Auxiliary instruments for the absolute calibration of the ASTRI SST-2M prototype for the Cherenkov Telescope Array

Maria Maccarone, Alberto Segreto, Osvaldo Catalano, Giovanni La Rosa, Francesco Russo, et al.

Maria Concetta Maccarone, Alberto Segreto, Osvaldo Catalano, Giovanni La Rosa, Francesco Russo, Giuseppe Sottile, Carmelo Gargano, Benedetto Biondo, Mauro Fiorini, Salvatore Incorvaia, Giorgio Toso, "Auxiliary instruments for the absolute calibration of the ASTRI SST-2M prototype for the Cherenkov Telescope Array," Proc. SPIE 9149, Observatory Operations: Strategies, Processes, and Systems V, 914918 (6 August 2014); doi: 10.1117/12.2054526

Event: SPIE Astronomical Telescopes + Instrumentation, 2014, Montréal, Quebec, Canada

Auxiliary instruments for the absolute calibration of the ASTRI SST-2M prototype for the Cherenkov Telescope Array

Maria Concetta Maccarone[*a], Alberto Segreto[a], Osvaldo Catalano[a], Giovanni La Rosa[a], Francesco Russo[a], Giuseppe Sottile[a], Carmelo Gargano[a], Benedetto Biondo[a], Mauro Fiorini[b], Salvatore Incorvaia[b], Giorgio Toso[b], for the ASTRI Collaboration[c] and the CTA Consortium[d]

[a] INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo, Via U. La Malfa 153, 90146 Palermo, Italy
[b] INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica di Milano, Via E. Bassini 15, 20133 Milano, Italy
[c] http://www.brera.inaf.it/astri
[d] http://www.cta-observatory.org

ABSTRACT

ASTRI SST-2M is the end-to-end prototype telescope under development by the Italian National Institute of Astrophysics, INAF, proposed for the investigation of the highest-energy gamma-ray band in the framework of the Cherenkov Telescope Array, CTA. The ASTRI SST-2M prototype will be installed in Italy at the INAF station located at Serra La Nave on Mount Etna during Fall 2014. The calibration and scientific validation phase will start soon after.

The calibration of a Cherenkov telescope includes several items and tools. The ASTRI SST- 2M camera is equipped with an internal fiber illumination system that allows to perform the relative calibration through monitoring of gain and efficiency variations of each pixel. The absolute calibration of the overall system, including optics, will take advantage from auxiliary instrumentation, namely UVscope and UVSiPM, two small-aperture multi-pixels photon detectors NIST-calibrated in lab. During commissioning phase, to measure the main features of ASTRI SST-2M, as its overall spectral response, the main telescope and the auxiliary UVscope-UVSiPM will be illuminated simultaneously by a spatially uniform flux generated by a ground-based light source, named Illuminator, placed at a distance of few hundreds meters. Periodically, during clear nights, the flux profiles of a reference star tracked simultaneously by ASTRI SST-2M and UVscope-UVSiPM will allow to evaluate the total atmospheric attenuation and the absolute calibration constant of the ASTRI SST-2M prototype.

In this contribution we describe the auxiliary UVscope-UVSiPM and Illuminator sub-system together with an overview of the end-to-end calibration procedure foreseen for the ASTRI SST-2M telescope prototype.

Keywords: Image Atmospheric Cherenkov Telescope, ASTRI, CTA, small size telescope, absolute calibration, auxiliary systems, UVscope, Illuminator

1. INTRODUCTION

ASTRI ("Astrofisica con Specchi a Tecnologia Replicante Italiana") is a *flagship project* of the Italian Ministry of Education, University and Research, led by the Italian National Institute of Astrophysics, INAF. The ASTRI project is strictly linked to the development of the ambitious Cherenkov Telescope Array, CTA[1,2]. A first goal of the ASTRI project is the realization of an end-to-end prototype, compliant with the CTA requirements, of the small-size class of telescopes in a dual-mirror configuration (SST-2M) devoted to the investigation of the energy range from a few TeV up to 100 TeV[3]. As a second step, the ASTRI project is addressed to the implementation of an ASTRI/CTA mini-array[4,5] composed of seven SST-2M telescopes; placed at the final CTA Southern Site, the mini-array could represent a precursor of the whole CTA Observatory.

Several challenging but innovative technological solutions characterize the ASTRI concept: the telescope adopts a dual-mirror Schwarschild-Couder optical design and the camera at the focal plane is composed by a matrix of Silicon photo-multipliers managed by an appropriate front-end electronics. The end-to-end prototype, named ASTRI SST-2M, is

[*] Cettina.Maccarone@iasf-palermo.inaf.it, http://www.iasf-palermo.inaf.it/~maccarone/

Observatory Operations: Strategies, Processes, and Systems V, edited by Alison B. Peck,
Chris R. Benn, Robert L. Seaman, Proc. of SPIE Vol. 9149, 914918 · © 2014 SPIE
CCC code: 0277-786X/14/$18 · doi: 10.1117/12.2054526

currently under construction and it will include all the necessary instrumentation for its absolute calibration as well as the software for data acquisition, archiving and analysis system. The ASTRI SST-2M telescope will be installed in Italy at the INAF "M.C. Fracastoro" observing station (1735 m a.s.l) located in Serra La Nave[6] during Fall 2014; the calibration phase will start soon after, followed by scientific observations of the Crab Nebula, MRK 421 and MRK 501.

