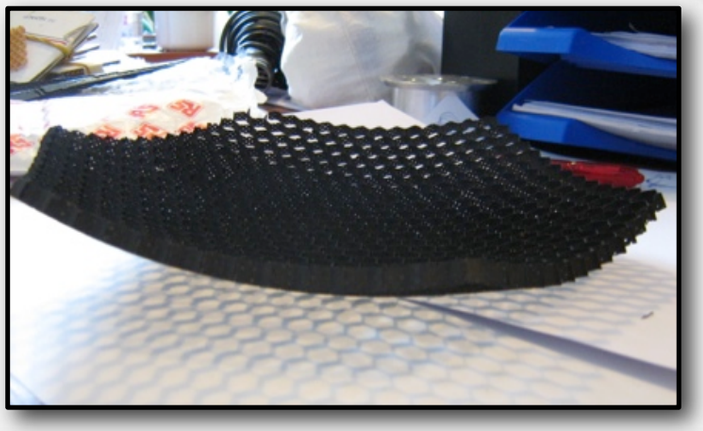
The Prototype Secondary Mirror (M2)



3 lateral constrains support the lateral component of the mirror's weight (which varies with the elevation).



3 actuators connected to the mirror with load spreaders (*whiffletree*)



Ad-hoc curved honeycomb structure

The ASTRI Prototype Camera

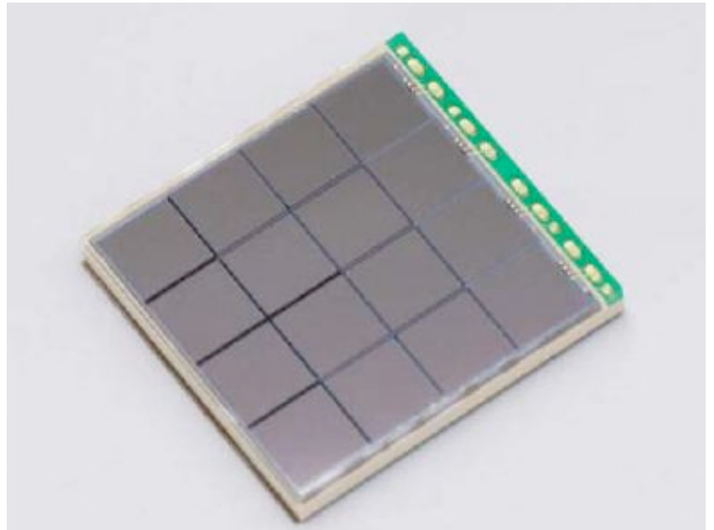
Camera' main characteristics:

- **Detector type:** monolithic MPPC array
- **Logical Pixel size:** 6.2 mm x 6.2 mm [0.17°]
- **Plate scale:** 37.5 mm/°
- **Number of Pixels :** 7936
- **Number of channels :** 1984 (grouping 2 x 2 pixels)

The ASTRI Prototype Camera

Monolithic MPPC array in SMD package

S11828-3344M



■ Features

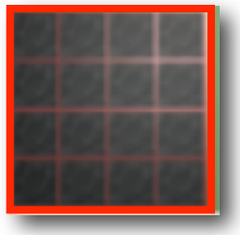
- Monolithic array: 16 ch (4 x 4 array)
- Nonmagnetic package
- Effective active area: 3 x 3 mm/ch
- Pixel pitch: 50 μm
- Allows multiple devices to be arranged in a buttable format

■ Specifications

Parameter	Condition	Value	Unit
Number of elements		16 (4 x 4)	elements
Effective active area / channel		3 x 3	mm
Pixel pitch		50	μm
Number of pixels / channel		3600	-
Number of pixels / device		57600	-
Fill factor		61.5	%
Photon detection efficiency *	λ=440 nm	50	%
Dark current / channel	per channel	3	μA
Terminal capacitance / channel		320	pF
Gain		7.5×10^5	-

