# The ASTRI* Program

Stefano Vercellone (INAF/IASF Palermo)
on behalf of the ASTRI Collaboration


* Astrofisica con Specchi a Tecnologia Replicante Italiana

# The ASTRI Program

## Talk Outline

**Part 1**

The ASTRI SST-2M Prototype

**Part 2**

The ASTRI Mini-array

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**Part 1**

The ASTRI SST-2M Prototype

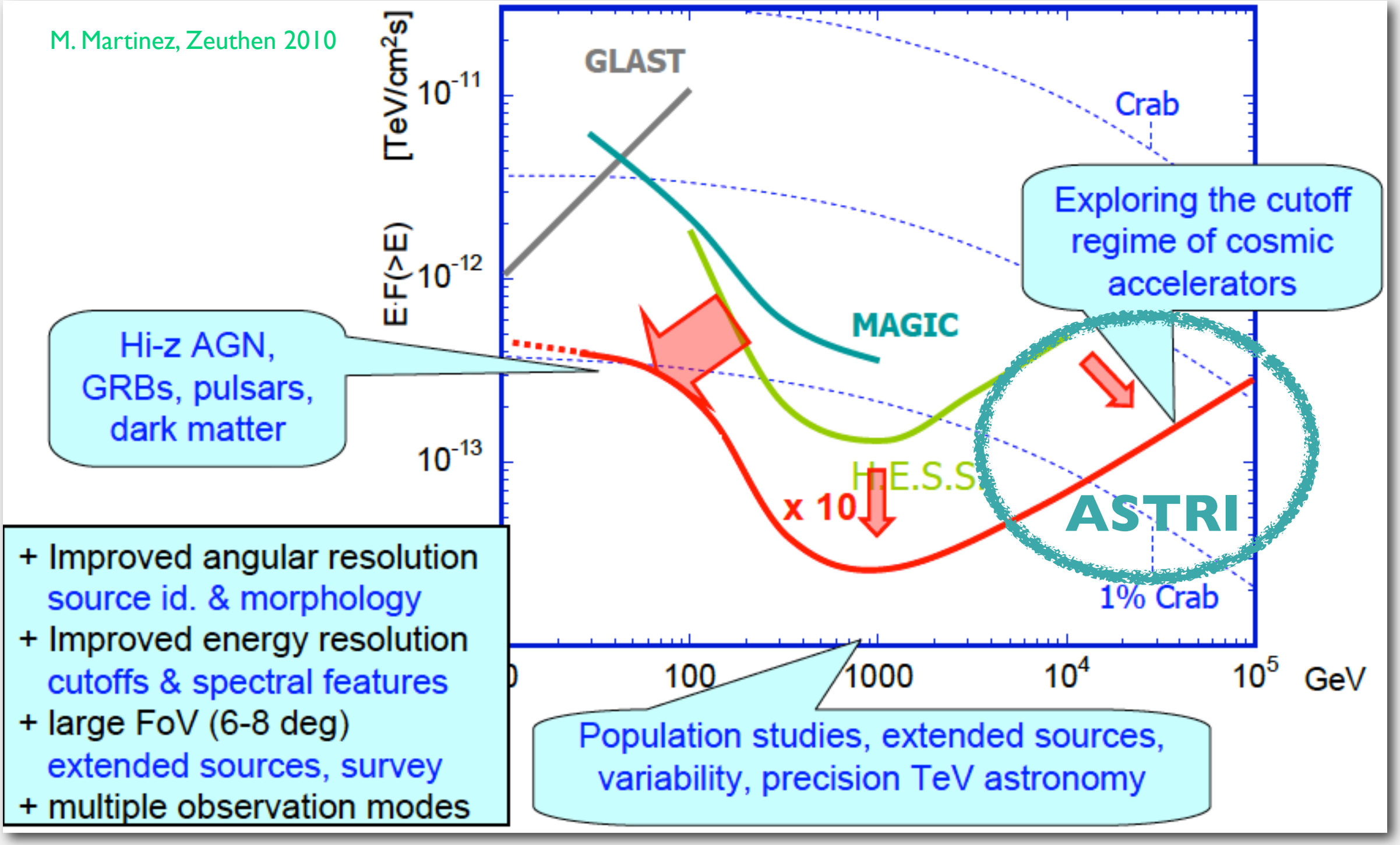
**Part 2**

The ASTRI Mini-array

# The ASTRI Program

## CTA sensitivity

M. Martinez, Zeuthen 2010



# The INAF ASTRI Project

The ASTRI Program is an **Italian "Progetto Bandiera"** 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 production, **within the CTA framework and following its requirements**, of both an **end-to-end prototype** of the CTA SST to be tested under field conditions in **2014**, and a **SST mini-array** to be placed at the chosen CTA Southern Site during **2016.**

**INAF is in charge of the design and production of the mirrors and the camera, the development of the end-to-end software, MC simulations and other related activities.** The telescope structure is designed by external firms.

INAF contributes with more than **30 FTE/year** (end 2012) to the project. The Project is subject to annual reviews by MIUR in order to review the status and allocate the budget according to the following scheme: **2011 (3 M€), 2012 (2 M€), 2013 (2 M€), and 2014 (1 M€)**.

# The ASTRI Program

## The ASTRI Project

**Principal Investigator** **G. Pareschi**

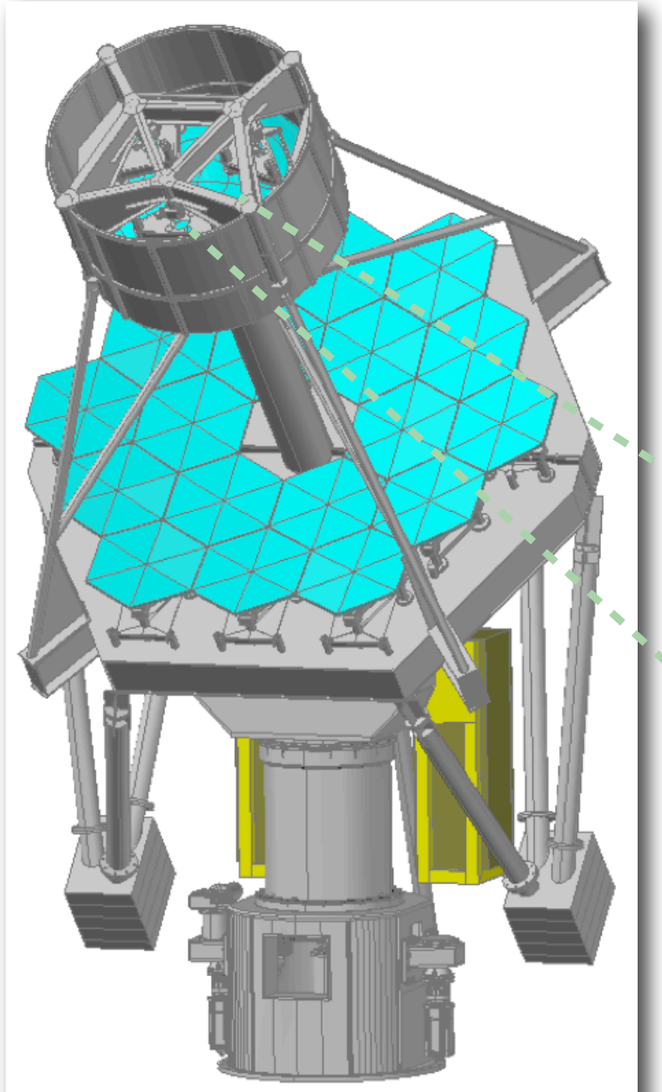
| | |
|---|---|
| Co-PIs | O. Catalano & S. Vercellone |
| Program Manager | M. Fiorini |
| System Engineer | L. Stringhetti |
| INAF/CTA Responsible | P. Caraveo |

