The ASTRI* Program

Stefano Vercellone (INAF/IASF Palermo)
on behalf of the ASTRI Collaboration
Part 1
The ASTRI SST-2M Prototype

Part 2
The ASTRI Mini-array
Part 1

The ASTRI SST-2M Prototype

Part 2

The ASTRI Mini-array
The ASTRI Program

CTA sensitivity

M. Martinez, Zeuthen 2010

- Improved angular resolution source id. & morphology
- Improved energy resolution cutoffs & spectral features
- Large FoV (6-8 deg) extended sources, survey
- Multiple observation modes

Exploring the cutoff regime of cosmic accelerators

Population studies, extended sources, variability, precision TeV astronomy

Hi-z AGN, GRBs, pulsars, dark matter
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€).
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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 cm³) 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°
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The ASTRI Prototype Mirrors

Secondary mirror (M2)
Monolithic
Supporting structure may allocate sectors
3 actuators: tip-tilt and piston for alignment and focusing purposes

Primary mirror (M1)
18 hexagonal shaped mirrors (11.2 m²)
850 mm face-to-face, 1 m diagonal
3 types of segments
2 actuators + 1 fixed point: tip-tilt corrections for alignment purposes
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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.
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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
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)
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The ASTRI Prototype Camera

1 ASTRI Focal Surface
37 PDMs
FoV diameter = 9.6°

Size imposed by the manufacturer

1 Photon Detection Module (PDM) = 4x4 Units

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

0.17° Logical pixel
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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

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

Mosaic of four PDM with mounted three matrix of SiPM 4x4
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, L1a, L1b,...)
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

Fully operative INAF Observatory
High-speed internet connection
Mechanical & Electronics Labs

ASTRI SST-2M Prototype

61cm Dome
91cm Dome
Domes
Guests House, Offices and Labs
Main entrance

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The ASTRI SST-2M Prototype Site
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 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.
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.
Part 1
The ASTRI SST-2M Prototype

Part 2
The ASTRI Mini-array
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.
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
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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)

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

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

PRELIMINARY → TO BE UPDATED
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Southern Hemisphere

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

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

Hinton & Vercellone, 2012
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Southern Hemisphere

- **Vela X** → $30 \times 10^{-12}$
- **RX J1713** → $10$
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- **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 $\sim 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ at 10 TeV

A few observable in pairs with $\sim 9$ degree FoV.

Opportunity for **serendipitous detections** of new hard spectrum Galactic sources.
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**Prime targets (South)**

- 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)

**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

**VERY PRELIMINARY :::: TO BE UPDATED**

Hinton & Vercellone, 2012
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Next Steps

Courtesy of R. Canestrari

HMMMM....
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Next Steps

SST & MST

Courtesy of R. Canestrari
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.
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.
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References:

Vercellone et al., Proc. 4th Fermi Symp, ArXiv:1303.2024
Canestrari et al., Procs. 32nd ICRC, Vol.9, 115 (2011)

Thanks!

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

10 Papers will be presented here

ICRC 2013
2-9 July 2013 – Rio de Janeiro – Brazil
THE ASTROPARTICLE PHYSICS CONFERENCE