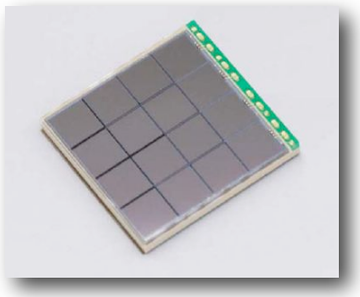
* Includes cross-talk and after-pulse

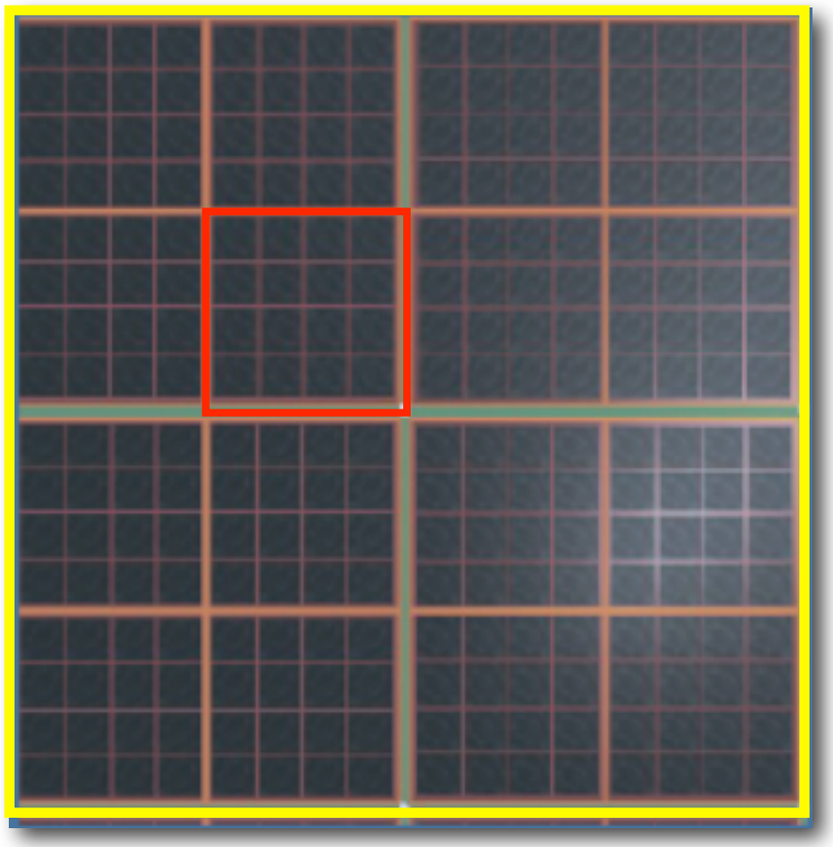
The ASTRI Prototype Camera



1 Unit
4x4 pixel