The technological solutions adopted for ASTRI SST-2M need to be verified through a careful calibration phase. The camera relative calibration will be achieved monitoring its gain and efficiency nightly variations making use of an innovative illumination system[7]. The absolute calibration of the overall system, including optics, will be performed with the support of auxiliary instrumentation external to the telescope and basically composed by a calibrated illumination system, hereafter named Illuminator, and two small-aperture photon detectors, called UVscope and UVSiPM, whose sensors are NIST[1]-calibrated in lab.

After a brief overview of the ASTRI SST-2M telescope, we describe the auxiliary UVscope-UVSiPM and Illuminator sub-system and the end-to-end calibration strategy that will be followed in Serra La Nave. The same strategy will be applied, with few hardware modifications, for the absolute calibration of the ASTRI/CTA mini-array telescopes.

2. ASTRI SST-2M TELESCOPE IN BRIEF

A detailed description of the ASTRI SST-2M telescope is provided in bibliography[3] and references therein as well as in the various ASTRI contributions in these proceedings. Here we briefly report those features which are of main interest in the end-to-end calibration context and in the definition of the hardware configuration of the auxiliary instrumentation.

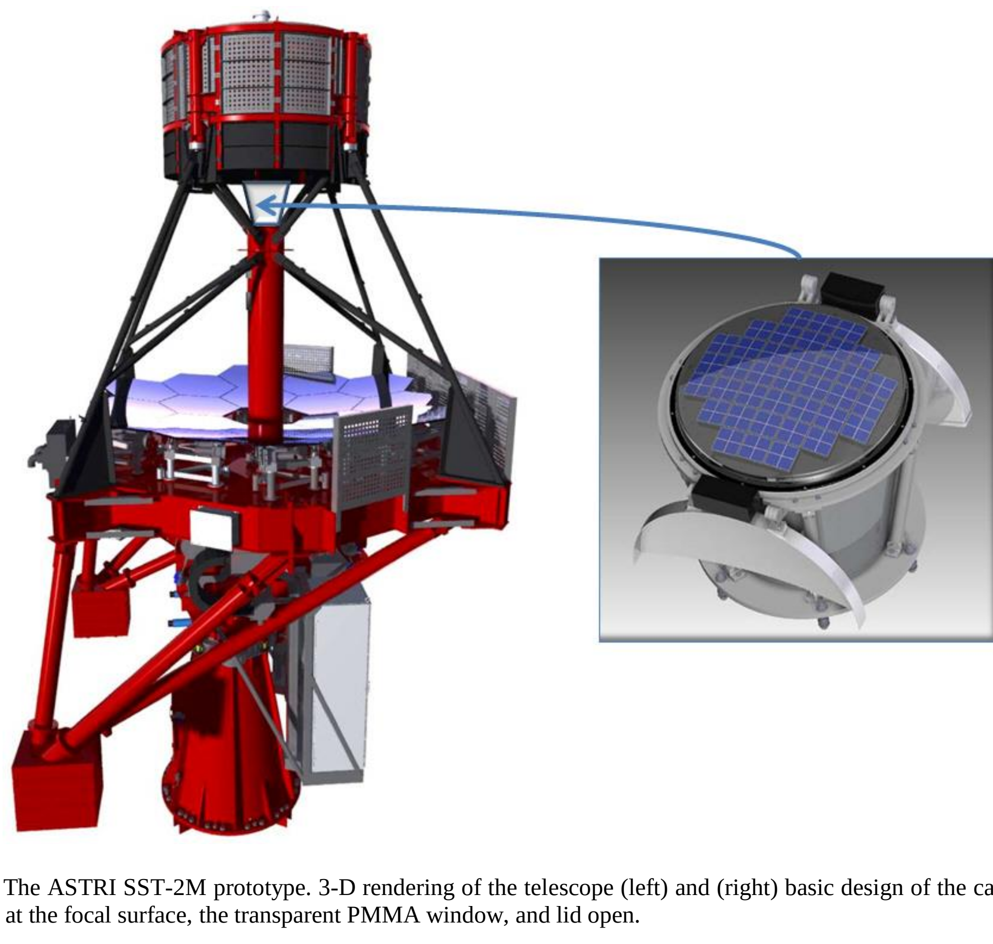

Figure 1. The ASTRI SST-2M prototype. 3-D rendering of the telescope (left) and (right) basic design of the camera with its PDMs at the focal surface, the transparent PMMA window, and lid open.

