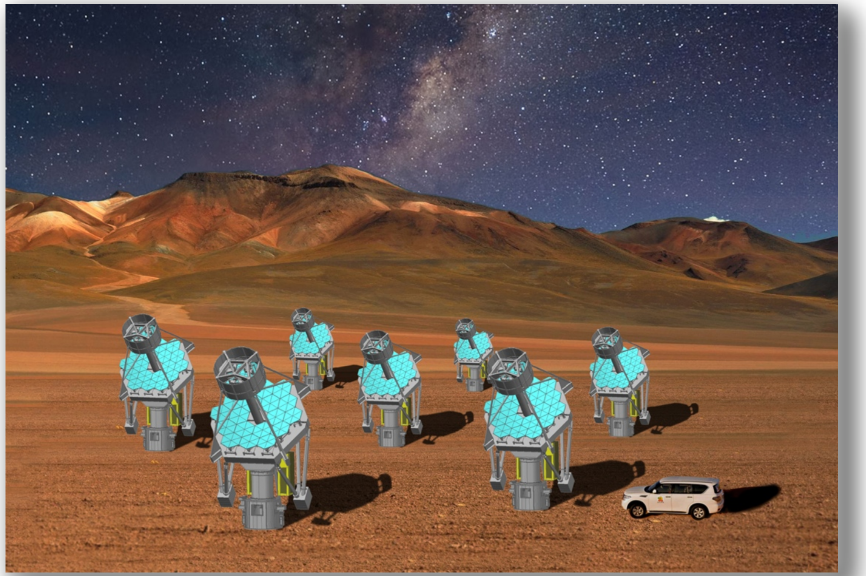

The ASTRI/CTA SST mini-array: a seed of the future Cherenkov Telescope Array

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for the ASTRI Collaboration & the CTA Consortium

Outline

Introduction

The ASTRI Project

The ASTRI/CTA mini-array science cases

Credit: E. Giro

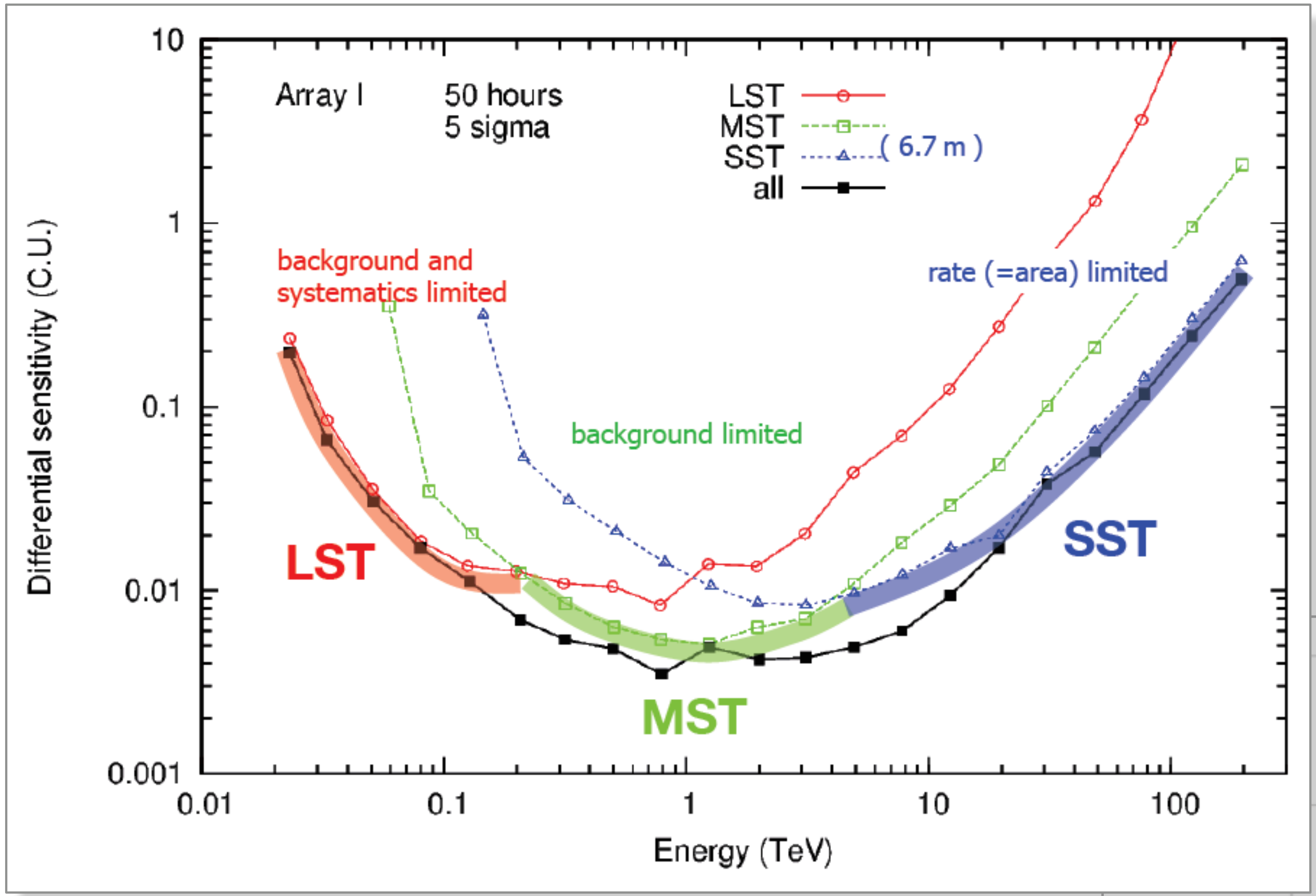
The ASTRI Project

ASTRI is an Italian “Flagship Project” funded by the Ministry of Education, University and Research (MIUR) and led by the Italian National Institute for Astrophysics (**INAF**).

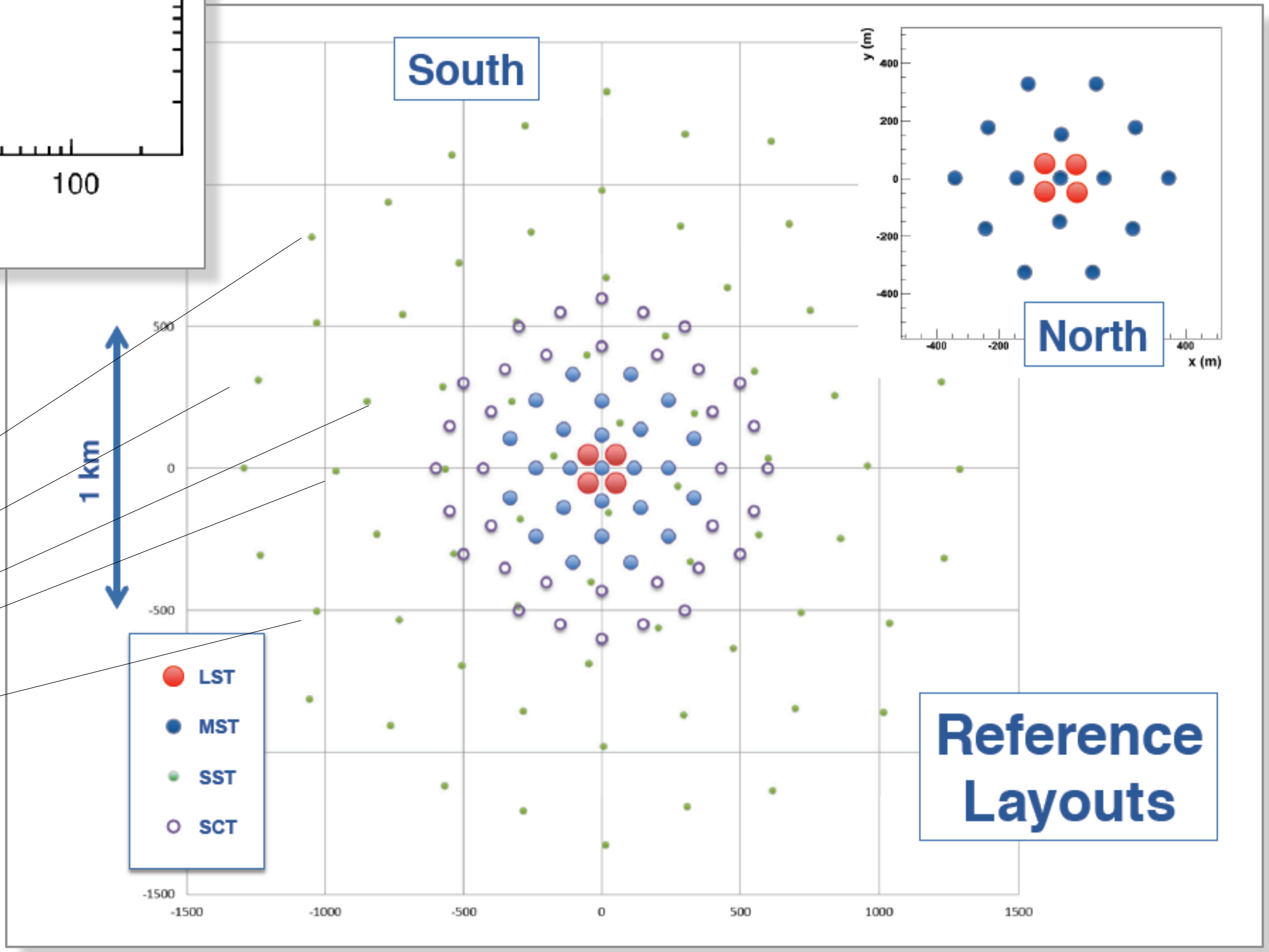
The main goals of the project are the design, development and deployment, **within the CTA framework**, of:

- **an end-to-end prototype** of the CTA small-size telescope in a dual-mirror configuration (ASTRI SST-2M) to be tested under field conditions at the INAF observing station on Mt. Etna (Sicily), **inaugurated on 2014 Sept. 24th**;
- **an SST-2M mini-array** composed of seven telescopes units to be placed at the chosen CTA Southern site in **2016**.

ASTRI within the CTA framework



We aim at the production and deployment of about half of the CTA SST sub-array to explore the energy range above the TeV threshold.



The dual-mirror concept

Small pixel size, large field of view, and controlled cost requirements are mutually incompatible within the Davies-Cotton telescope design paradigm.

New **dual-mirror, Schwarzschild-Couder** (SC) based aplanatic design has been proposed and developed [Vassiliev, Fegan & Brousseau, 2007, A.Ph., 28, 10]

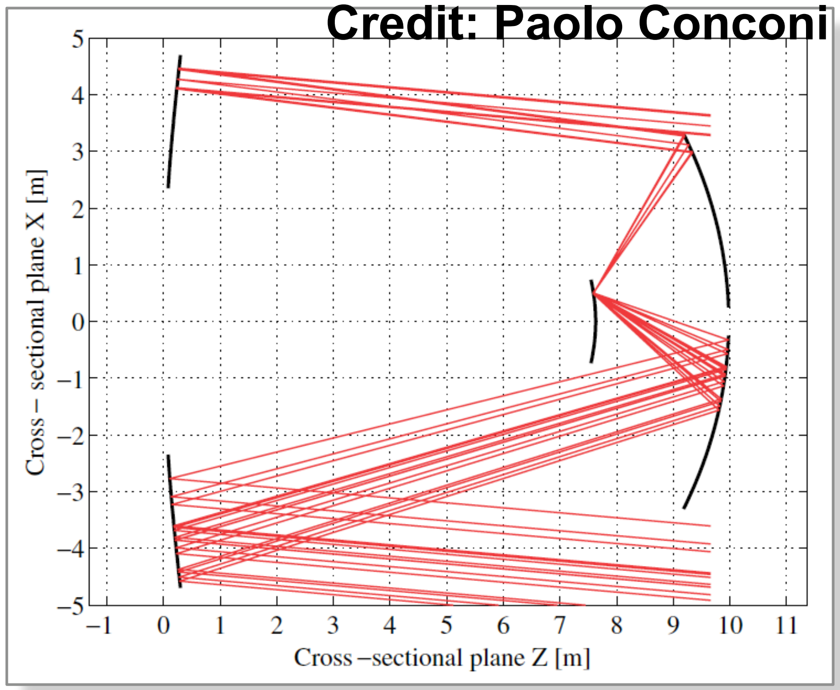
The dual-mirror layout allows us:

- ✦ to obtain a more compact mechanical structure
- ✦ to reduce the dimension, the weight, and the cost of the camera
- ✦ to adopt SiPMs as light detectors, thanks to the reduced plate-scale.
- ✦ to have an optimal imaging resolution across a wide field of view

In the SC telescope, the focal plane is located in-between two aspherical mirrors, close to the secondary mirror.

No Cherenkov telescope adopted this optical system up to now.

Credit: Paolo Conconi



The ASTRI SST-2M Prototype

Energy threshold

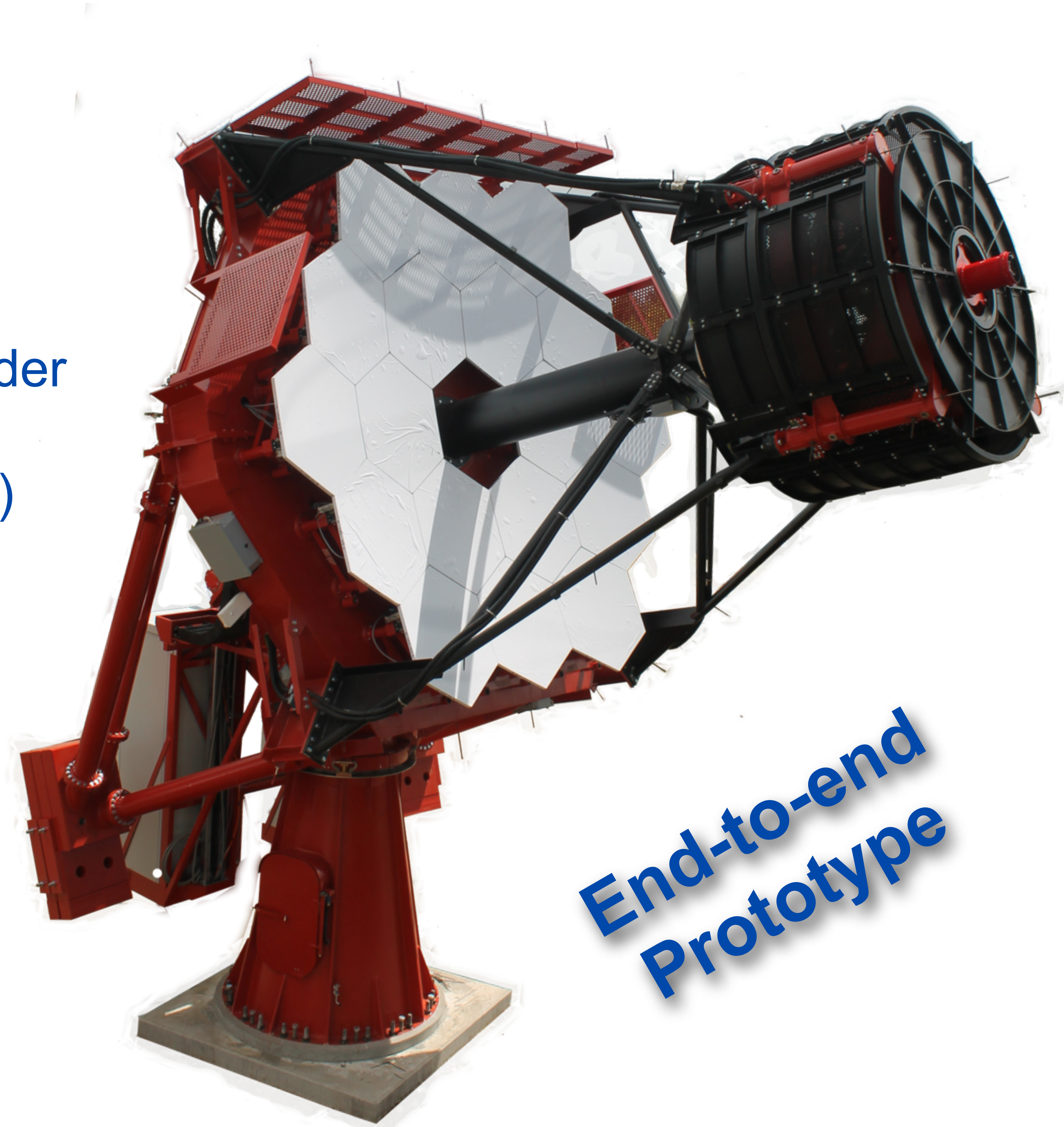
- 1 TeV

Telescope properties

- Primary mirror = 4.3m
- Optical design = Schwarzschild-Couder
- M1 type = Segmented
- Secondary mirror = 1.8m (2.2m RoC)
- M2 type = Monolithic
- M1-M2 distance = 3m
- Effective area = 6.5m^2
- F/D$_1$ = 0.5, F = 2.15m