1px = 3mm x 3mm

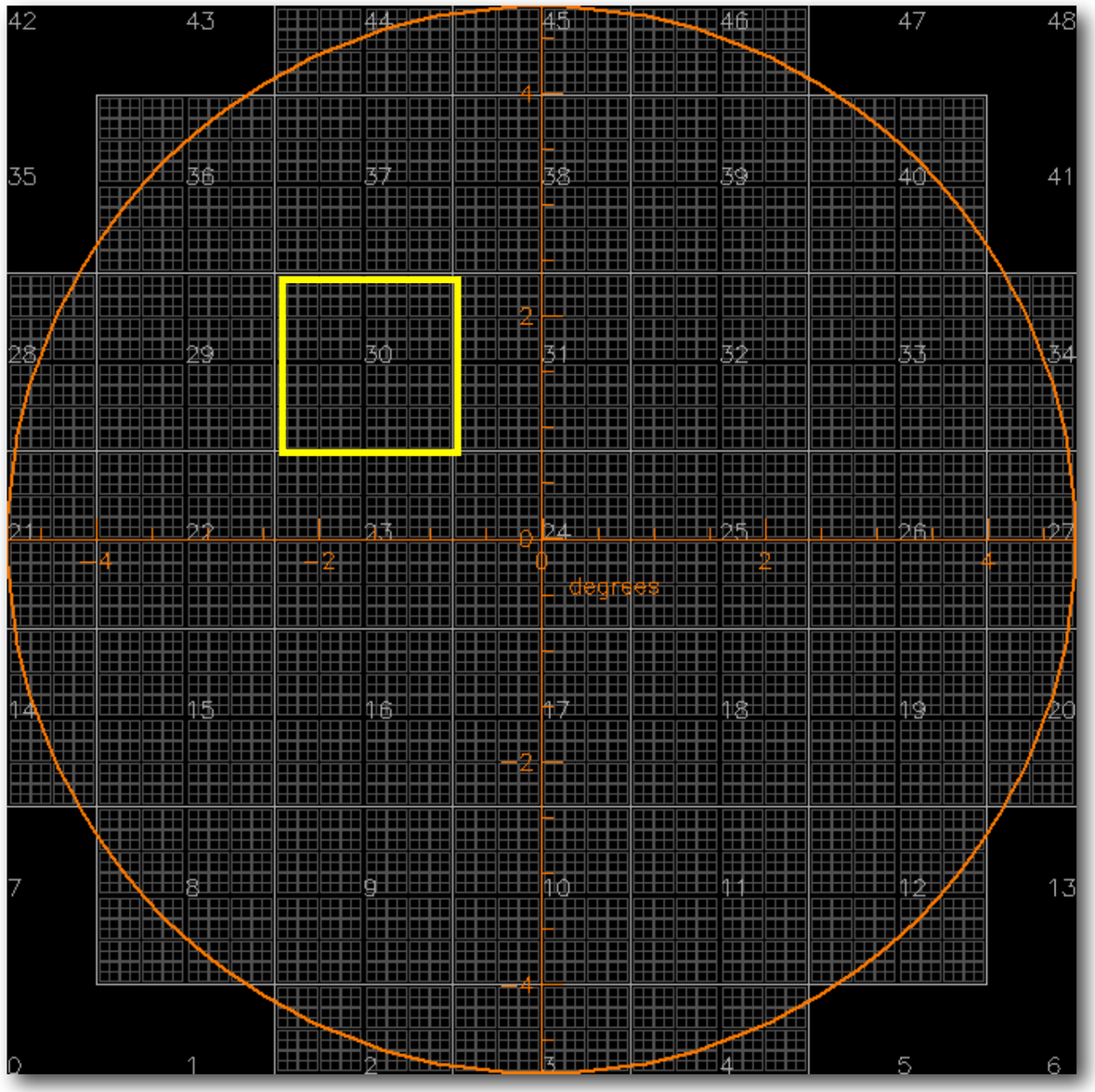
Size imposed by the manufacturer





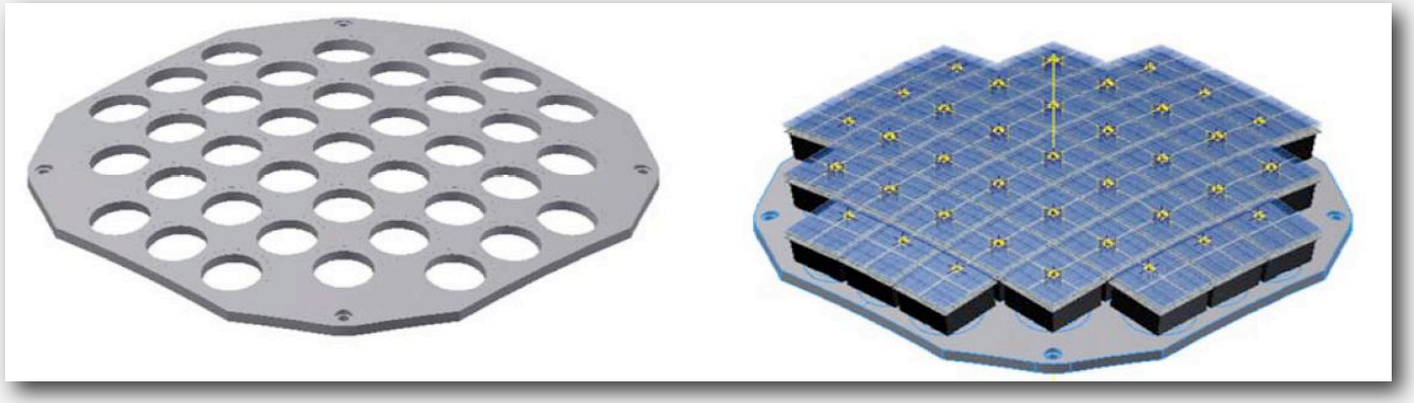
1 Photon Detection Modul (PDM)
4x4 Units