[1] National Institute of Standards and Technology

Figure 1, left side, shows a 3-D rendering drawing of the ASTRI SST-2M prototype currently under construction. The telescope mount is of the alt-azimuthal type. The optical design is based on a dual-mirror Schwarzschild-Couder configuration: the primary mirror (4.3 m diameter) is segmented in 18 facets; the secondary mirror (1.8 m diameter) is a monolithic one with a radius of curvature of 2.2 m. The focal length of 2.15 m and the F-number f/0.5 correspond to a full field-of-view of 9.6° with angular resolution of 0.17°. This optical configuration allows to design a compact and lightweight camera to be placed at the curved (1 m of radius of curvature) focal surface of the telescope.

A sketch of the ASTRI SST-2M prototype camera[7] is shown in Figure 1, right side. The camera is composed of a matrix of monolithic multipixel Silicon Photo Multipliers (SiPM) managed by a non-conventional front-end electronics. The model of the sensors forming the camera of the prototype is Hamamatsu S11828-3344M (other sensors are being tested for the ASTRI/CTA mini-array). A total of 496 SiPMs, organized in 37 Photon Detection Modules (PDM) will cover the full field-of-view of 9.6° thanks to 1984 logical pixels with a sky-projected angular size of 0.17° each, so matching the angular resolution of the optical system. To fit the curvature of the focal surface, each PDM is appropriately tilted with respect to the optical axis of the telescope. In order to protect the camera sensors from the external atmospheric environment, an optical-UV transparent, down to 300 nm, PolyMethylMethAcrylate (PMMA) window is mounted on the PDM support structure. Between the PMMA window (along its inner circumference) and the upper surface of the backbone structure of the camera, an optical fiber illuminated by a Light Emission Diode (LED) will be allocated for relative calibration purposes. Eventually, the ASTRI SST-2M camera is equipped with a two-petals light-tight lid in order to prevent sunlight exposure.

3. AUXILIARY INSTRUMENTATION FOR THE END-TO-END CALIBRATION

The calibration of a Cherenkov telescope, as well as in many other fields, is a complex task that can include several separated and redundant procedures which in turn can require different tools, both hardware and software. The final aim is to obtain the calibration coefficients necessary to correctly reduce and 'calibrate' the observational scientific data. Moreover, a clear distinction must be done between relative and absolute calibration.

The relative calibration of the ASTRI SST-2M camera[7] is performed through built-in specific procedures embedded in its FPGA (Field Programmable Gate Array) and making use of the inner fiber optic system which allow to obtain a camera flat-field; it will be then possible to achieve the camera relative calibration, monitoring the pixel gain and efficiency variations (see [7] for details).

The absolute end-to-end calibration of the ASTRI SST-2M overall system, including optics, will take advantage from auxiliary instrumentation external to the telescope. At the Serra La Nave site, where the prototype will be installed, the auxiliary sub-system will be composed by two small-aperture NIST-calibrated photon detectors, UVscope and UVSiPM, and a portable illumination system, named Illuminator, all of them remotely controlled.

3.1 UVscope

UVscope[8] is a stand-alone portable multi-pixels photon detector developed at INAF-IASF-Palermo to support experimental activities in the high-energy astrophysics and cosmic rays field. The instrument is designed to measure, in Single Photon Counting (SPC) mode[9], light flux in the wavelengths range 300-650 nm. The use of UVscope has been successfully validated in the past years[10] observing the sky at different wavelengths through a motorized filter wheel with a set of UV filters. The simple and effective design makes it suitable both for on-field and lab measurements. Its flexibility allows using it as a support instrument for monitoring sky transparency and measure the diffuse Night Sky Background (NSB) as well as for non-invasive cross-calibration of large cameras of fluorescence and Cherenkov telescopes. In the ASTRI framework, the primary application of UVscope is devoted to the absolute end-to-end calibration of the ASTRI SST-2M prototype .

The UVscope instrument designed for the ASTRI SST-2M calibration is a simplified version of what used in the past. It basically consists of: a photon detector with its front-end and data acquisition electronics units working in SPC mode, and a disk emulator interface card for computer connection; a pinhole collimator to regulate the angular aperture of the detector and to protect its sensitive area against stray light; a filter; a motorized diaphragm to open/close the entrance pupil during night/day; an air-ventilation system; the power unit.

The UVscope light sensor is a Multi Anode Photo Multiplier Tube (MAPMT) manufactured by Hamamatsu, series R7600-03-M64, which allows moderate imaging properties with its 64 anodes arranged in a matrix of 8×8 pixels. The MAPMT has a bi-alkali photocathode deposited on an UV-glass window; this ensures a good Quantum Efficiency (QE) for wavelengths longer than 300 nm with a peak of more than 20% at 420 nm. The device has a metal channel dynode structure with 12 stages providing a gain of the order of $3x10^5$ at 800 V. The MAPMT is coupled, in DC mode, to the 64-channels Front-End Electronic (FEE) unit working in SPC mode which allows to measure the number of output pulses from the photo-sensors corresponding to the number of incident photons with a double pulse time resolution of 10 ns. In the SPC mode, the electronics noise is kept negligible: small pixel size (as in the R7600-03-M64 case) is required to minimize the probability of photoelectrons pile-up within intervals shorter than the given acquisition time unit. The FEE unit amplifies and discriminates the signals coming from the MAPMT anodes; a programmable threshold allows to both equalize Input Offset Voltage differences among the discriminators and gain differences among the 64 anodes. The MAPMT is connected through a socket to the FEE which is in turn coupled, through a backplane, to the programmable Data Acquisition (DAQ) and handling unit. Signals detected by the FEE are sampled by DAQ (internally managed by a reprogrammable FPGA) and then processed according to suitable and flexible user algorithms. The data read-out is achieved by an external computer connected through an interface card which emulates a disk unit. The MAPMT sensitive unit, the FEE and DAQ units are grouped together in the UVscope acquisition module as shown in Figure 2.