Camera properties

- Number of logical pixels = 1984
- Pixel size = 0.17°
- Field of View = 9.6°
- Sensors type = SiPMs



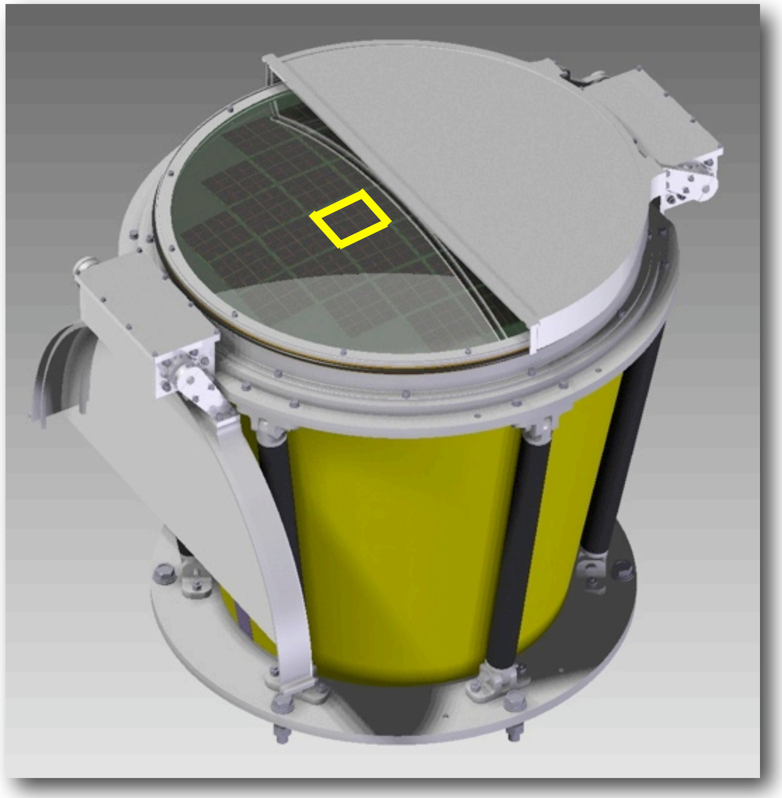
End-to-end Prototype

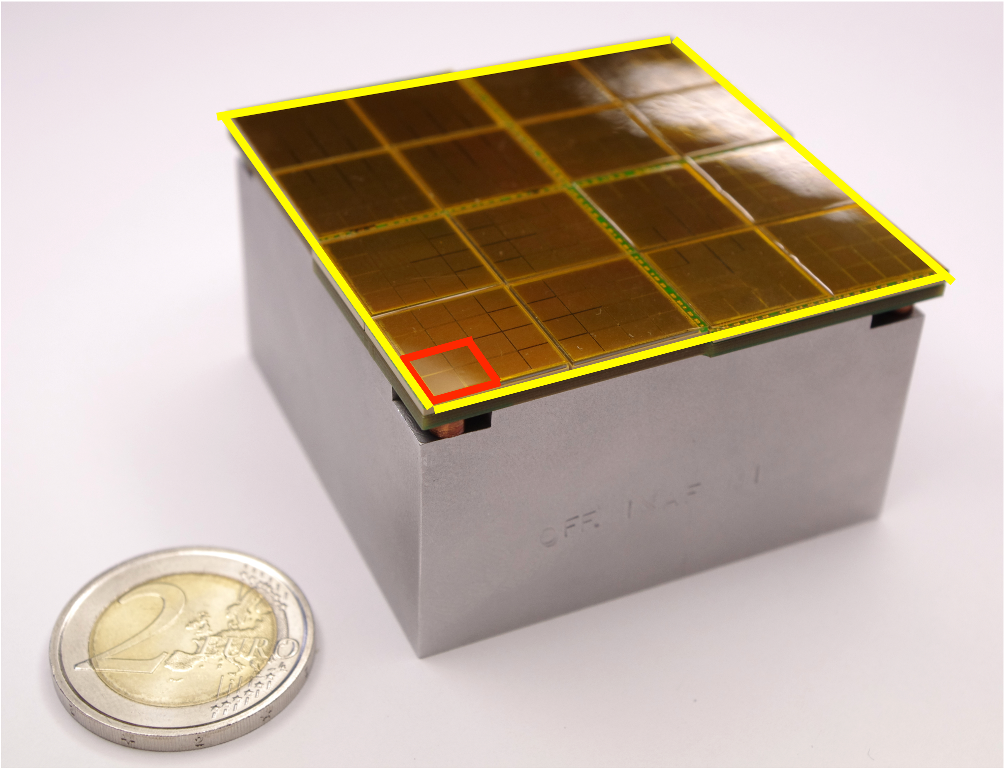
Inauguration

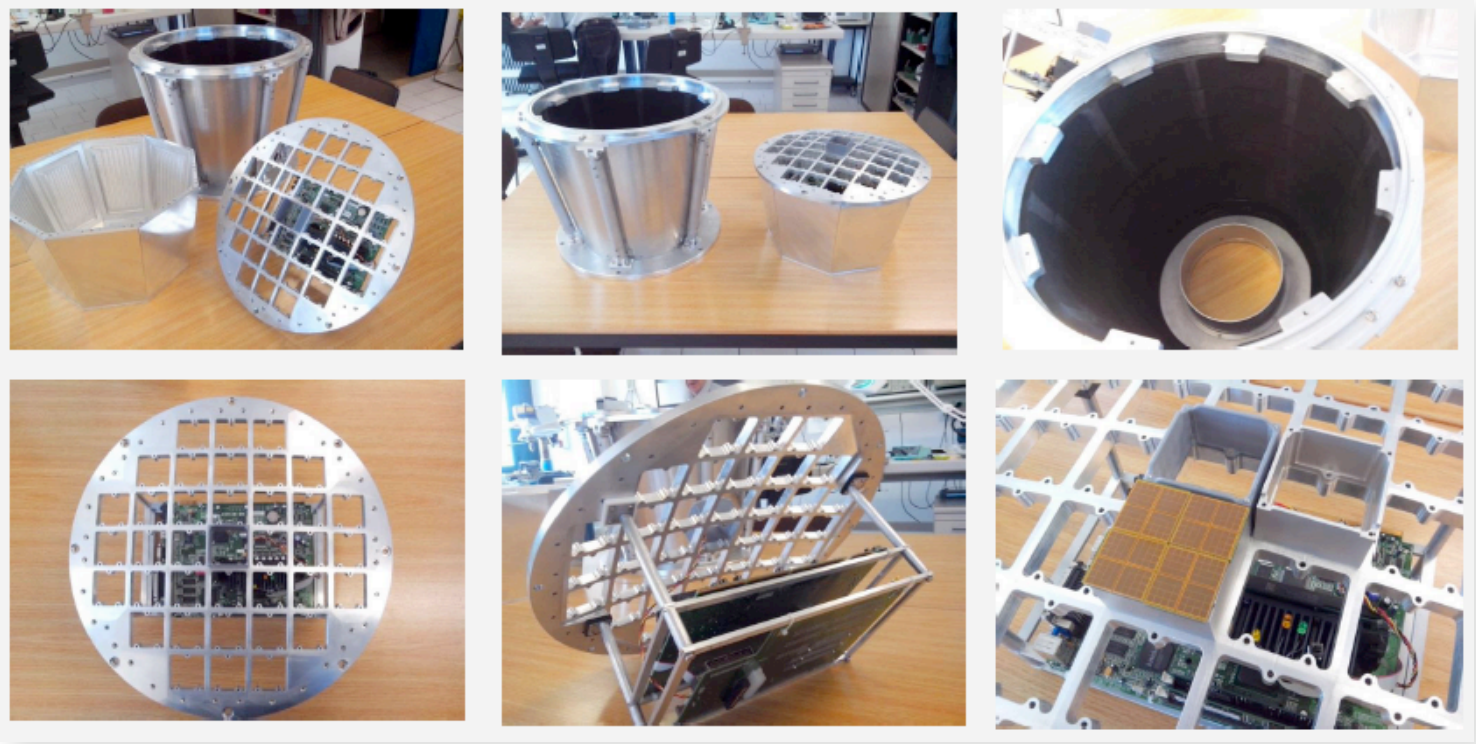
Credit: S. Vercellone

Credit: T. Abegg

Camera