**INAF Institutions**

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

**University Partners**

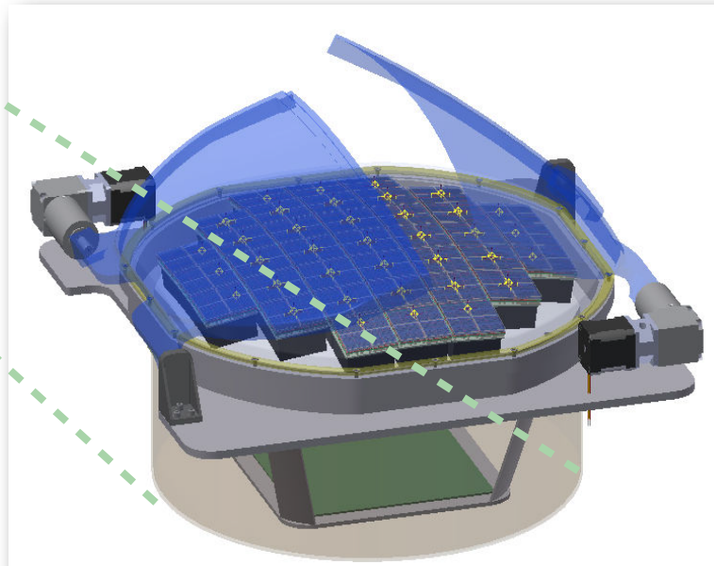
- Univer. of Padova
- Univer. of Perugia



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.

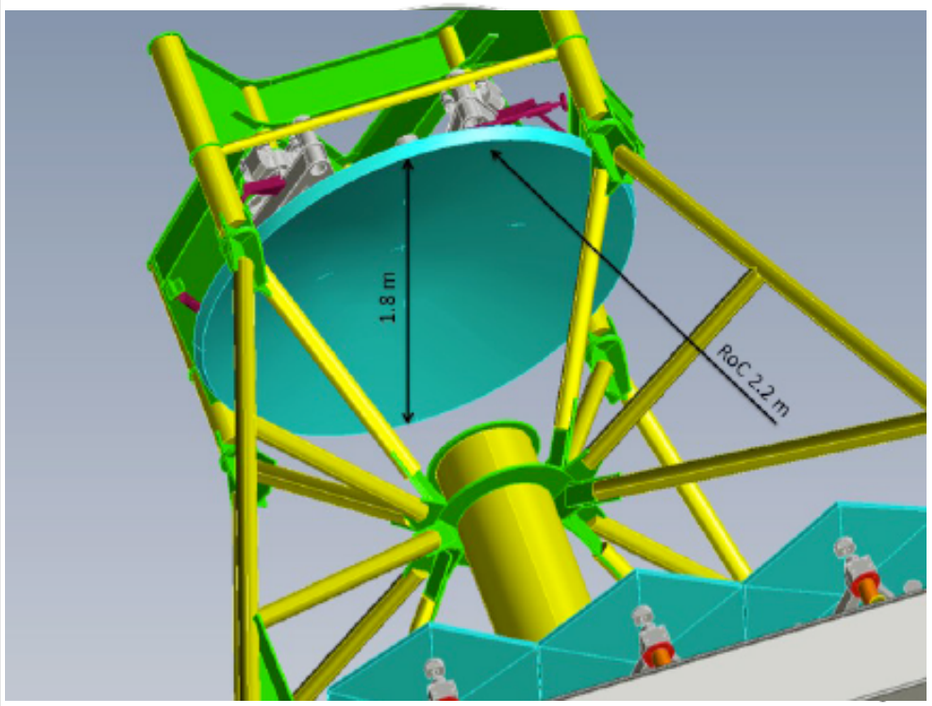


## The ASTRI Prototype Mirrors

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

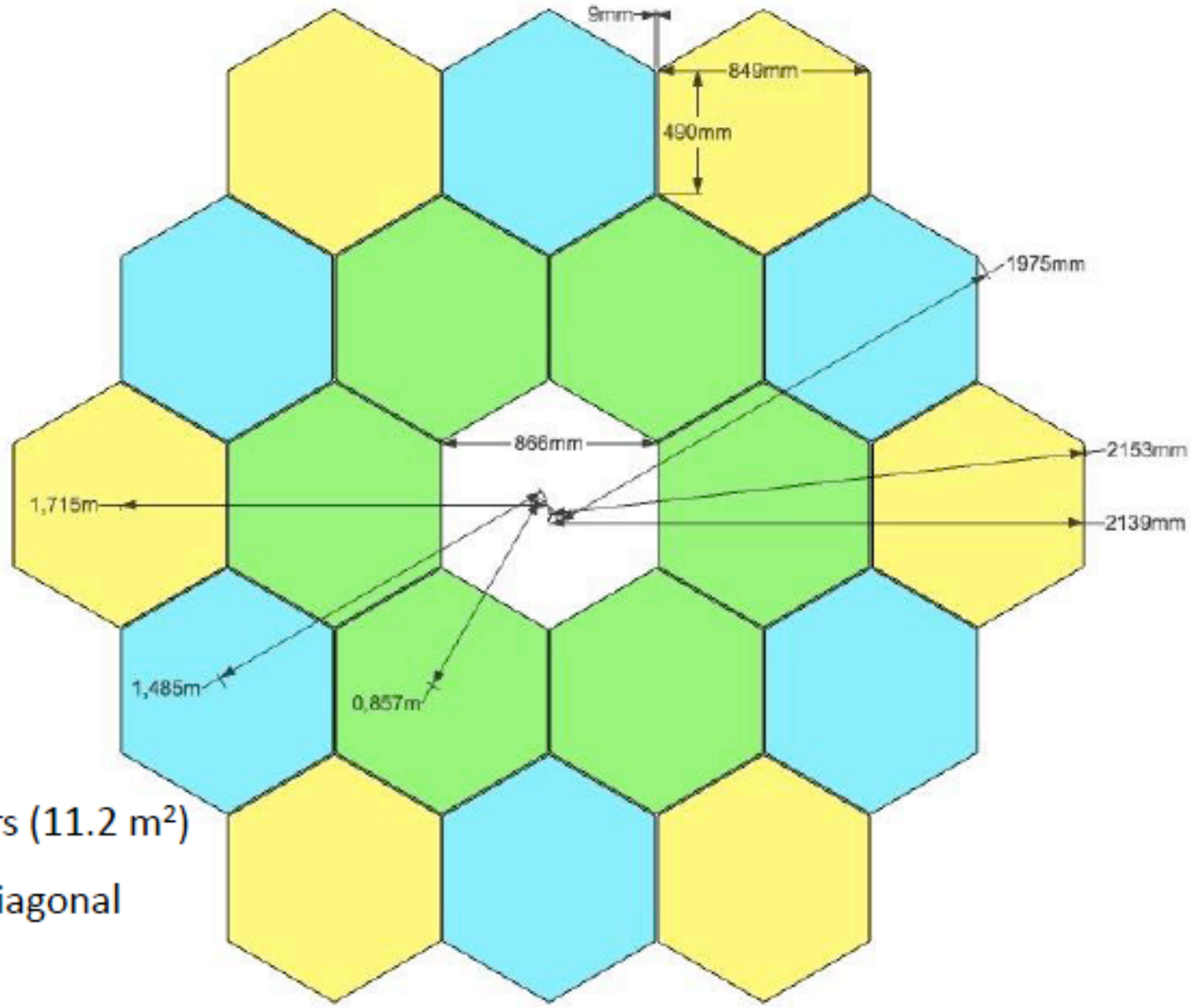



**Secondary mirror (M2)**

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 $m^2$)