1 ASTRI Focal Surface
37 PDMs
FoV diameter = 9.6°

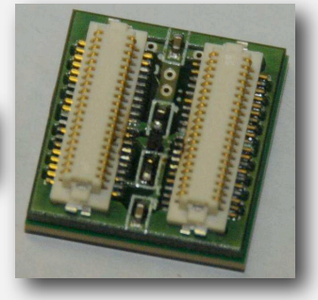


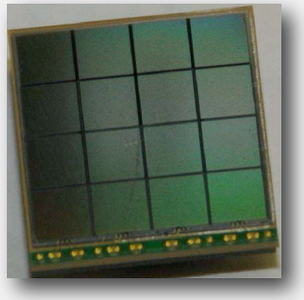
The ASTRI Prototype Camera

Mechanical housing drawing and 37 Photon Detection Modules mounted on the mechanical housing.

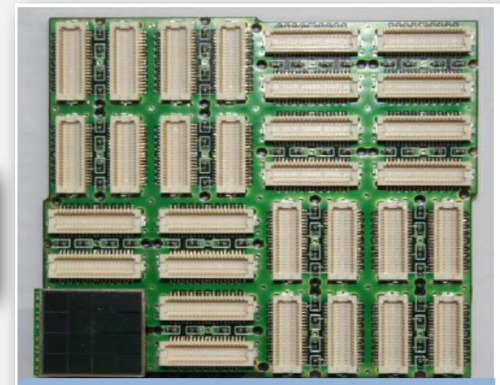


SiPM 4x4 Board n.1



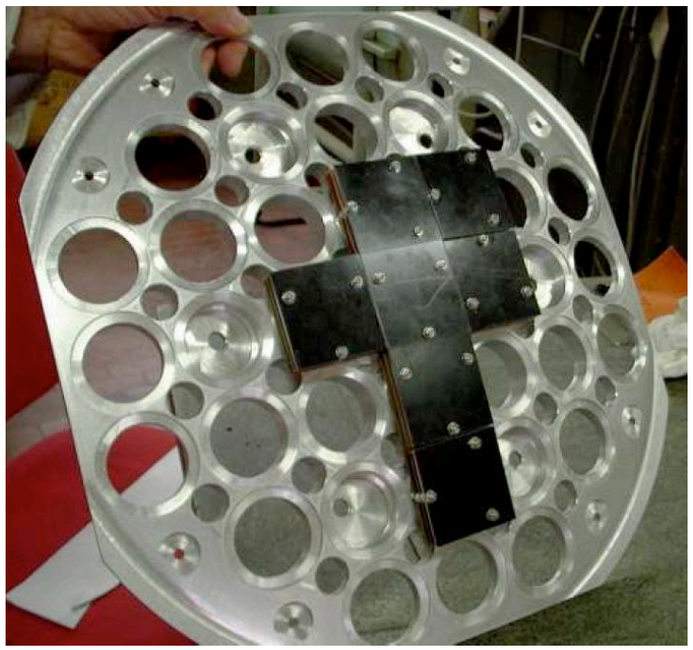


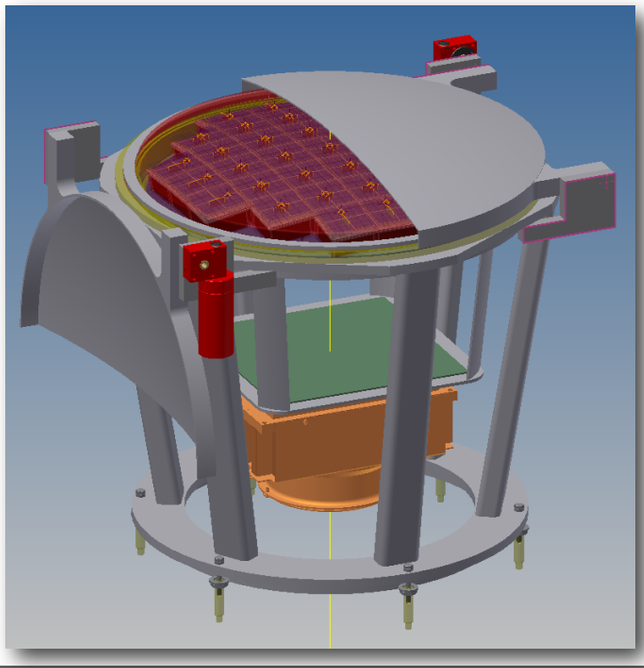
Photon Detection Module - Board n.2



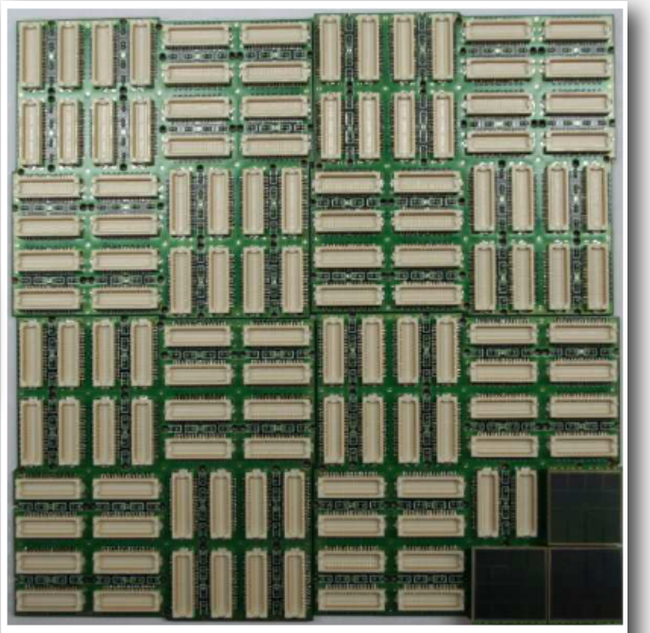
PDM top view with mounted one matrix SiPM 4x4

Mock-up of the mechanical housing + PDMs and sketch of the ASTRI Camera with the Camera-Telescope I/F.





Focal Plane PDM Mosaic



Mosaic of four PDM with mounted three matrix of SiPM 4x4

The ASTRI SW and Data Archiving