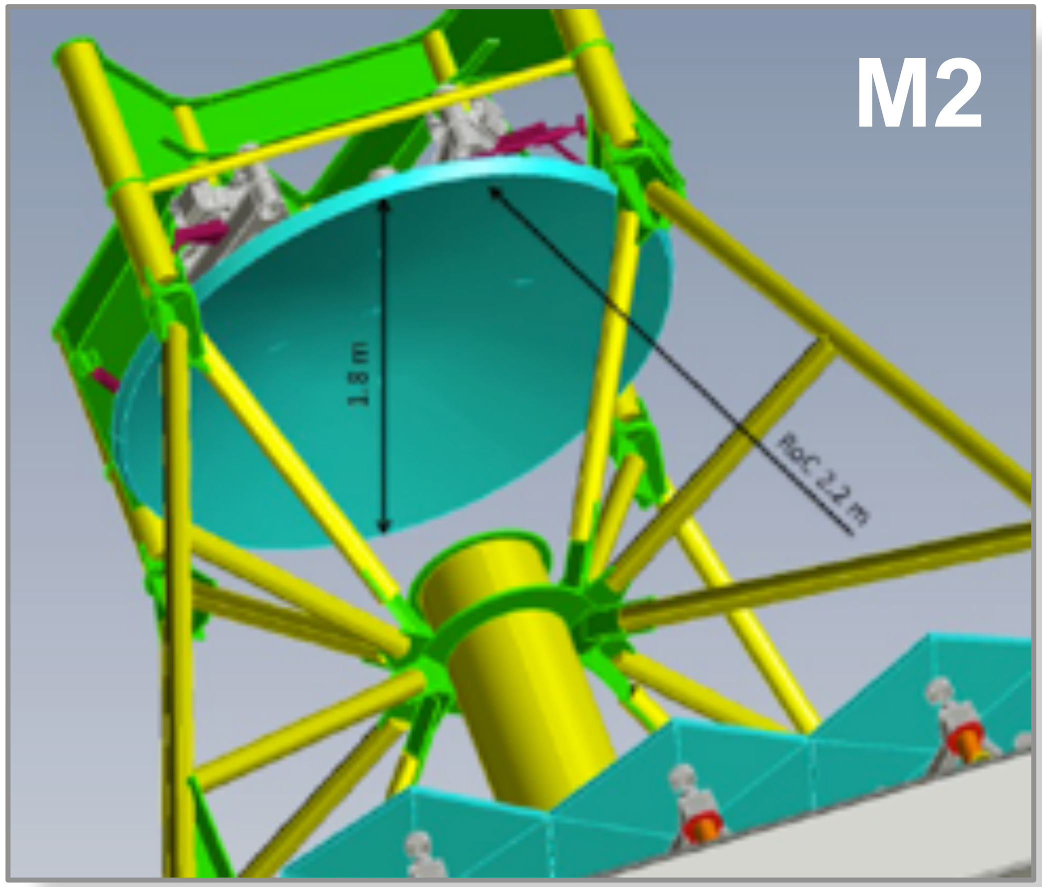


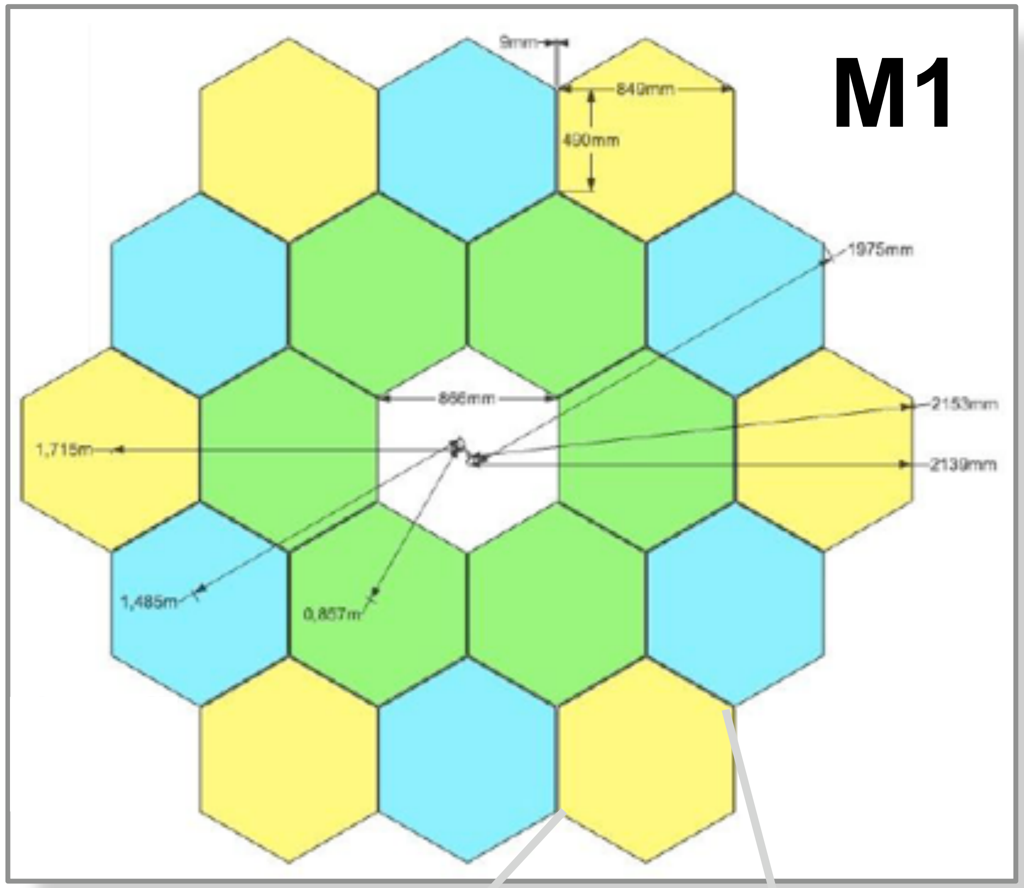


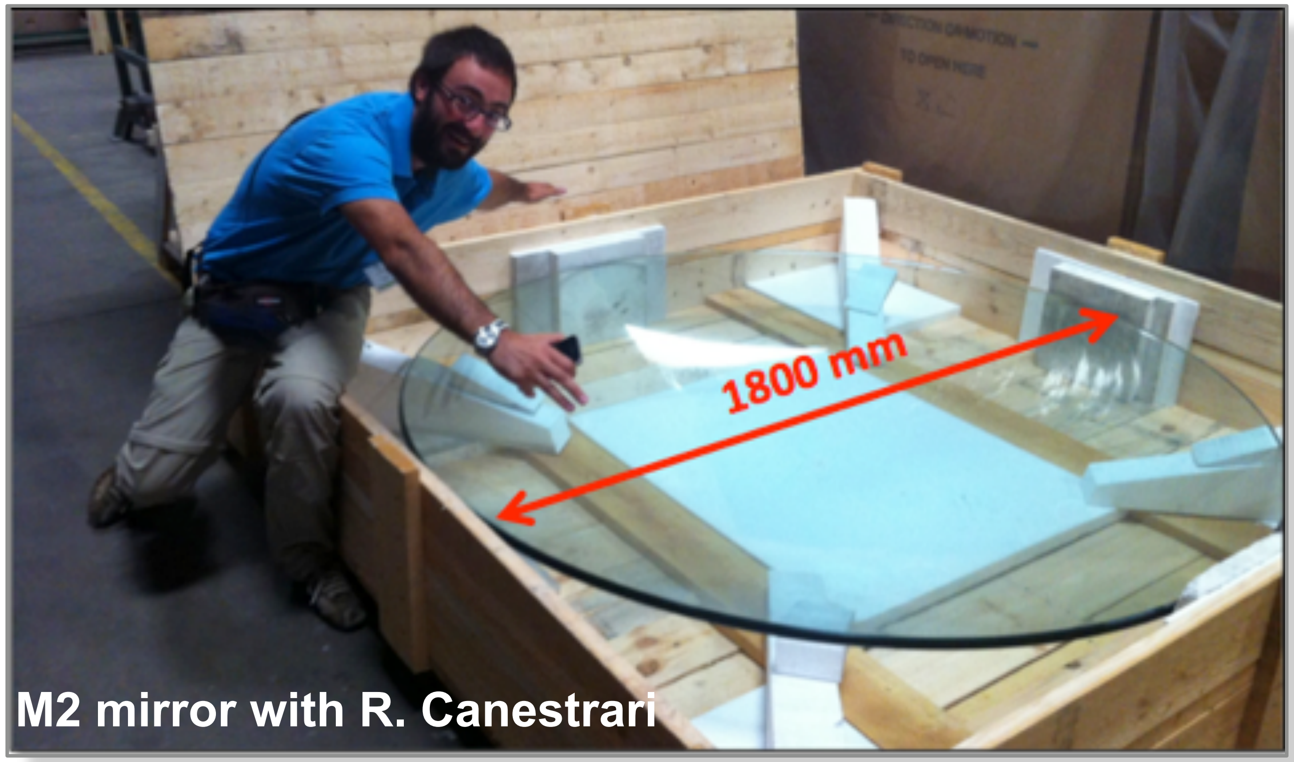
Take-away numbers

Logical pixel size = 6.2mm x 6.2mm
Number of pixels = 1984
Field of view = 9.6° (RoC = 1m)
Weight ~ 50kg
FFE ASIC = CITIROC [signal shaper]
Photo-sensors = SiPMs (S11828-3344M, other sensors under test for the mini-array)