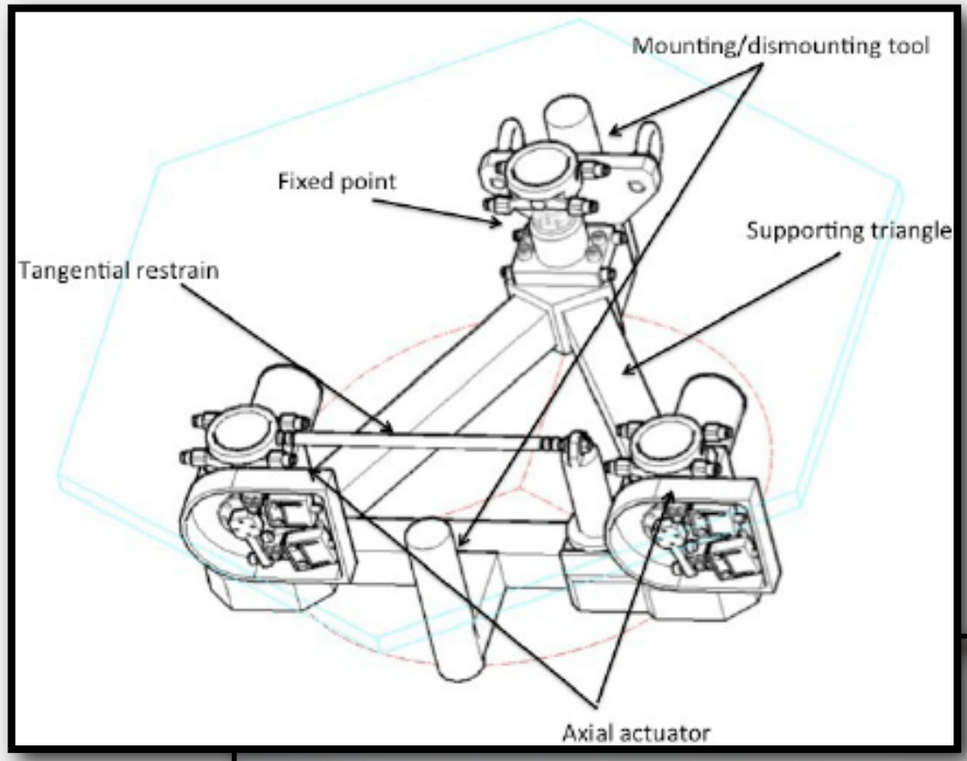
850 mm face-to-face, 1 m diagonal

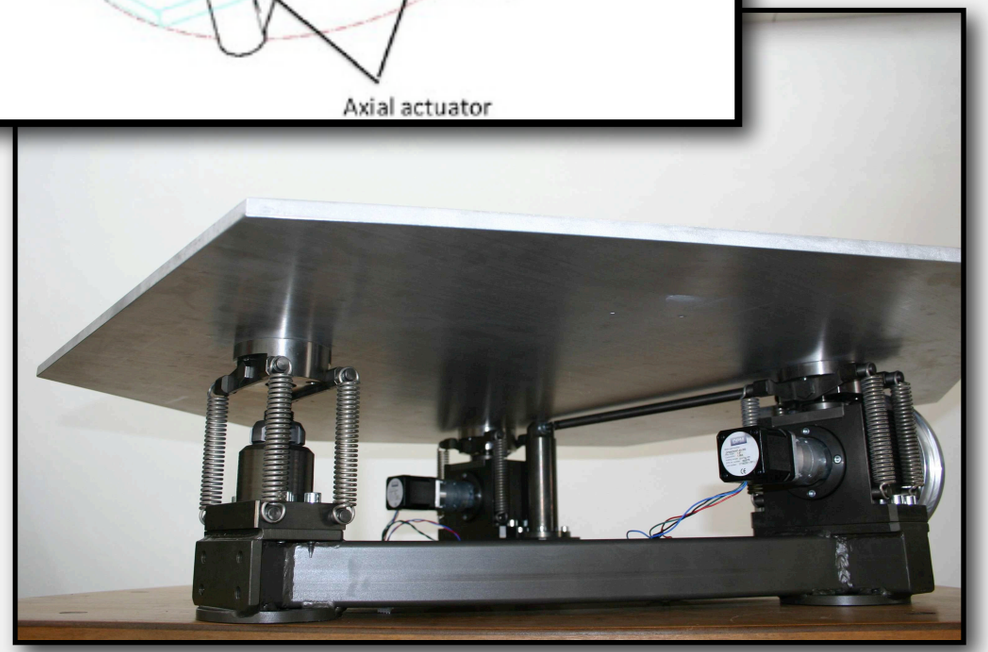
3 types of segments

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

# The ASTRI Program

## The Prototype Primary Mirror (M1)



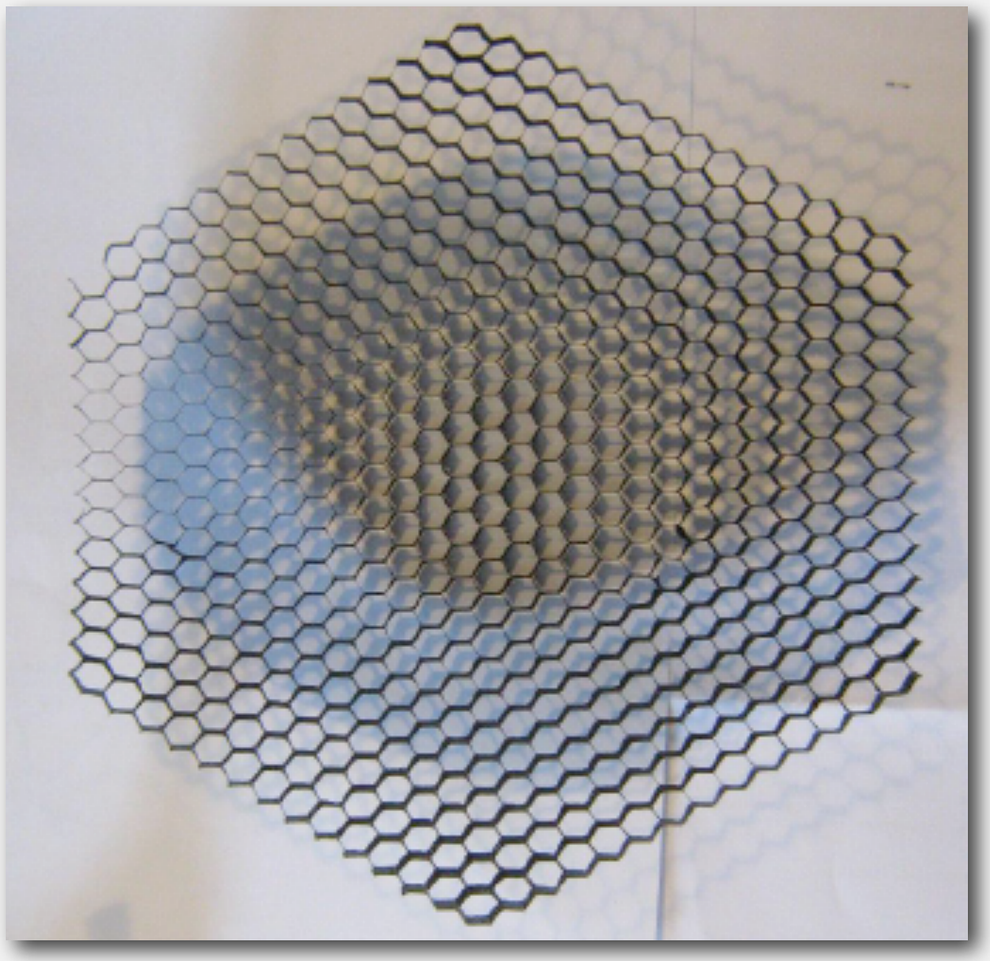



- off-axis aspherical profile obtained with the glass Cold-Shaping technology
- Physical Vapor Deposition of a multilayer of pure dielectric materials