The ultimate goal is to have an end-to-end prototype as much as possible compliant w.r.t. the CTA requirements also on the data and SW components.

Several activities are related to the Software development:

- Dedicated full Montecarlo simulations of the ASTRI SST-2M
- Ray-tracing modeling of the focal plane-optical systems
- Cleaning, reduction and analysis pipelines
- Telescope control, automation, data acquisition, monitoring and archiving software

These activities are strictly related to the CTA SW architecture:

- The extensive use of standard FITS files
- The inclusion of our telescope properties into the `simtel_array` architecture
- The use of the different data levels (L0, L1a, L1b,...)

The ASTRI Prototype Site

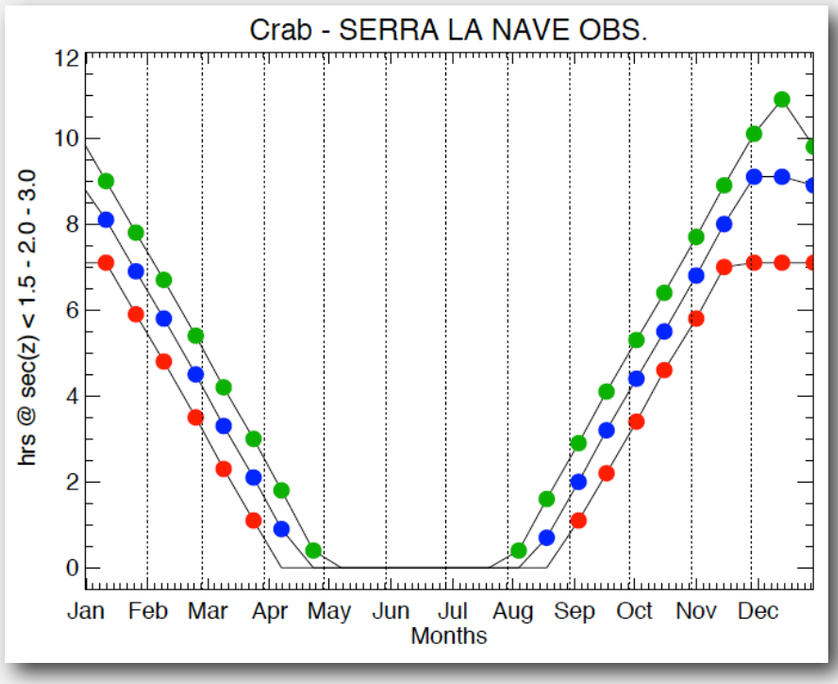
INAF - Catania Astrophysical Observatory