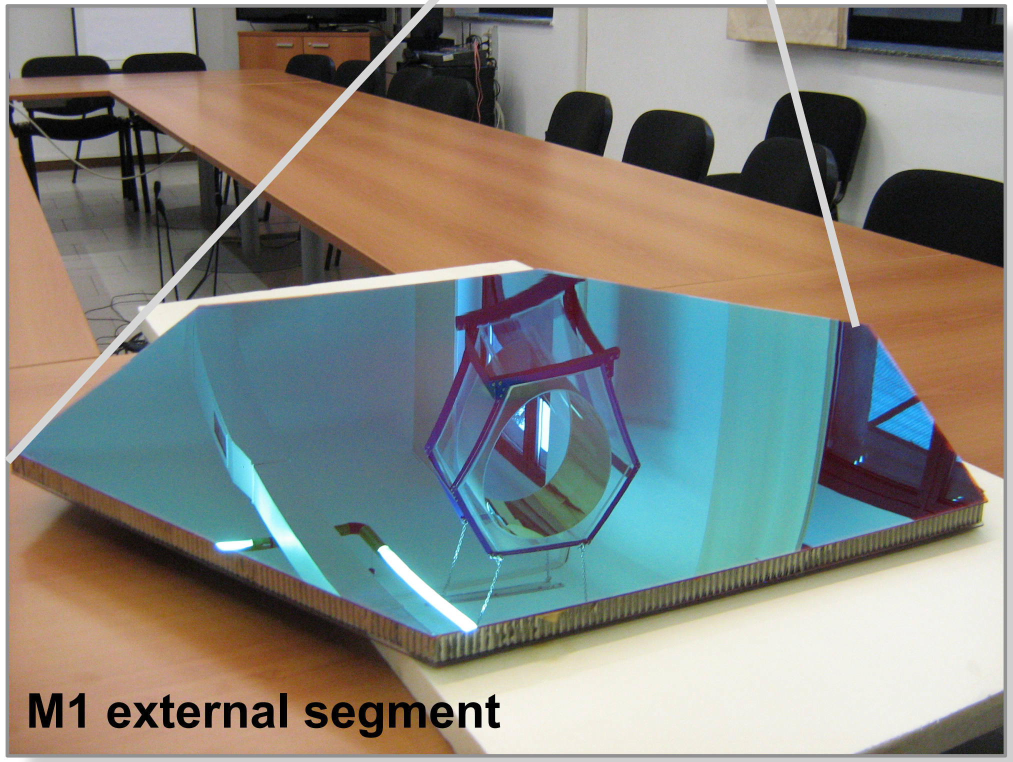
Mirrors







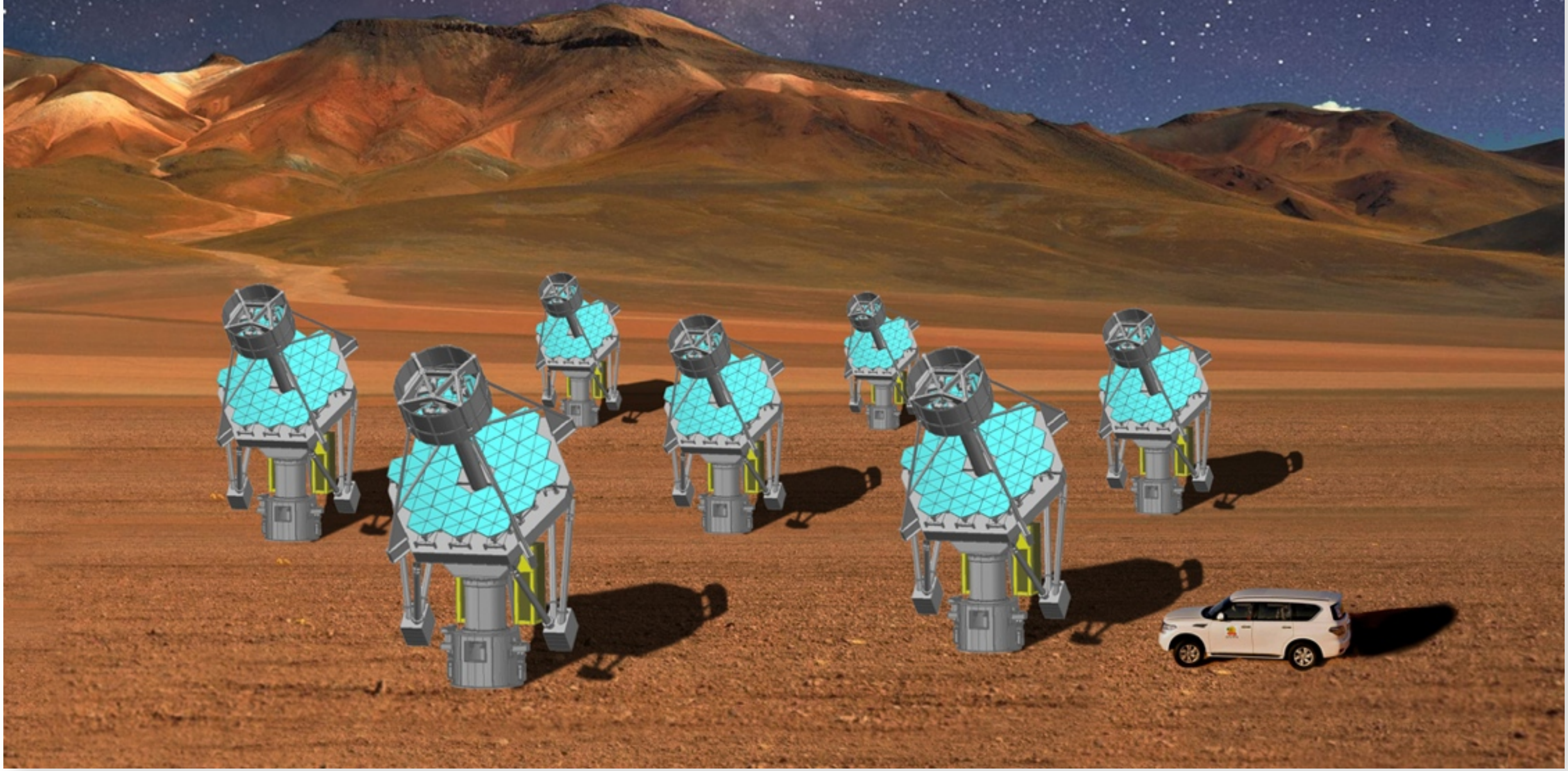
M2 mirror with R. Canestrari


M1 external segment

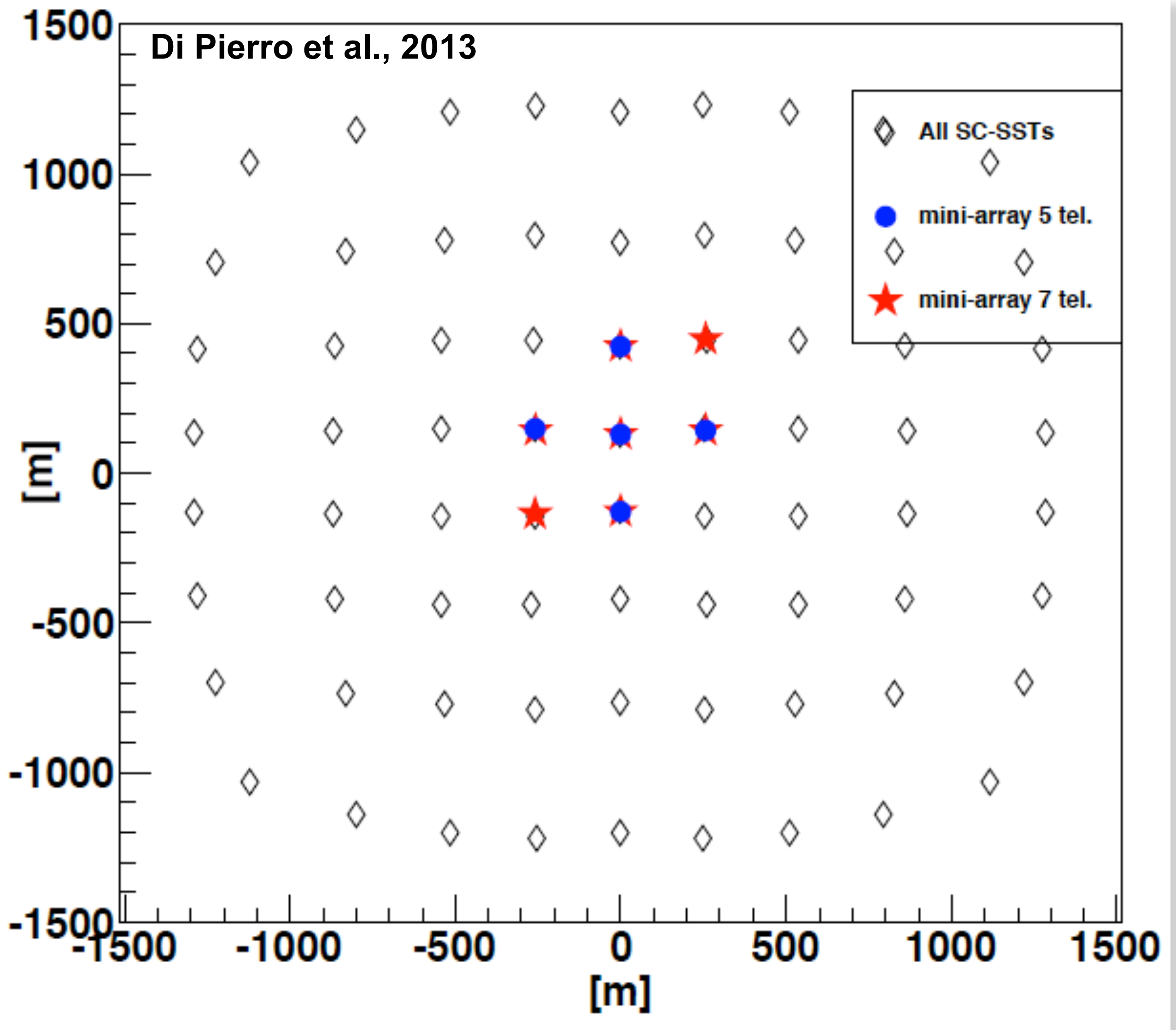
The ASTRI/CTA mini-array

Led by the Italian National Institute for Astrophysics (3 units)
supported by the ASTRI and TeChe.it projects

Additional contributions from
Universidade de São Paulo, Brazil (3 units)
North-West University, Potchefstroom, South Africa (1 unit)



The ASTRI/CTA mini-array



Limiting flux

- comparable or slightly better than H.E.S.S. above a few TeV for an array composed of 7 telescopes

Angular resolution

- a few (4-5) arcmin

Energy resolution

- of the order of 10-15 %

The ASTRI/CTA mini-array

The ASTRI/CTA SST-2M mini-array can verify some array properties:

✦ **Check of the trigger algorithms**
- Preliminary MC simulations show that a typical event will trigger a number O(5-7) of the whole CTA-SSTs sub-array.

✦ **Check of the wide field-of-view performance**
- by detecting VHE showers with the core at a distance up to 500m

✦ **Compare the mini-array performance with the Monte Carlo expectations**
- by means of deep observations of the Crab

✦ **Do the first CTA precursor science**
- by means of a few solid detections during the first year

The ASTRI/CTA mini-array science cases

✦ **Supernova Remnants**
- SNRs
- Pevatrons
- SNRs interacting with molecular clouds