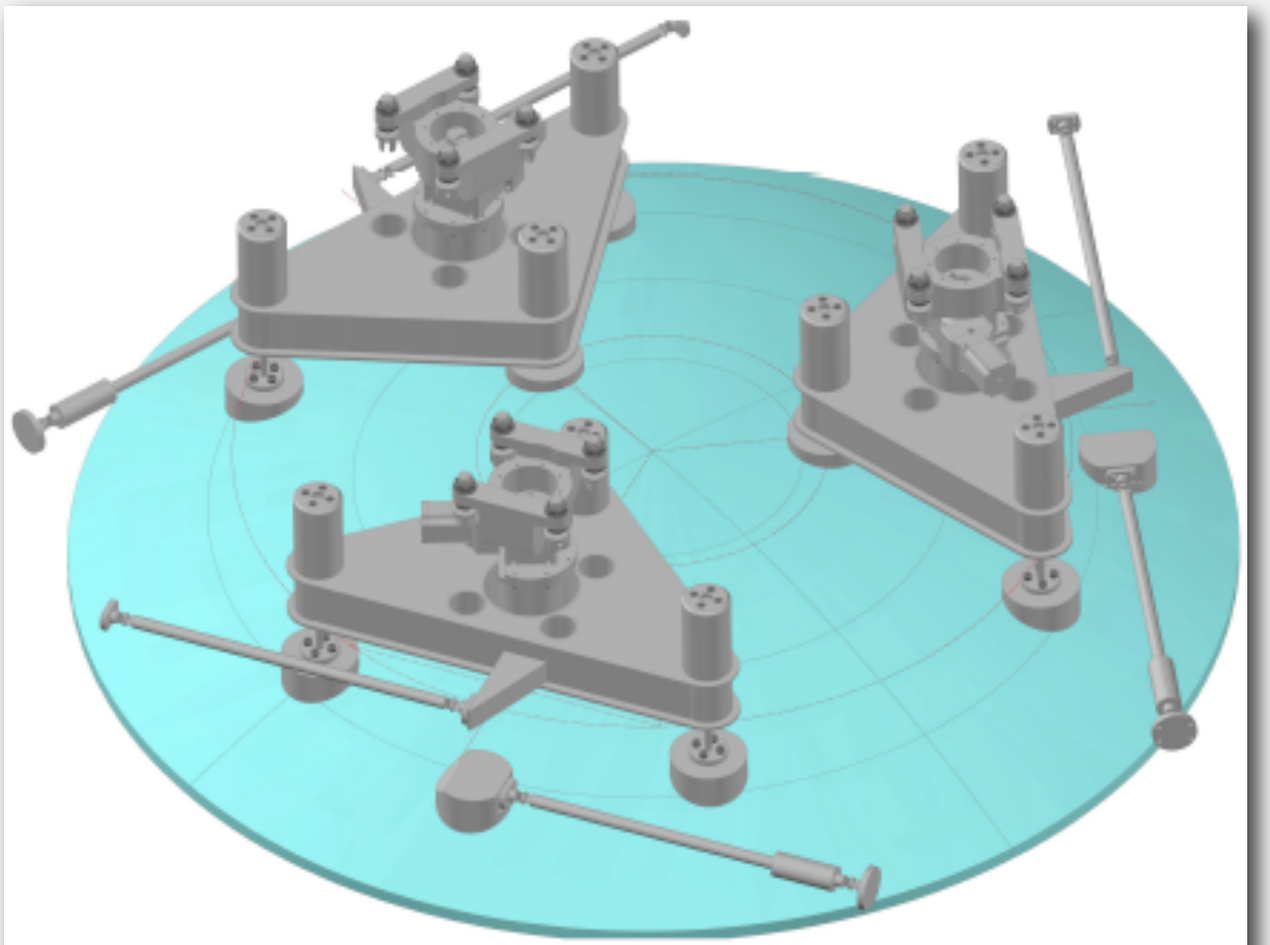
Triangle with mounting pins, 2 actuators, 1 fixed point, 1 tangential restrain, and the alignment system.

# The ASTRI Program

## The Prototype Secondary Mirror (M2)



Scaled-down prototype of the curved honeycomb core structure of the monolithic secondary mirror



3D CAD view of the support and alignment system of M2

## The ASTRI Prototype Camera

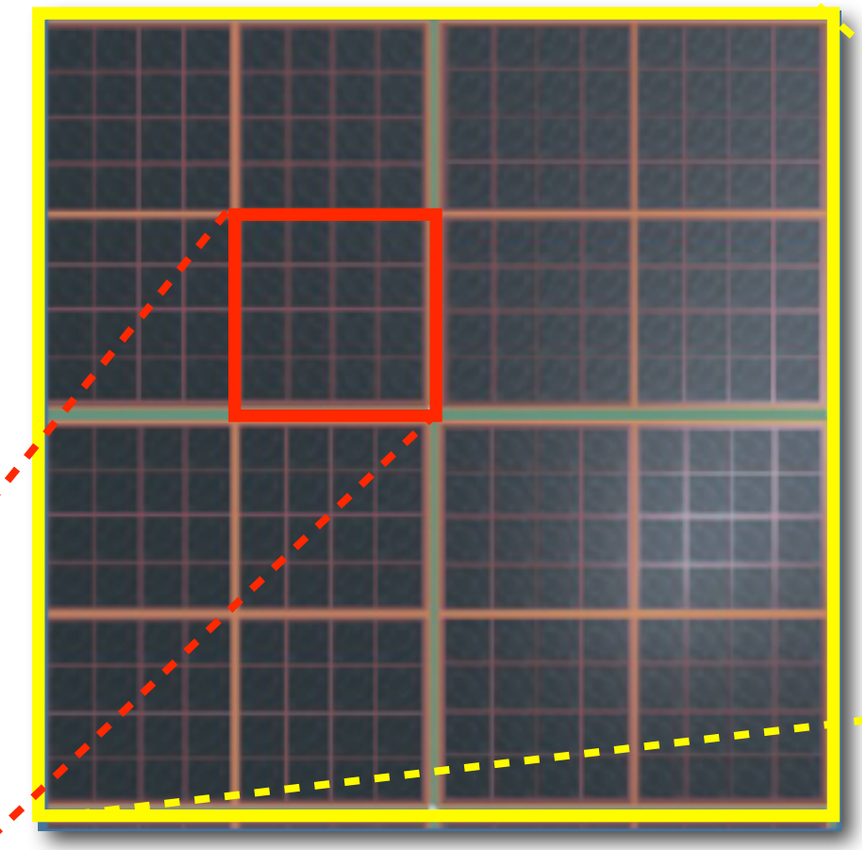
Camera' main characteristics:

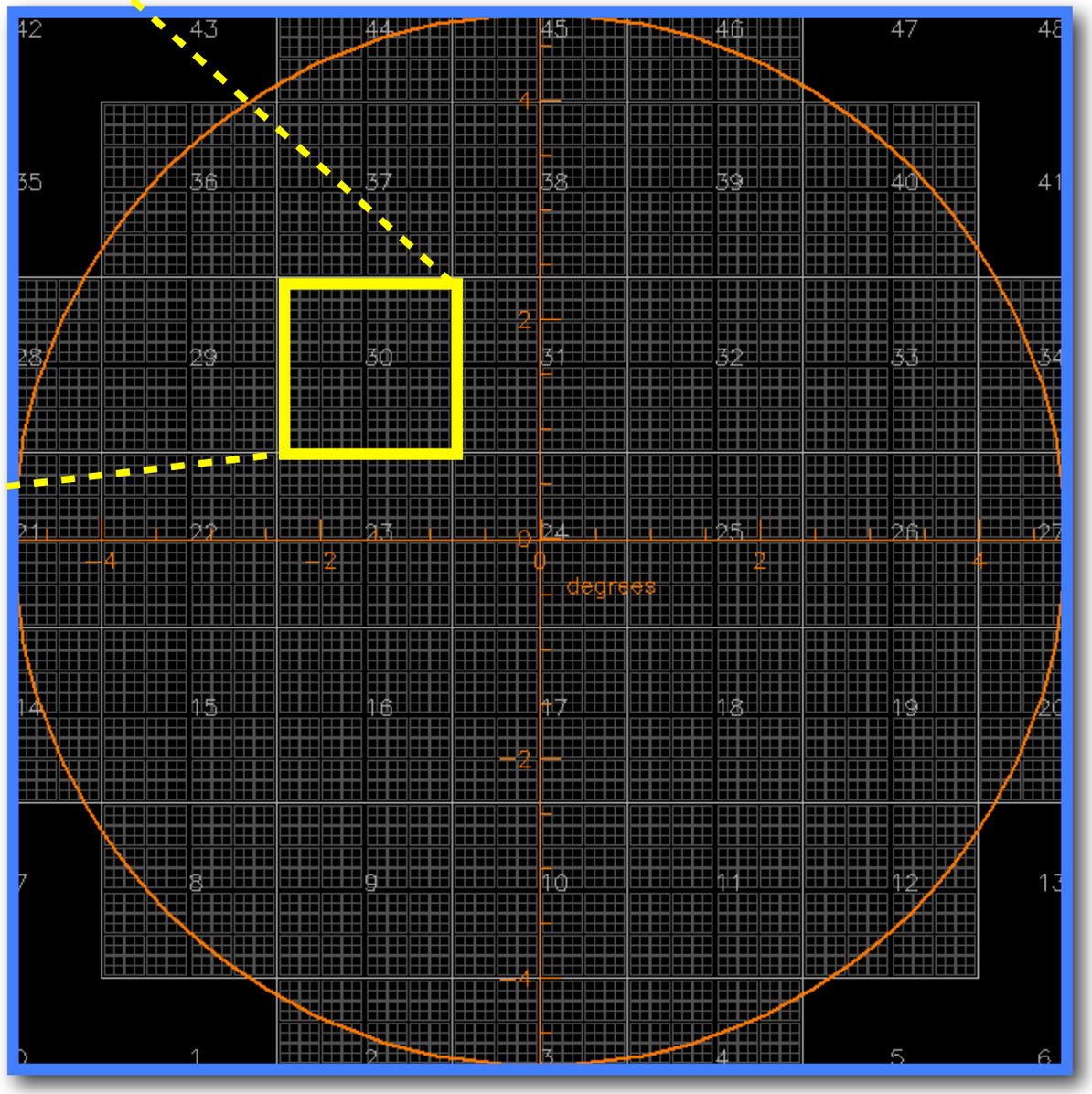
- **Detector type:** monolithic MPPC array (SiPMs)
- **Logical Pixel size:** 6.2 mm x 6.2 mm [0.17°]
- **Plate scale:** 37.5 mm/°
- **Number of Pixels :** 7936
- **Number of channels :** 1984 (grouping 2 x 2 pixels)