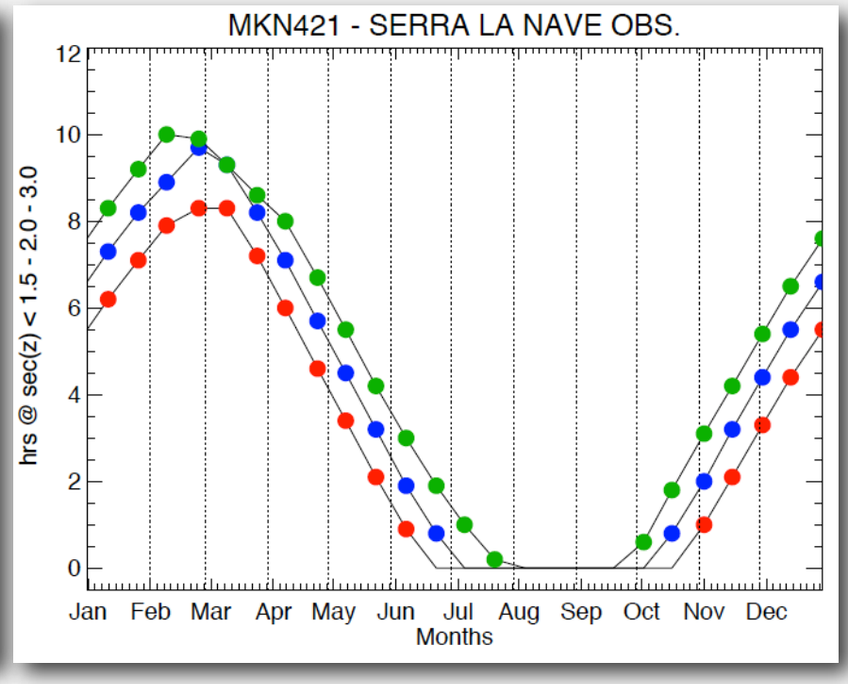
The "M. G. Fracastoro" Mountain Station - Serra La Nave (Mt. Etna)

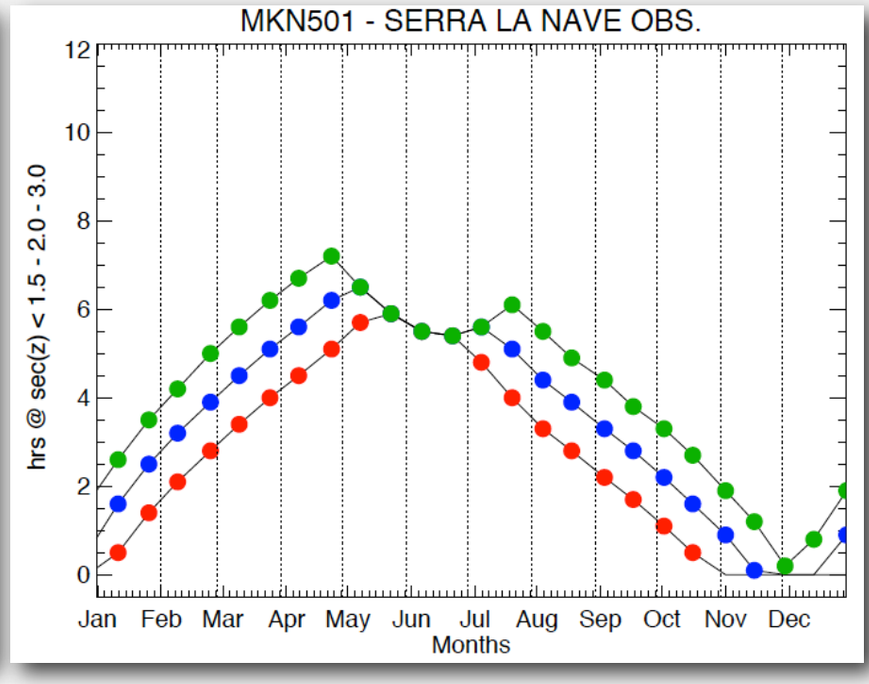
Altitude: 1735 m a.s.l.