The absolute spectral response of the MAPMT is measured in lab[8] by comparison with a NIST calibrated photodiode.

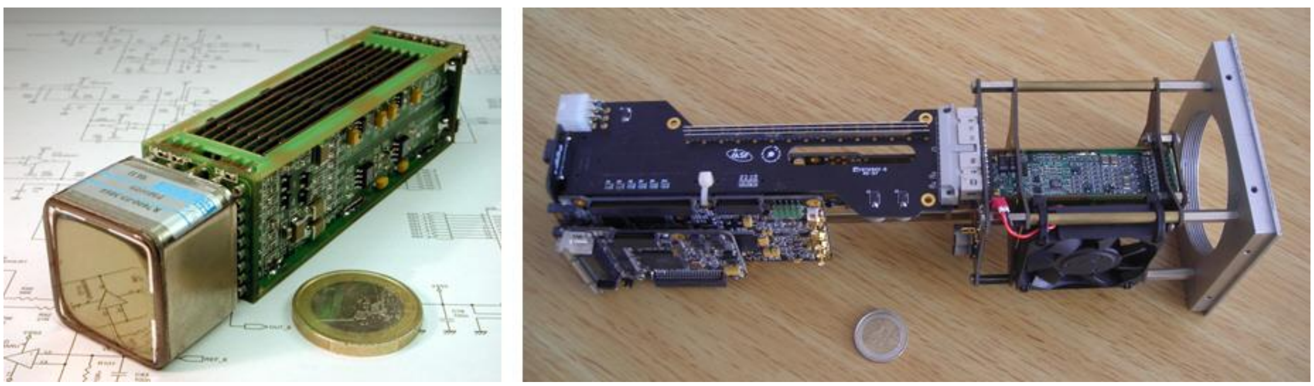

Figure 2. Inside the UVscope acquisition module. The FEE unit connected to the MAPMT (left), the DAQ and FEE connected through the backplane (right).

The data acquired with UVscope are stored in ASCII files. The header maintains general information as date and start time of the acquisition, electronics setup, integration time window. Then the acquired data are registered, pixel by pixel, as number of counts in a pre-selected integration time, accompanied by the value of the temperature of the electronic boards inside the instrument box and the high voltage detected between anode and last dynode. A set of home-made software programs and utilities completes the system, both for the quick-look and data analysis; among them, the conversion from count rate to photon flux, based on the information obtained during the NIST-calibration in lab of the MAPMT sensor.

The apparatus requires a collimator, whose length can vary on the basis of the measurements to be performed and the desired field-of-view (FoV); the configuration adopted for the ASTRI SST-2M calibration at Serra La Nave is defined in a next paragraph.

3.2 UVSiPM

Based on the successful experience with UVscope, a similar instrument, named UVSiPM[11] has been designed and implemented at the INAF-IASF-Palermo to be strictly used in the prototypal phase of the ASTRI project. The UVSiPM light sensor is in fact a Silicon PhotoMultiplier of the same model Hamamatsu S11828-3344M used in the camera at the focal plane of the ASTRI SST-2M telescope prototype.

As its progenitor, UVSiPM is a stand-alone portable multi-pixel photon detector instrument; its inner structure is shown in Figure 3. The operative wavelength range is 300-900 nm. The instrument is designed around a single multipixel (4×4 pixels) SiPM sensor whose spectral response is characterized in lab. The SiPM sensor is coupled to an electronic chain working in SPC mode, capable of 10 ns double pulse resolution. The SPC is the best operation mode for SiPM sensors characterization. Normally the Photon Detection Efficiency (PDE) of a SiPM is measured from the mean value of the output current, when the device is exposed to a known photons flux. In this way, pulses coming from crosstalk or after-pulses are included in the total PDE leading to an overestimate of the real efficiency. Operating in SPC mode makes it possible to eliminate the contribution given by crosstalk and after-pulses. The electronics that performs the SPC is composed by a pre-amplifier coupled to the SiPM, followed by a shaping circuit that gives the derivative of the signal cutting out the negative undershoot (zero-pole cancellation); eventually an inverting amplifier drives a comparator whose threshold is set through a 12-bit DAC. An FPGA is in charge to manage the pulse counting and the house-keepings collection. The electronic chain follows the same logic adopted for UVscope and the data read-out is achieved by an external computer connected through an interface card which emulates a disk unit. The data acquired with UVSiPM are stored in ASCII files with a structure coherent with that used in UVscope; this allowed us to adopt, with small modifications, the home-made software programs and utilities already developed, both for the quick-look and data analysis. Eventually, the UVSiPM unit needs to be thermal stabilized and it requires a collimator to regulate the angular aperture of the instrument.