# The ASTRI Program

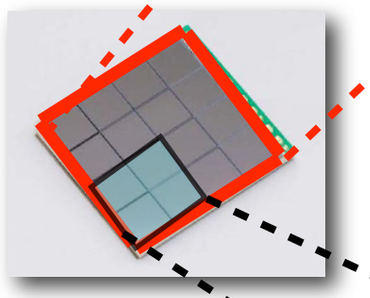
## The ASTRI Prototype Camera

I ASTRI Focal Surface
37 PDMs
FoV diameter = 9.6°






Size imposed by the manufacturer



I Photon Detection Module (PDM) = 4x4 Units

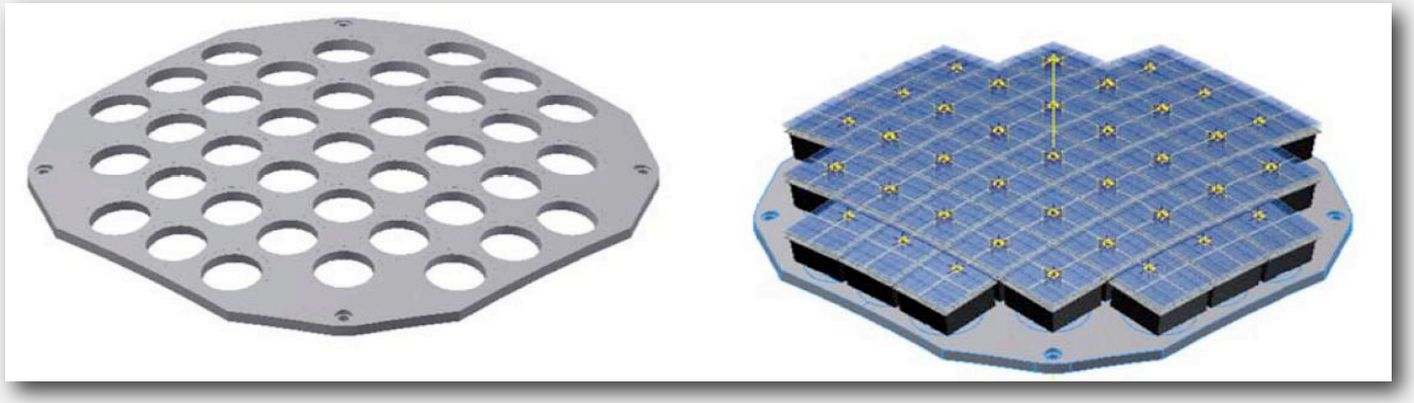
I Unit
4x4 pixel
1px = 3mm x 3mm

0.17° Logical pixel

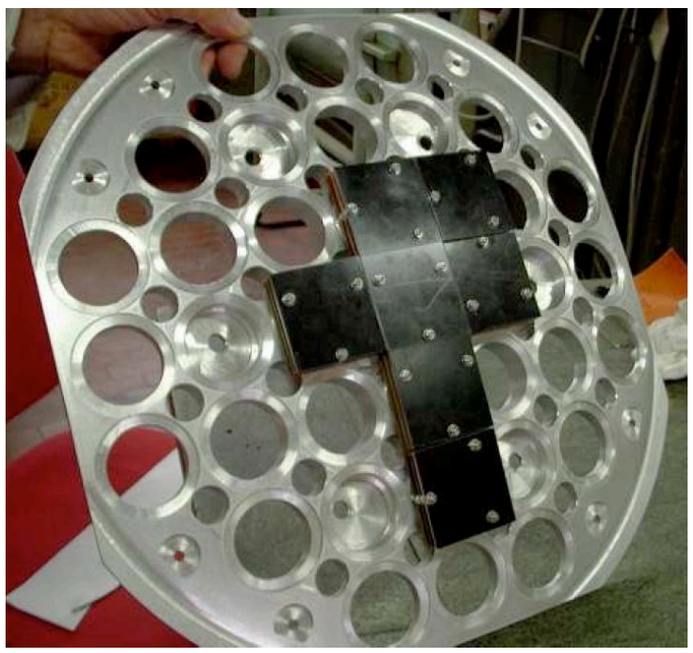
# The ASTRI Program

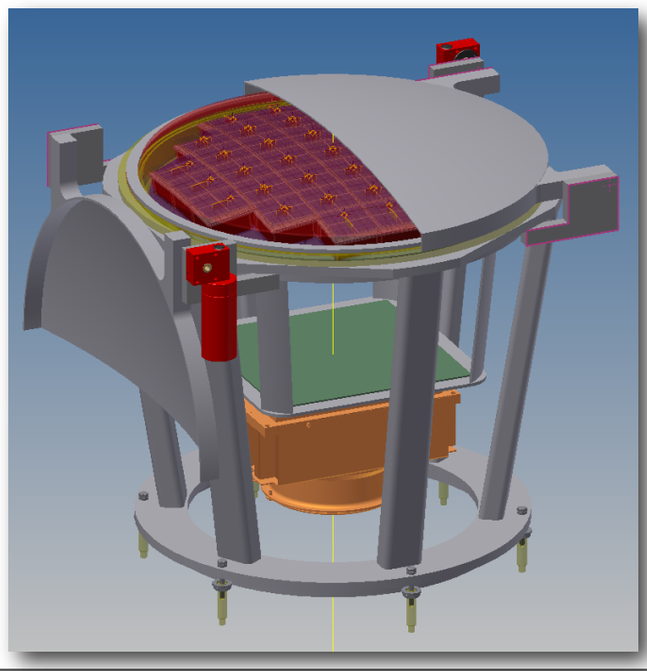
## The ASTRI Prototype Camera

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

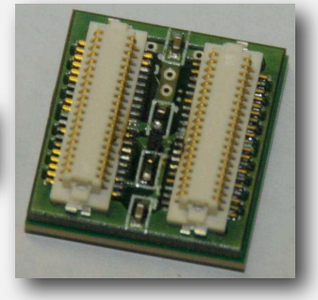


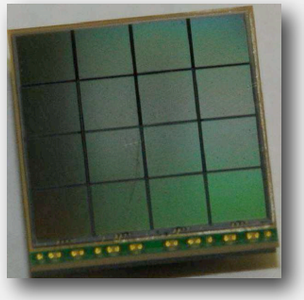
Mock-up of the mechanical housing + PDMs and sketch of the ASTRI Camera with the Camera-Telescope I/F.



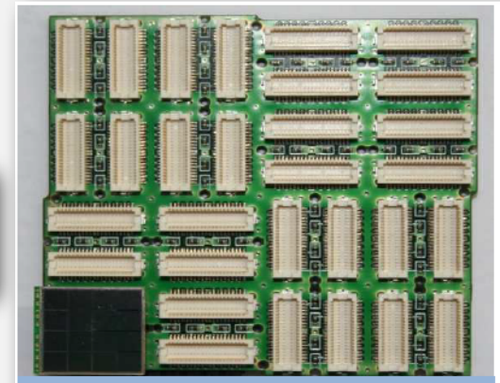


SiPM 4x4 Board n.1



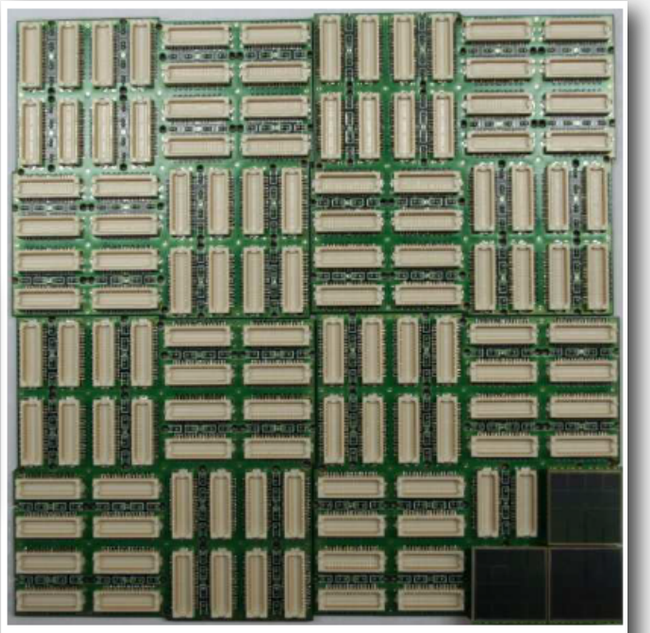


Photon Detection Module - Board n.2



PDM top view with mounted one matrix SiPM 4x4

First prototype of a 4x4 PDMs Mosaic with 3 SiPMs already mounted



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 Monte Carlo 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, Lla, L1b,...)

# The ASTRI Program

## The ASTRI SST-2M Prototype Site

INAF - Catania Astrophysical Observatory

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

Altitude: 1735 m a.s.l.

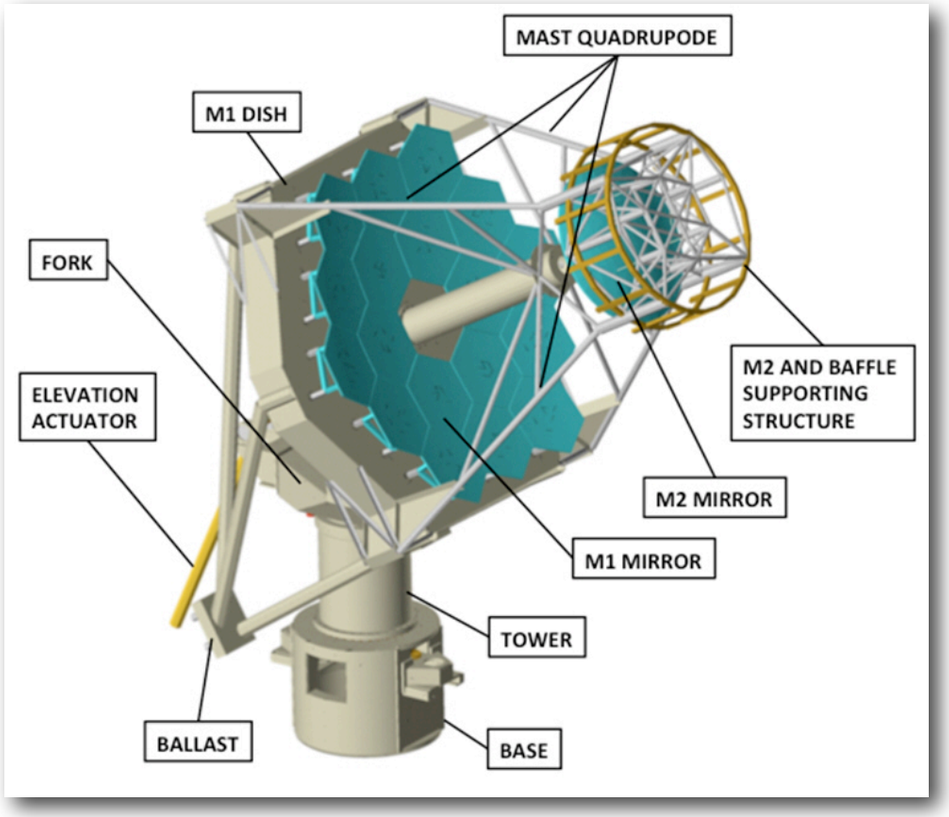
Longitude: +14° 58'.4;  Latitude +37° 41'.5