Longitude: +14° 58'.4; Latitude +37° 41'.5

The ASTRI Prototype Science







The ASTRI Prototype is mainly a technological demonstrator, but science might be feasible.

Maximum sensitivity : 2 - 5 TeV (1 Crab @ 5s.d. in some hours)

In the range 10 - 20 TeV : (1 Crab @ 5s.d. in a few tens of hours)

PRELIMINARY

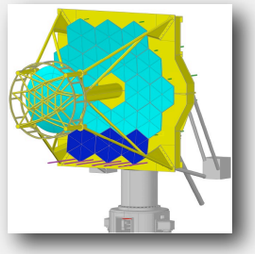
First Crab observations with a Schwarschild-Couder-SiPM Cherenkov telescope.

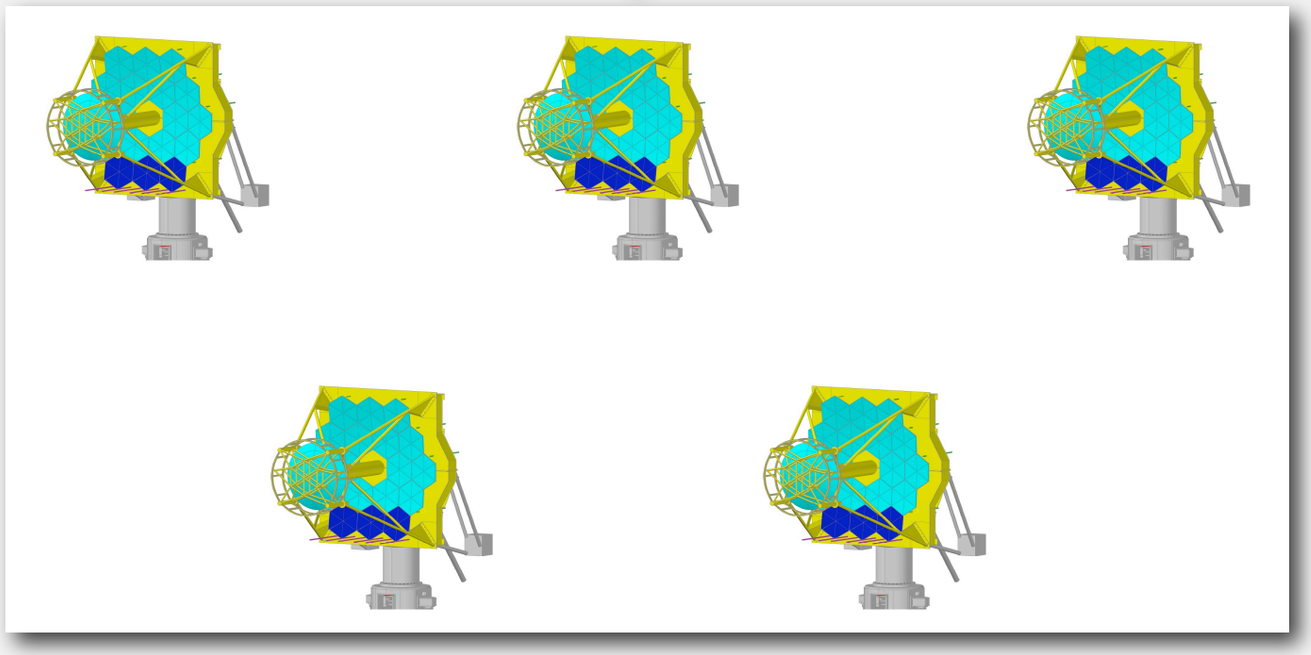
Possible sources (from Sicily): Crab, Mkn 421, Mkn 501

Intense flares (~5 Crab) should allow intra-night variability studies.