The use of UVSiPM is currently foreseen only at Serra La Nave where the ASTRI SST-2M prototype will be installed.

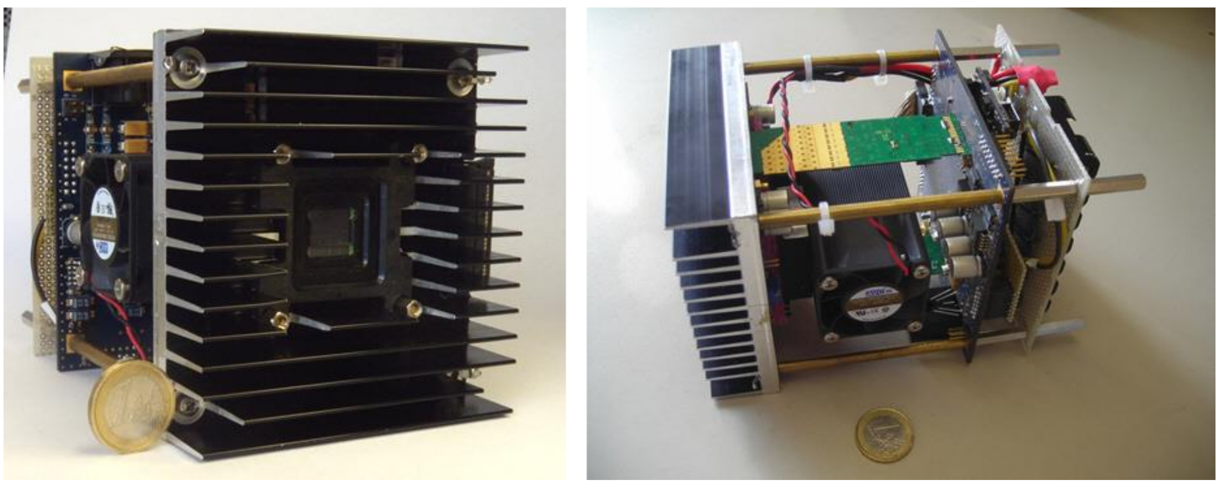

Figure 3. Inside the UVSiPM acquisition module. Front view with the SiPM sensor at the center (left); lateral view with the electronics components connected through the backplane (right).

3.3 Configuration of UVscope-UVSiPM at Serra La Nave

Although UVscope and UVSiPM are designed to be portable systems that can be allocated on independent telescope mounts, at the Serra La Nave site the two instruments will be mounted directly onto the support structure of the main telescope primary mirror, as schematized in Figure 4, co-aligned with the ASTRI SST-2M camera axis, so to observe along the same direction of the main telescope. Each auxiliary will be enclosed in a separate box, thermal stabilized by an air-to-air thermo-electric ventilation unit (Peltier); through external tubes the air flux will be piped away from the ASTRI SST-2M primary mirror. Each box is equipped with a motorized diaphragm to open/close the entrance pupil during night/day. Both UVscope and UVSiPM will be configured with an entrance pupil and a collimator in order to obtain the same field-of-view of the main ASTRI SST-2M telescope (9.6° full FoV). A filter will be placed inside the collimator of each auxiliary to make easier the comparison of their spectral response; in this way the Night Sky Background will be measured in the same wavelength band correcting only for the different quantum efficiency. Taking into account the simulation results of the ASTRI SST-2M overall spectral response, a calibrated Johnson-Bessel (John-B) filter has been chosen. The center wavelength of the John-B filter is at ~437.7 nm with FWHM coordinates 391 nm and 484 nm around it; the peak transmission is ~73%.

The operation of each auxiliary, UVscope and UVSiPM, is remotely controlled and integrated in the ASTRI SST-2M software system[12]. Data are stored in a dedicated archive, together with the related housekeeping information, to be processed and used in the ASTRI SST-2M data reduction and calibration pipeline[13].