## ASTRI Prototype Major Milestones

# ASTRI SST-2M Prototype

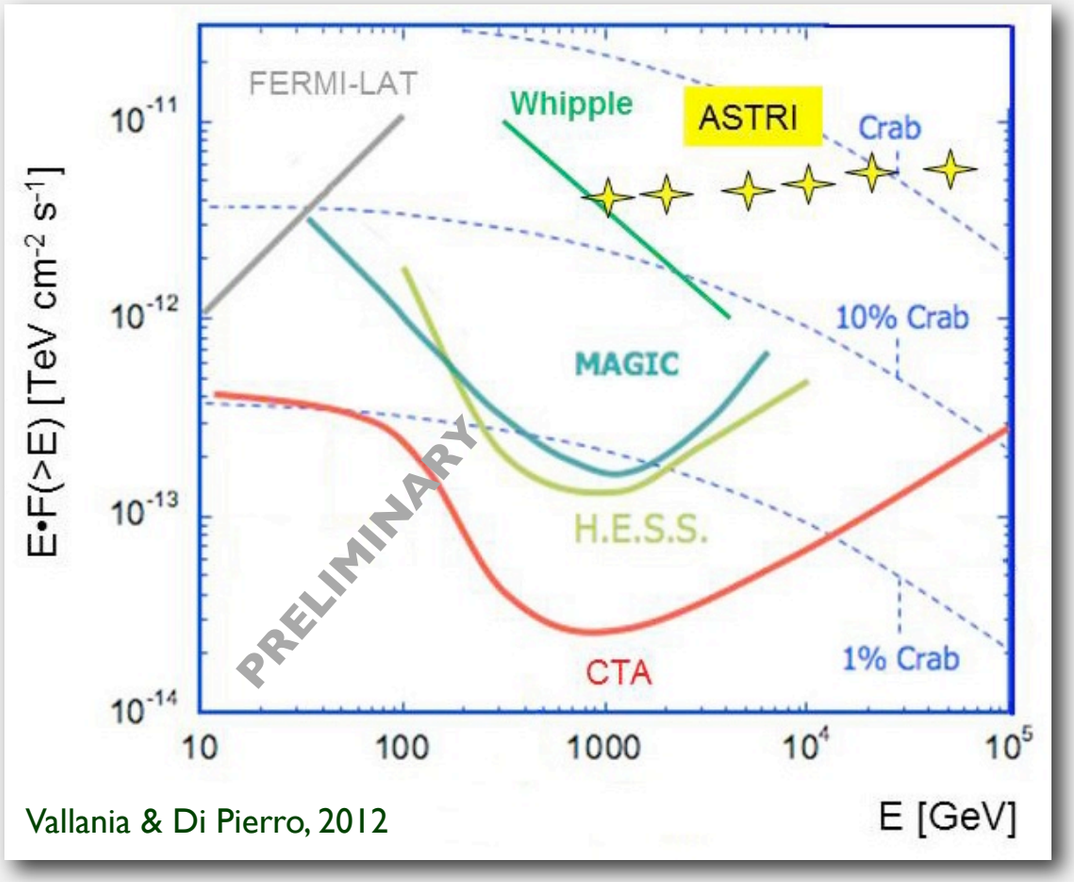
April 2013 ➔ call for tenders on
4 ASTRI SST-2M structures
[1 for the prototype and 3 for the mini-array phase 1]

July 2014 ➔ ASTRI SST-2M Prototype
*in situ* for AIV & scientific evaluation

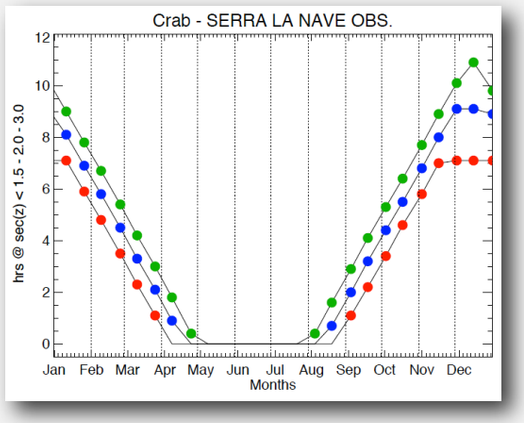


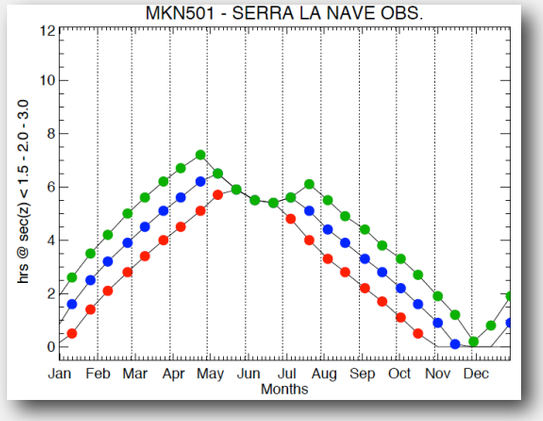
# The ASTRI Program

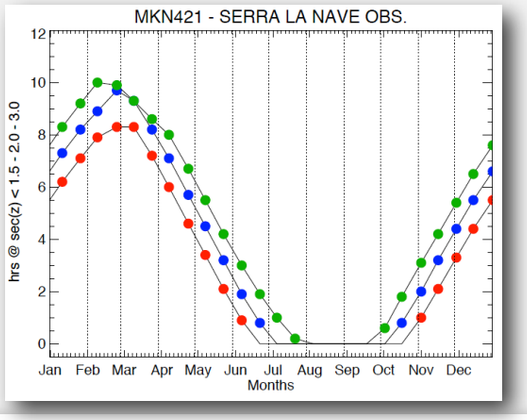
## The prototype scientific perfomance




Vallania & Di Pierro, 2012




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

**Maximum sensitivity : E > 1 TeV (1 Crab @ 5$\sigma$ in a few hours)**

In the range E > 10 TeV : (1 Crab @ 5$\sigma$ in a few tens of hours)

**First Crab observations with a SC, SiPM Telescope**

Possible cross-calibrations activities with current IACTs both based on PMTs and G-APDs.

**Accessible sources from Sicily : Crab, Mkn 421, Mkn 501**

Intense flares (~5-10 Crab) should allow blazars intra-night variability studies.

## Synergies within CTA

# The ASTRI Project works in synergy with other CTA Projects.

**The ASTRI Prototype CAM/STR interface is designed to host the CHEC Camera**

This will allow us to perform functional tests and data acquisition.

**Agreement between ALMA, INAF, DESY and HUB**

This will allow us to share the software developed by the ALMA Observatory with the INAF ASTRI Project and the DESY/HUB MST Project.

**Agreement with the North-West University in Potchefstroom (South Africa)**

The North-West University will provide about 300 k€ for the construction of a part of an additional SST-2M telescope for the ASTRI mini-array.

**INAF funding proposal submission to tighten the collaboration with GATE**

INAF recently submitted a funding proposal to MIUR in order to cover the common activities that could be carried on between the two projects.

# The ASTRI Program

## Talk Outline

**Part 1**

The ASTRI SST-2M Prototype

**Part 2**

The ASTRI Mini-array

# The ASTRI mini-array concept

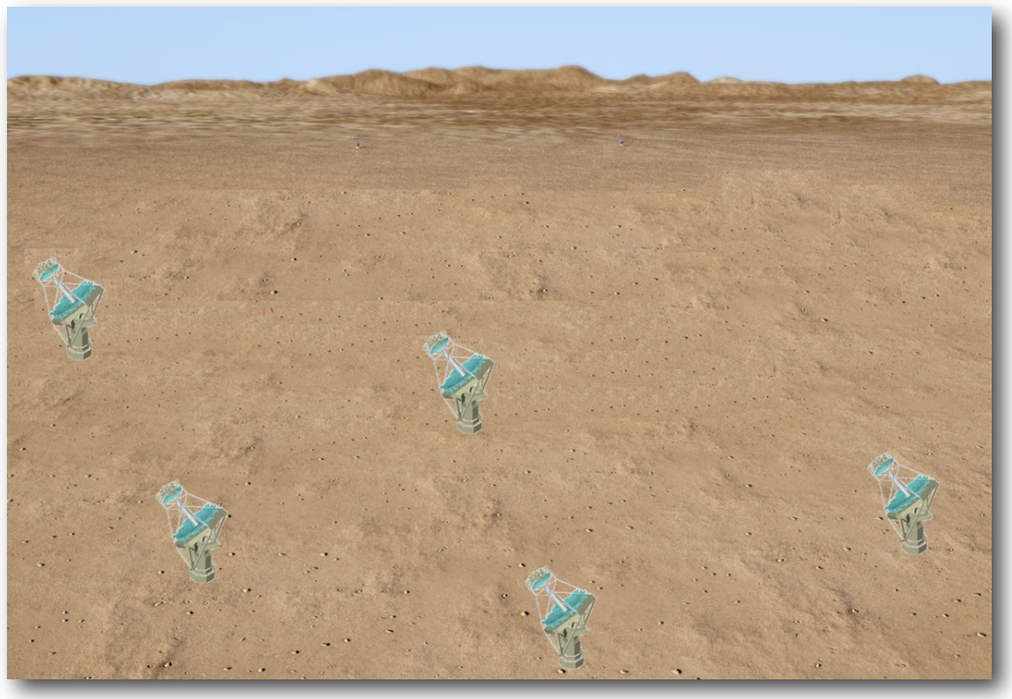
Our goal is the deployment and the operation of a **mini-array composed of a few SST-2M telescopes** at the final CTA southern site.