The Mini-array Concept

The budget provided by the MIUR to INAF will allow us to plan the realization of a **mini-array** composed by **5 SST-2M telescopes to be installed at the final CTA southern site.**





An ancient concept...

The Mini-array Concept

Design and realization of a SST-2M mini-array to be installed at the CTA southern site will verify the following array properties:

- array performance in terms of reliability and cost at the chosen site
- check of the trigger algorithms (single telescope, array)
- **check of the wide field of view performance**
- check of the HW/SW configurations for the array
- check of the data-handling chain
- **compare the mini-array performance with the MC expectations**
    - validate performance predictions for the full SST array (need well chosen target objects and long observations)
- **do the first CTA science!** (need ~5 solid detections in year 1 to build confidence and help secure funding for the full array)

The Mini-array Performance

- **Limiting flux of about 10^{-12} erg/cm2/s @ 10 TeV**

- **Should not expect better than a few arcmin angular resolution**

VERY PRELIMINARY :::TO BE UPDATED

- **Energy resolution of the order of 10-15 %**

S.V. acknowledges useful discussions with J. Hinton

The Mini-array Primary Target (South)

- Mrk 421 (ToO - high zenith angle)
- M 87 (ToO)
- PKS 2155-304
- 1ES 0229+200
- Crab Nebula
- Vela X / Vela Junior
- RX J1713 / HESS J1718
- HESS J1825/LS 5039
- The Galactic Centre (central source + diffuse)

PSF and Spectral Calibration
Weak source detection
Point-like and extended objects

VERY PRELIMINARY ::: TO BE UPDATED

Electron acceleration+cooling
Relativistic + non-relativistic shocks
The search for CR Pevatrons
CR propagation
FIR EBL
…

Summary

We plan to start the ASTRI SST-2M Prototype Commissioning at Serra La Nave at the beginning of 2014.

The ASTRI Prototype will allow us to test the main innovative components: the optical dual-mirror design and the SiPM-based focal plane.

We are fully compliant w.r.t. the CTA requirements and we work on a day-by-day basis in collaboration with the CTA technical management.

The SST mini-array will be a quantum-leap w.r.t. the ASTRI SST-2M prototype performance, allowing us to validate several CTA array properties.

Astrofisica con Specchi a Tecnologia Replicante Italiana

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Welcome to ASTRI project Home Page

ASTRI (Astrofisica con Specchi a Tecnologia Replicante Italiana) is a **flagship project** of the Italian **Ministry** of Education, University and Research related to the next generation **IACT** (Imaging Atmospheric Cherenkov Telescope), within the framework of the CTA (Cherenkov Telescope Array) International Observatory.

In this context, INAF (Italian National Institute of Astrophysics) is currently developing a scientific and technological breakthrough to allow the study of the **uppermost end of the VHE domain** (a few TeV - hundreds of TeV).

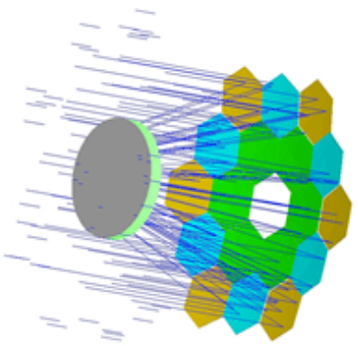
The ASTRI project **timeframe** is of about 3 years, and foresees the full development, installation and calibration of a **Small Size class Telescope prototype** compliant with the requirements of the **High Energy array of CTA**.

The **ASTRI prototype** will adopt an aplanatic, wide field, double reflection optical layout in a Schwarzschild-Couder configuration.

Moreover, the focal plane instrument will explore **small pixelated detector sensors** such as multi-anode PMTs or Silicon PM.

Among the number of **technological challenges**, this telescope will be the very first instrument implementing both the **Schwarzschild-Couder optical configuration** and the **double reflection for air Cherenkov imaging.**

Go to Foto-Gallery



3D view of the optical design implemented for the ray-tracing simulations

http://www.brera.inaf.it/astri/

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