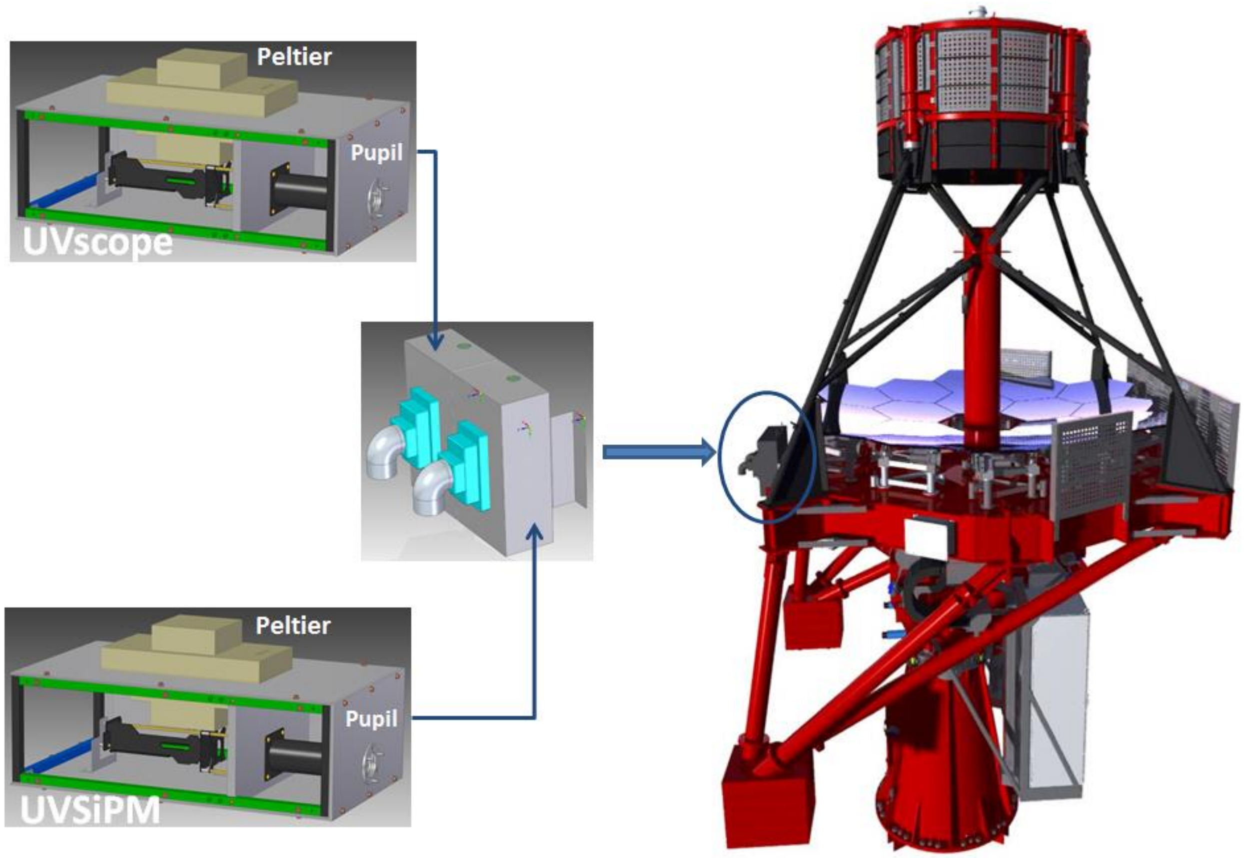

Figure 4. Sketch of the UVscope and UVSiPM allocation onto the external board of the ASTRI SST-2M primary mirror.

3.4 Illuminator

The conceptual design of the Illuminator comes from the INAF-IASF-Palermo Institute and its implementation is now a collaborative effort with the INAF-IASF-Milano Institute in the framework of the ASTRI Project.

The Illuminator[14] is a portable system designed to provide, from a certain distance, an uniform illumination of the ASTRI SST-2M telescope aperture; moreover, thanks to its flexible design, the Illuminator can be easily adapted for use on any other telescope. The Illuminator is constituted by two main blocks: a Light Generator and Control Box, and a Projection Box. The Light Generator Box can contain different kinds of light source, both narrow-band (LED, Laser Diode) or wide-band (Halogen lamp) with a monochromator. Light wavelength and intensity selection are performed by a local computer, remotely controlled via WiFi. The light generated will be delivered by means of a fiber optic cable to the Projection Box whose optical system will produce a spatially uniform beam toward the telescope aperture. The absolute intensity of the output beam will be monitored by a NIST-calibrated photodiode whose signal will be delivered to the Control Box.

The portability of the system is guaranteed both from the mechanical and electrical point of view. The Light Generation and Control part is enclosed into a heavy duty waterproof case (86 cm × 56 cm × 43 cm) of the GT-Line Explorer with self-oiling free running wheels and lifting handles. The necessary power supply (230 VAC) can be provided both by a 220 VAC cable (when an external power source is available, as in lab) and by an internal Lithium battery pack plus

DC/AC inverter (to be used on field). Moreover, the Control Box is provided with a series of electrical interfaces which allow to connect the internal instruments to external systems without opening the case. The illumination system is installed inside a lightweight aluminum case (32 cm × 55 cm × 18 cm), the so-called Projection Box, that can be allocated on any common (manual or motorized) telescope mount for pointing. Some features of the overall system are shown in Figure 5 and 6.

At the Serra La Nave site, due to the particular orography and presence of trees, the Illuminator will be placed on a small hill at ~700 m distance from the telescope. At this distance the light from the Illuminator will not perfectly be focused, but the light will anyway be concentrated on about 2×2 camera pixels of the ASTRI SST-2M telescope.