## ASTRI SST-2M mini-array

CTA Southern site should be decided within the current milestone (end of 2013)

2014 - 2015 ➔ ASTRI mini-array re-assessment study phase

2015 - 2016 ➔ Extension of the ASTRI mini-array [phase 2], and mini-array deployment phase.



## The ASTRI 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 Monte Carlo expectations**
  - by means of deep observations of a few selected targets
- **do the first CTA science**
  - by means of a few solid detections during the first year

# The Mini-array Performance

Di Pierro et al., 2012

- **Limiting flux a factor 1.5 better than H.E.S.S. at 10 TeV for an array composed by 7 telescopes**

- **Should not expect better than a few arcmin angular resolution** (vs 0.2° of HAWC)

PRELIMINARY → TO BE UPDATED

- **Energy resolution of the order of 10-15 %** (vs 20% of HAWC)

- ***Fermi* and *Swift* still in operation → not only a technological pathfinder**

# The ASTRI Program

## Southern Hemisphere

Hinton & Vercellone, 2012

- Vela X → $30 \times 10^{-12}$
- RX J1713 → 10
- Vela Junior → 10
- HESS J1616 → 6
- HESS J1837 → 4
- HESS J1813 → 3
- HESS J1825 → 3
- HESS J1745/GC → 2
- HESS J1702 → 2
- HESS J1804 → 2
- HESS J1303 → 2
- HESS J1718 → 2
- LS 5039 → 0.5-2

Assuming a mini-array limiting flux of ~$10^{-12}$ erg cm$^{-2}$ s$^{-1}$ at 10 TeV

# The ASTRI Program

## Southern Hemisphere

Hinton & Vercellone, 2012

- **Vela X → 30x10$^{-12}$**
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- HESS J1303 → 2
- **HESS J1718 → 2**
- **LS 5039 → 0.5-2**

Assuming a mini-array limiting flux of ~10$^{-12}$ erg cm$^{-2}$ s$^{-1}$ at 10 TeV

A few observable in pairs with ~9 degree FoV.

Opportunity for **serendipitous detections** of new hard spectrum Galactic sources.

# The ASTRI Program

## Prime targets (South)

Hinton & Vercellone, 2012

- PKS 2155-304 (HBL)
- 1ES 0229+200 (E-HBL) and other extreme HBLs
- Crab Nebula (VHE variability ?)
- Vela X / Vela Junior
- RX J1713 / HESS J1718 (SNR, PWN)
- HESS J1825/LS 5039 (PWN, XRB)
- The Galactic Centre (central source + diffuse)

VERY PRELIMINARY ::: TO BE UPDATED

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

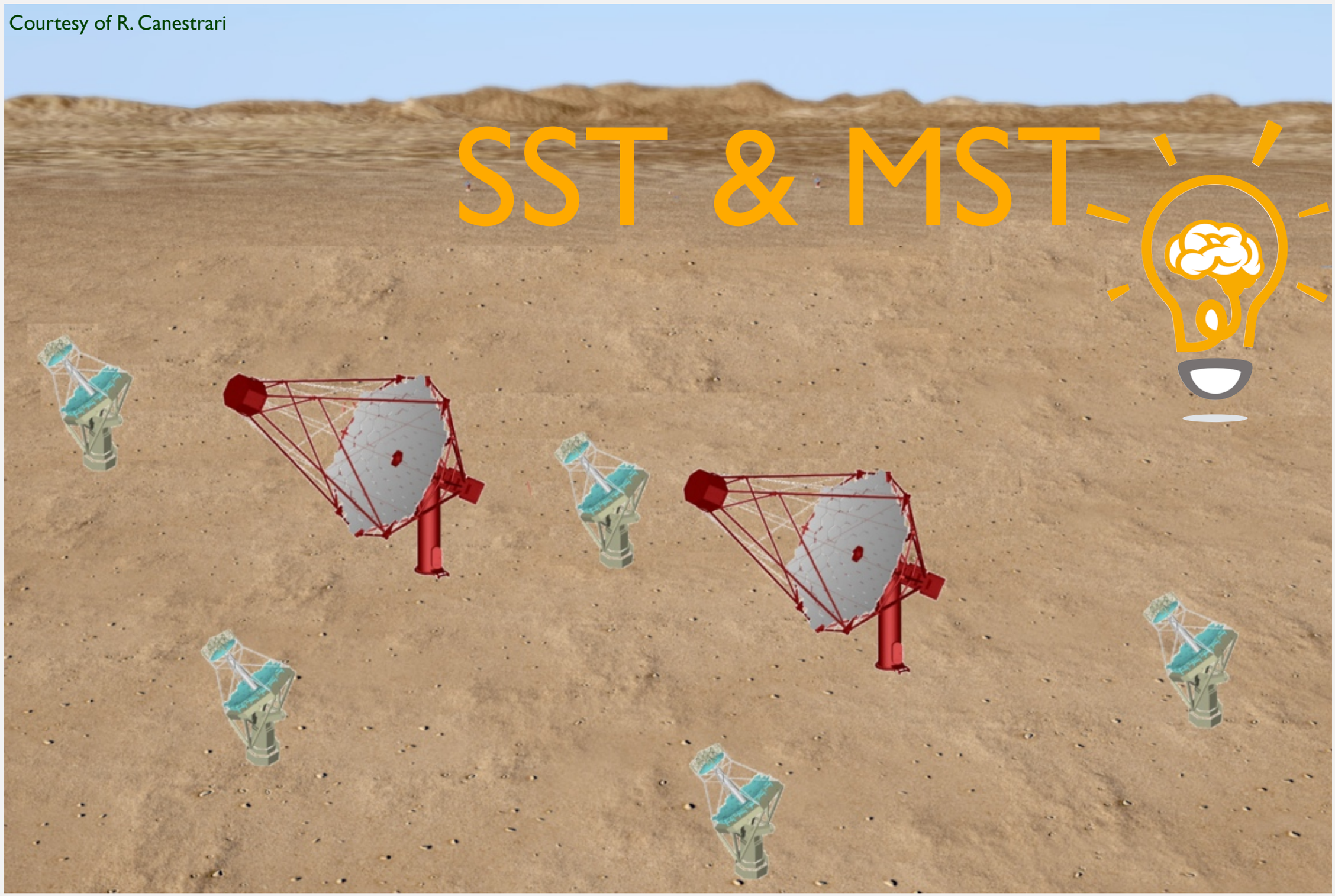
PSF and Spectral Calibration
Weak source detection
Point-like and extended objects

# Next Steps

Courtesy of R. Canestrari

# Next Steps

Courtesy of R. Canestrari



## SSTs + MSTs = CTA *seed*

Coupling **SSTs with MSTs** would constitute the first ***CTA seed***.

Dramatic boosting in performance.

MST Team at DESY already contacted and willing to tighten the collaboration.

Excellent synergies with *Swift* and *Fermi* satellites

## Summary

**We plan to start the ASTRI SST-2M Prototype activities at Serra La Nave during Summer 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.**

# The ASTRI Program

## Thanks !


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

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