✦ **PWNe**

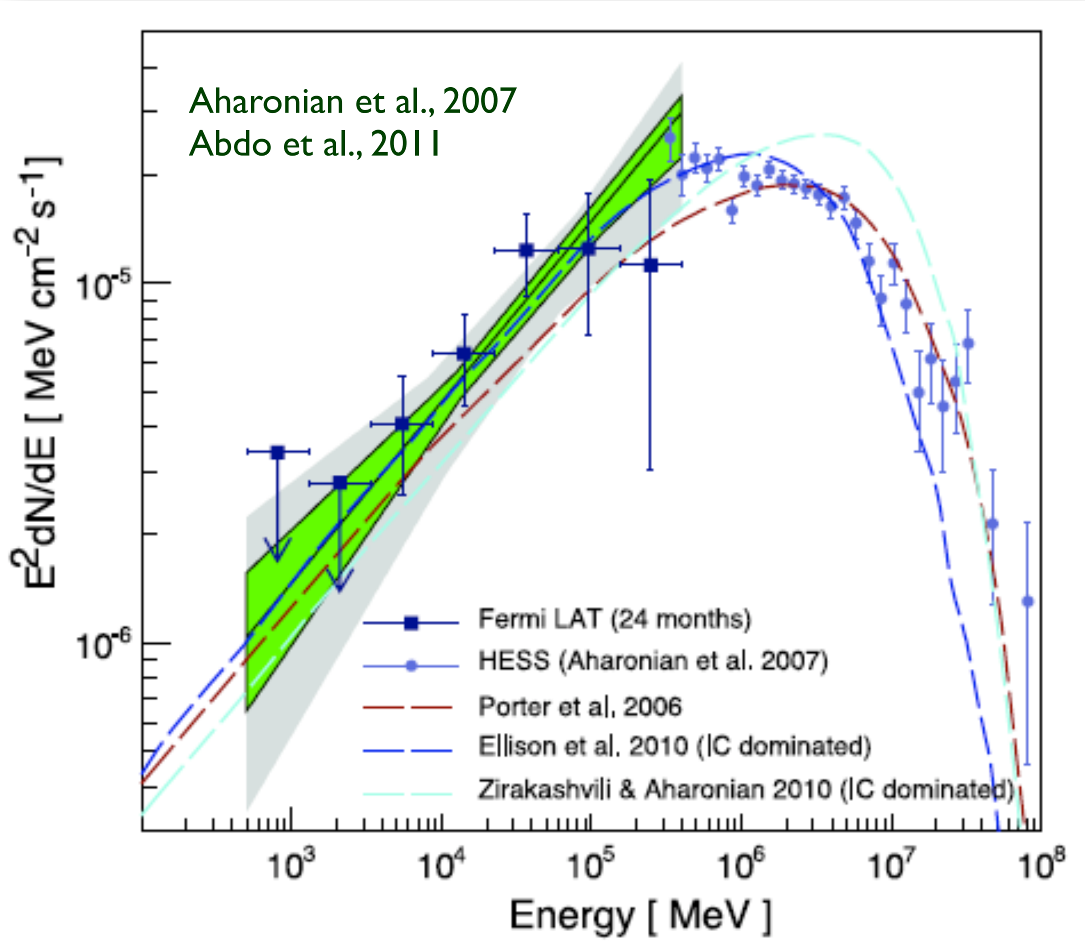
✦ **Gamma-ray binaries**

✦ **Extreme BL Lacs**
- Synchrotron peak > 1 keV
- Inverse Compton peak > 1 TeV

✦ **Less-beamed AGNs**
- Radio-galaxies
- Starburst galaxies

We will provide just a couple of examples

The ASTRI/CTA mini-array science cases



RX J1713.7−3946: young shell-like SNR

Fermi/LAT (24 months)
H.E.S.S. (combined 63 hours)

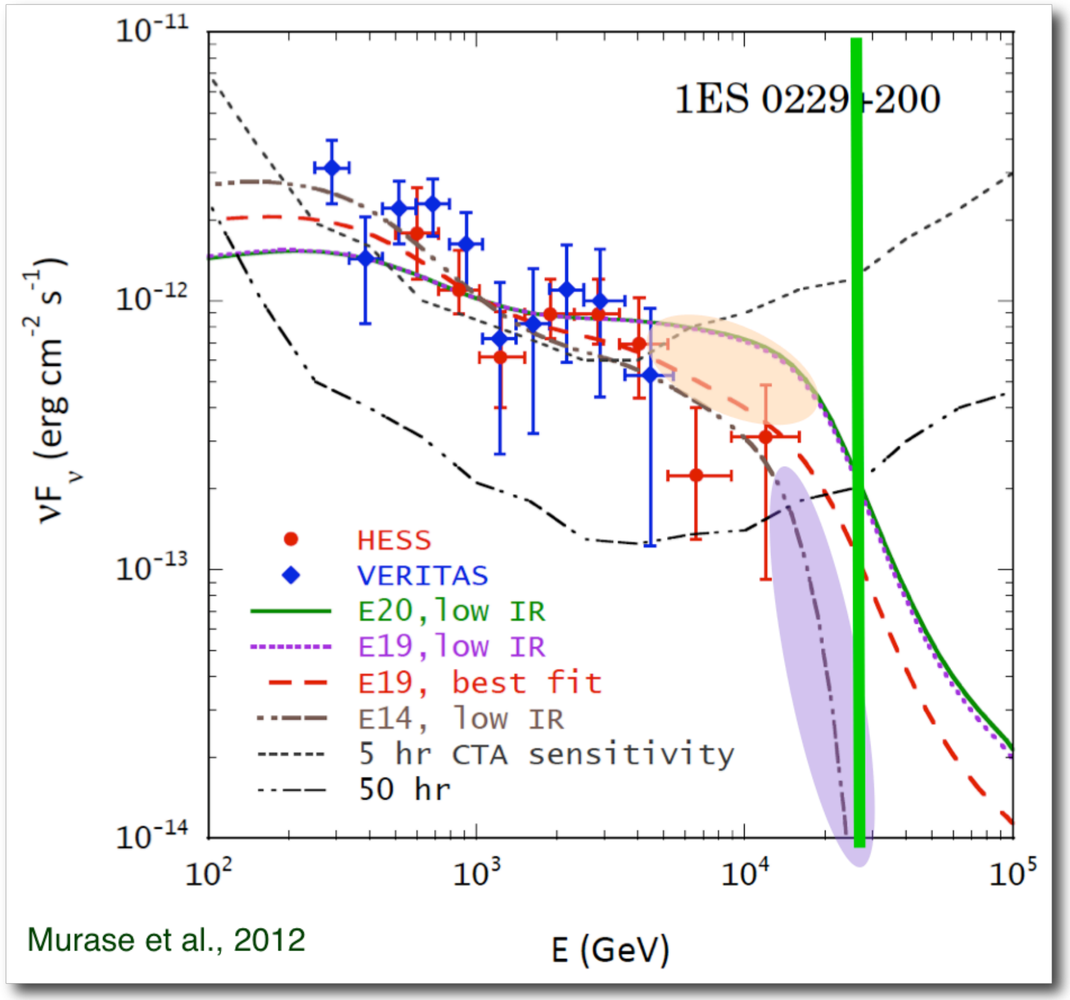
Significant emission (4.8σ) E>30 TeV.

Broadband SED suggests a leptonic scenario (but see Gabici & Aharonian 2014).

The improved and uniform sensitivity within a few degrees and the comparable angular resolution of the ASTRI/CTA mini-array at E>10 TeV w.r.t. the current IACTs could allow us:

- to investigate the VHE emission in the different regions of this source, studying their spectra;
- to extend the current SED well above a few tens of TeV, searching for possible spectral cut-offs.

The ASTRI/CTA mini-array science cases

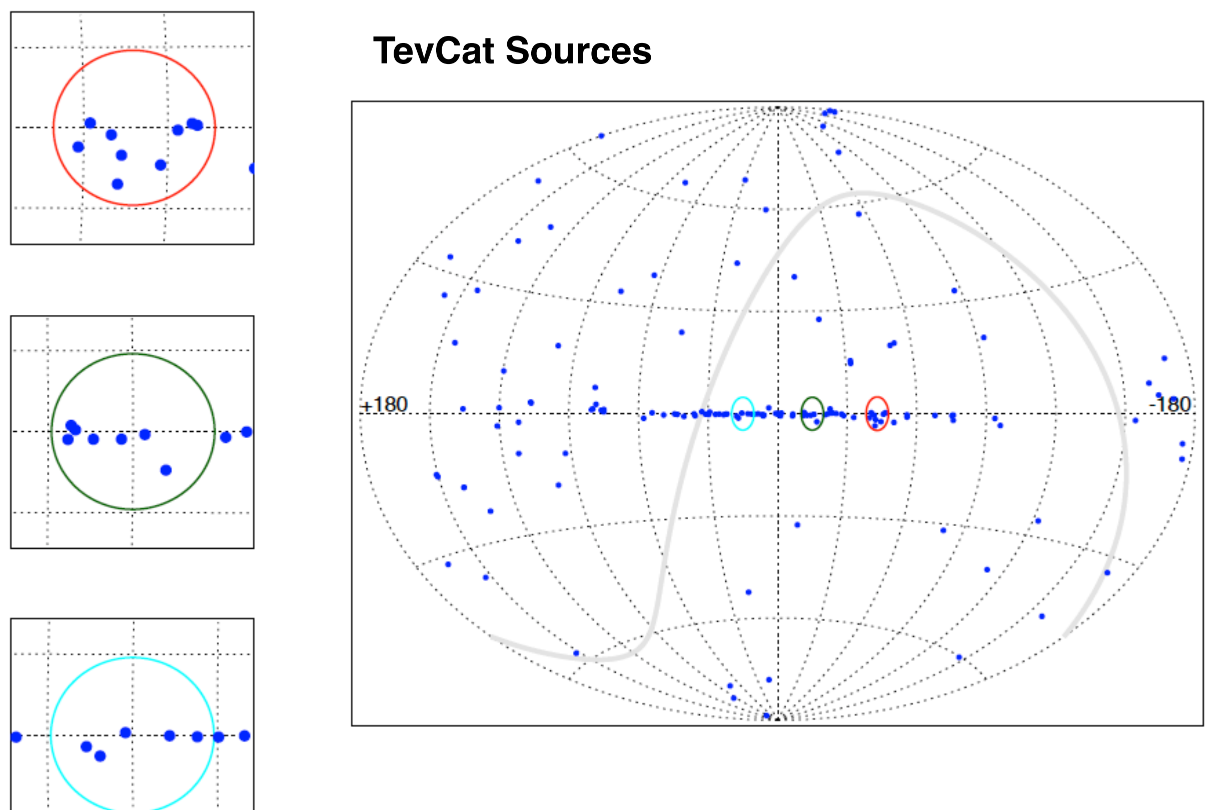


1ES 0229+200 E-HBL SED can be fit by both the γ-ray-induced cascade and proton-induced cascade emissions.