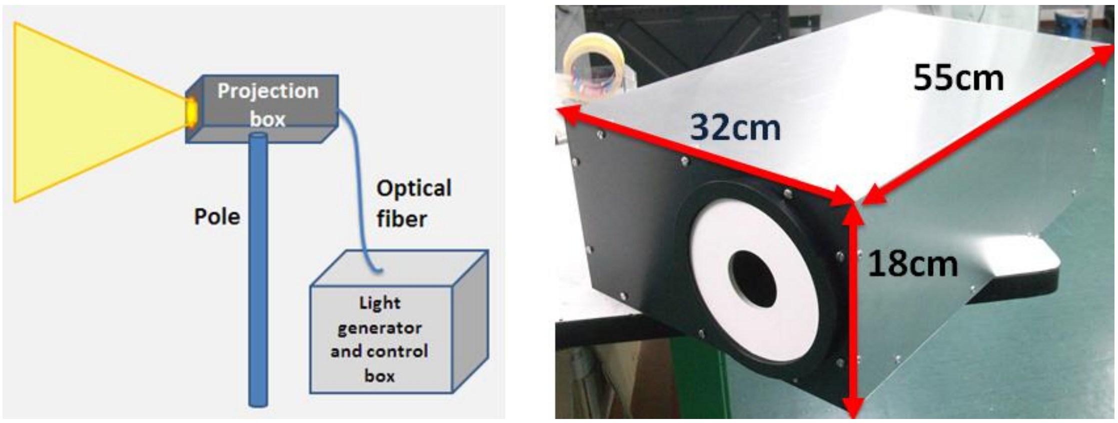

Figure 5. Illuminator. Basic design of the overall system (left) and aluminum case of the Projection Box (right).

Figure 6. Illuminator. Light generator and control box. Exterior and interior views in top and bottom panels, respectively.

4. THE ASTRI END-TO-END CALIBRATION STRATEGY

Let us present very briefly the procedure[15] which allows the absolute calibration of the ASTRI SST-2M telescope as it will be fulfilled at Serra La Nave where both UVscope and UVSiPM, as previously described, will operate.

Different procedures and tasks are foreseen, basically making use of the portable auxiliary instrumentation and of the observation of the night sky (diffuse emission and reference stars). First of all, given the broad wavelength range covered by the Cherenkov signal, an in-situ measurement of the overall telescope spectral response (including mirrors reflectivity and detector efficiency) with a fine spectral resolution is mandatory.

- To measure the telescope end-to-end spectral response, ASTRI SST-2M and UVscope-UVSiPM will be illuminated simultaneously by the spatially uniform and monochromatic source at several wavelengths (Illuminator). The measurements obtained by the auxiliary UVscope-UVSiPM allow to determine the illuminating flux at the ASTRI ST-2M telescope aperture and thus completely eliminate the uncertainty due to the atmospheric transmission and propagation; by changing the telescope pointing with respect to the illumination device, the response of the telescope w.r.t. off-axis angles (flat-field) will be measured.
- Once the telescope spectral response has been determined, it becomes possible to compute the camera signal induced by stars whose spectral shape is known with a fine spectral resolution. During clear nights, both ASTRI SST-2M telescope and UVscope-UVSiPM will simultaneously observe a reference star (as Vega) in tracking mode, following it at different elevation angles. Being the auxiliary UVscope-UVSiPM absolutely calibrated devices, the three flux profiles so obtained as a function of the star elevation will allow to determine the total atmospheric attenuation and the absolute calibration constant for the ASTRI SST-2M telescope. Periodic observations of the reference star will allow to verify and monitor with very high accuracy the long term evolution of the telescope calibration.
- To verify the telescope response to Cherenkov like pulses, a fast pulsed (few ns) light source will be connected to the Illuminator. Given its small aperture, the auxiliary UVscope-UVSiPM, working in single photon counting mode, will provide an accurate calibration of the illuminating flux at the ASTRI SST-2M telescope aperture.
- The calibration evolution on short time scale (due to e.g. nightly pixel gain evolution) will be monitored by the inner camera calibration system based on the optical fiber. A further check of the calibration status (including mirror reflectivity) along the observing period will be done by comparing the NSB measurements in correspondent sky directions with the auxiliary UVscope-UVSiPM thus verifying, in real time and without any interference with the data acquisition, the flat field calibration of the field-of-view of the main ASTRI SST-2M telescope.

The ASTRI SST-2M end-to-end calibration strategy, making use of UVscope and Illuminator, will be applied to the absolute calibration of the future ASTRI/CTA mini-array telescopes that will be deployed at the final CTA Southern site.

In particular, the calibration among telescopes will be obtained by comparing simultaneous measurements of a bright star using UVscope as reference. Main advantage of this strategy is that all telescopes are illuminated by the same star flux, independently from their position and atmospheric attenuation

Moreover, the ASTRI strategy is currently under study for the absolute calibration of any telescope in the CTA array[16].

5. CONCLUSION

The ASTRI SST-2M telescope absolute calibration is based on the “end to end” measurement strategy applied to all the calibration issues: spectral response, absolute calibration, timing response, point spread function, …

Key points are the use of small-aperture auxiliary telescopes (UVscope, UVSiPM) and observation of the night sky (diffuse emission and reference stars) and of ground artificial (pulsed or continuous) sources (Illuminator). The Illuminator will be used during the telescope commissioning phase to measure the actual spectral, temporal, and spatial response. Results will be used to obtain, for each camera pixel, the corrective factor for the flat fielding of sky images. After absolute calibration, the telescope response will be continuously monitored by means of the inner fiber camera calibration system and by observation of the diffuse night sky background light. The absolute calibration will be periodically verified by observation of reference stars and, in case of evidence of degradation of the telescope response, the end-to-end calibration with the Illuminator will be repeated.

The auxiliary instrumentation has been here described in the configuration that will be adopted at Serra La Nave where the ASTRI SST-2M prototype will be installed during Fall 2014. Only few modifications are foreseen to implement it for the absolute calibration of the future ASTRI/CTA mini-array telescopes.

ACKNOWLEDGMENTS

This work was partially supported by the ASTRI “Flagship Project" financed by the Italian Ministry of Education, University, and Research (MIUR) and led by the Italian National Institute of Astrophysics (INAF). We also acknowledge partial support by the MIUR Bando PRIN 2009. We gratefully acknowledge support from the agencies and organizations listed in this page: http://www.cta-observatory.org/?q=node/22.

REFERENCES

[1] Acharya, B.S., et al., “Introducing the CTA concept”, Astroparticle Physics 43, 3–18 (2013).

[2] Actis, M. et al., “Design concepts for the Cherenkov Telescope Array CTA: an advanced facility for ground-based high-energy gamma-ray astronomy”, Experimental Astronomy 32(3) 193-316 (2011).

[3] Pareschi, G., et al., “The dual-mirror Small Size Telescope for the Cherenkov Telescope Array”, Proc. 33rd ICRC, ArXiv:1307.4962 (2013).

[4] Vercellone,S., “Small-size telescope array for gamma-ray astronomy”, SPIE Newsroom, <spie.org/x2418.xml>, DOI: 10.1117/2.1201405.005488, (14 May 2014).

[5] Pareschi, G., et al., “The ASTRI/CTA mini-array of Small Size Telescopes Dual-Mirror: a first seed for the Cherenkov Telescope Array”, Proc. SPIE Astronomical Telescopes + Instrumentation 2014, Paper#9145-22, *these proceedings*, (2014).

[6] Maccarone, M.C., Leto, G., Bruno, P., Fiorini, M., Grillo, A., Segreto, A., Stringhetti, L., “The Site of the ASTRI SST-2M Telescope Prototype”, Proc. 33rd ICRC, ArXiv: 1307.5139 (2013).

[7] Catalano, O., et al. “The camera of the ASTRI SST-2M prototype for the Cherenkov Telescope Array", Proc. SPIE Astronomical Telescopes + Instrumentation 2014, Paper#9147-12, *these proceedings*, (2014).

[8] Maccarone, M.C., Catalano, O., Giarrusso, S., La Rosa, G., Segreto, A., Agnetta, G., Biondo, B., Mangano, A., Russo, F., Billotta. S., “Performance and applications of the UVscope instrument”, NIM-A, Nuclear Instrum. & Methods - Section A, 659(1), 569-578 (2011).

[9] Catalano, O., Maccarone, M.C., Sacco, B., “Single photon counting approach for imaging atmospheric Cherenkov telescopes”, Astroparticle Physics 29(2) 104-116 (2008).

[10] Segreto, A., for the Pierre Auger Collaboration, “Night sky background measurements by the Pierre Auger Fluorescence Detectors and comparison with simultaneous data from the UVscope instrument”, Proc. 32nd ICRC, id_0661 (2011).

[11] Sottile, G., et al., “UVSiPM: a light detector instrument based on a SiPM sensor working in single photon counting”, Proc. 9th SciNeGHE, Nuclear Physics B: Proc. Suppl. 239-240, 258-261, ArXiv:1303.2699 (2013).

[12] Tosti, G., et al., “The ASTRI/CTA mini-array software system”, Proc. SPIE Astronomical Telescopes + Instrumentation 2014, Paper#9152-2, *these proceedings*, (2014).

[13] Antonelli, L.A., et al., “The ASTRI Project within the Cherenkov Telescope Array. Data reduction and archiving”, Proc. SPIE Astronomical Telescopes + Instrumentation 2014, Paper#9152-94, *these proceedings*, (2014).

[14] Segreto, A., “Portable illumination system for the end-to-end calibration of ASTRI SST-2M telescope prototype”, 2nd CTA-CCF Meeting, Munich, Germany, 4-5 April 2014, (2014).

[15] Maccarone, M.C., Segreto, A., “The ASTRI SST-2M end-to-end calibration strategy”, 1st CTA Calibration Review, Heidelberg, Germany, 6-7 March 2014, (2014).

[16] Gaug, M., Berge, D., Daniel, M., Doro, M., Förster, A., Hofmann, W., Maccarone, M.C., Parsons, D., de los Reyes, R., van Eldik, C., “Calibration strategies for the Cherenkov Telescope Array”, Proc. SPIE Astronomical Telescopes + Instrumentation 2014, Paper#9149-45, *these proceedings*, (2014).