Because of the uncertainty in EBL models, it is not easy to distinguish between the two possibilities at ~1-10 TeV energies.

- At higher energies, however, UHECR-induced cascade emission becomes harder than γ-ray-induced cascade emission.
- A detection of >25 TeV γ-rays from 1ES 0229+200 is only consistent with an hadronic γ-ray emission.

The wide field of view



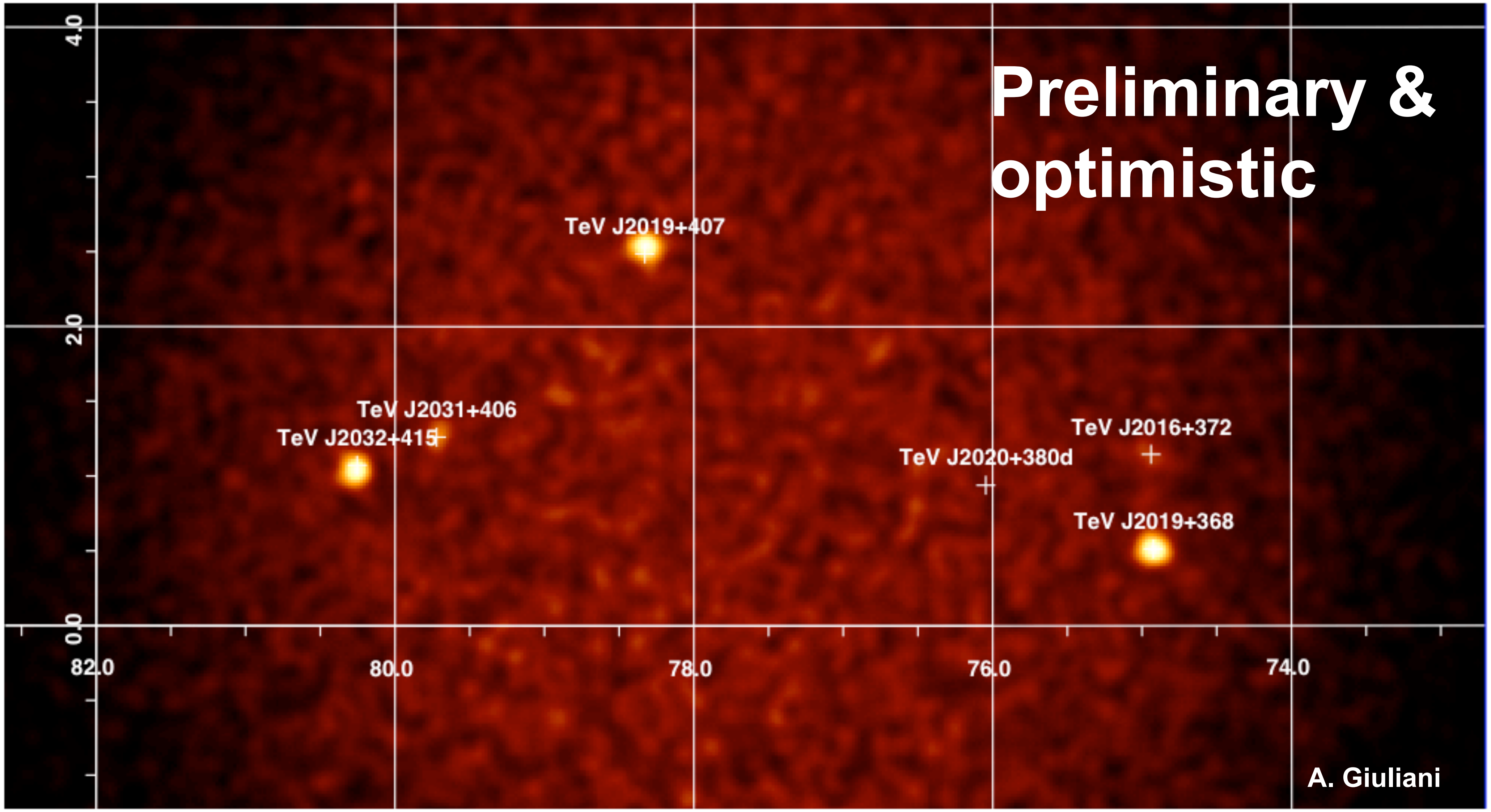
Vercellone et al., 2013

The ASTRI/CTA mini-array will have a larger field of view w.r.t. the current IACT ones.

Although the actual sensitivity will substantially drop for off-axis sources, a few targets can be monitored simultaneously.

- Close (angular distance < 3°) and bright (about 10^{-12} erg cm^{-2} s^{-1} above a few TeV) sources can be observed pointing in a "smart" direction:
  - HESS J1825-137 & LS 5039
  - Vela-X & Vela Junior
  - RX J1713.7-3946 & HESS J1718-385.
- Detections of serendipitous strong flares (a few Crab units) from hard spectrum sources will be possible as well.

Preliminary simulations



- ✦ Preliminary ASTRI/CTA mini-array simulation of the Cygnus region (similar regions also in the southern hemisphere).
- ✦ Net observing time of 150 hours.
- ✦ Energy greater than 3 TeV.
- ✦ Source parameters from the ASDC TeGeV Catalog.

Synergies - IACTs

"Given the similar sensitivities, how to compare with H.E.S.S. ?"

- We extend our sensitivity up to 100 TeV and beyond, a never-explored energy range by IACTs.
- CTA requires that at about 3^{o} off-axis the sensitivity should be not less than half of the on-axis one. Therefore, we will have a better sensitivity at the edge of very extended sources (e.g. RX J 1713.7-3946), investigating VHE emission at the very edges, spectral properties in different region of the source.
- We are free to choose just a few targets and devote to them very long exposures.

Sinergies - EAS

"Given the similar energy range, how to compare with EAS ?"

- The lower imaging energy threshold of current and future EAS (~100 GeV) and the wider energy range of the ASTRI/CTA mini-array (beyond 100 TeV) will allow us a direct comparison of scientific data (spectra, light-curves, integral fluxes) of those sources which could be monitored simultaneously (e.g., Crab Nebula, MKN 421 [at high ZA], MGRO J1908+06).

- The region near the Galactic Center will be accessible by both the ASTRI/CTA mini-array and future EAS. Thanks to the wide field of view of the ASTRI/CTA mini-array (9^{o} in diameter) a large portion of the sky will be investigated simultaneously.

- The high-energy boundary of both EAS and the ASTRI/CTA mini-array will allow us to study the VHE (E>10 TeV) emission from extended source such as SNRs and PWN, and to investigate the presence of spectral cut-offs.

Summary

- **CTA will be a 10-fold improvement in sensitivity** for VHE studies.
- **The ASTRI SST-2M prototype**, inaugurated on September 24th 2014 during the CTA Consortium Meeting in Sicily, will perform the first Crab observations with a Schwarzchild-Couder telescope equipped with SiPMs in 2015.
- **The ASTRI/CTA mini-array** will constitute a *seed* for the whole CTA array, allowing us to investigate innovative technological solutions.
- **CTA precursor early science** performed by means of ASTRI/CTA mini-array observations of a few selected targets will allow us to obtain several solid detections during the first year.
- **Excellent synergies** with ground- (e.g., HAWC, LHAASO, HiSCORE, TIBET ASγ) and space-based (e.g. *Fermi*, *Swift*) observatories from 2016 and beyond.


http://www.brera.inaf.it/astri/
Credit: R. Canestrari