THE SMALL SIZE TELESCOPE PROJECTS FOR CHERENKOV TELESCOPE ARRAY

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SST-1M, Krakow since Nov. 2013

ASTRI, Serra la Nave, Mt. Etna, Sicily since Aug. 2014

GCT, Observatoire Paris, Meudon, since Apr. 2015

3 designs with associated prototypes proposed for the CTA array:

• A Davies-Cotton telescope with single mirror - SST-1M

• Two dual-mirror Schwarzschild-Couder telescopes: SST-2M ASTRI (Astrofisica con Specchi a Tecnologia Replicante Italiana) and GCT (Gamma-ray Cherenkov Telescope)
REQUIRED AND GOAL SENSITIVITY

- Energy range 3-300 TeV
- SST sensitivity ≥ 2 (1.5) x full array required sensitivity above 10 (100) TeV
- Goal collection area of the Southern array > 7 km² for E > 100 TeV
  - 70 telescopes at distances of the order of 220-250 m
CTA SST SCIENCE

Entire plane surveyed to < 3.8 mCrab - several 100’s of sources

Planed surveys: Galactic plane, LMC, 1/4 of the sky

**1 mCrab = 5.07 x 10^{-13} photons cm^{-2} s^{-1} above 125 GeV**

| Experiment   | Hemisphere | Galactic Plane Coverage       | Energy (GeV) | Sensitivity (mCrab) |
|--------------|------------|-------------------------------|--------------|---------------------|
| H.E.S.S.-I   | S          | $-70^\circ < l < 60^\circ, |b| < 2^\circ$ | $\sim 300$         | 10 – 30             |
| VERITAS      | N          | $67^\circ < l < 83^\circ, |1^\circ < b < 4^\circ$ | $\sim 300$         | 20 – 30             |
| ARGO-YBJ     | N          | Northern Sky                 | $> 300$      | 240 – 1000          |
| HEGRA        | N          | $-2^\circ < l < 85^\circ, |b| < 1^\circ$ | $> 600$             | 150 – 250           |
| Milagro      | N          | Northern Sky                 | $> 10,000$   | 300 – 500           |

**Present/future Surveys**

| Observatory | Hemisphere | Energy Threshold | Angular Resolution | Pt. Source Sensitivity |
|------------|------------|------------------|--------------------|------------------------|
| CTA        | N, S       | 125 GeV          | $\sim 0.10^\circ$ at 300 GeV | 2 – 4 mCrab           |
| HAWC       | N          | 2 TeV            | 0.30°              | 20 mCrab               |
FLUX SENSITIVITY

Single Telescope
High Energy ➔ High photon density ➔ Small
Dish area ~ 4m
Array of Telescopes
Shower footprint ➔ Array collection area ➔
number of telescopes ~ 70

In 50 h, the spectrum above 60 TeV of a PeVatron flux (~10^{-12} ph/TeV/cm^2/s, spectral index -2, -2.2) will be reconstructed with an error <10%
First IACTs with FoV of > 8°

Requirement: 0.05° (0.025°) at 1 TeV (100 TeV)
OPTICAL DESIGN AND OPTICAL PSF

Davies-Cotton optics.

Schwarzschild-Couder optics.

Optical PSF from ray-tracing

ASTRI realistic & ideal

SST-1M realistic & ideal

GCT ideal
SILICON-BASED CAMERAS

- New technology in Imaging Cherenkov Astronomy, envisaged by E. Lorenz and applied by FACT;
- robust and stable;
- self calibrating;
- cost-effective;
- high photo-detection efficiency, low x-talk sensors, dark noise few 10 kHz;
- 30% additional exposure thanks to operation with high Moon;
- photosensor sizes available are suitable for SST cameras of diameter of 40-90 cm with 1300-2200 channels;
- uniform and mass producible.

FACT can operate at full Moon with 5 GHz/pixel Night Sky Background (NSB);
# THE SST-1M PROJECT

## Optical Properties

| Property                                      | Value       |
|-----------------------------------------------|-------------|
| Focal Length                                  | 5.6 m       |
| Dish Diameter                                 | 4 m         |
| Mirror Effective area (after shadowing & mirror TX) | 6.47 m²    |
| Mirror Facet Size (flat-to-flat)              | 780 mm      |
| RMS of optical time spread                   | <0.24 ns    |

## Mechanical Properties

| Property            | Value       |
|---------------------|-------------|
| Elevation range     | -16-97°     |
| Azimuth range       | ±280°       |
| Drive speed (min, max) | 1-4000 rpm |
| Oscillation Modes   | 2.8/3.4/3.8 Hz |
| Total Weight        | 8.6 tons    |

J. Niemiec et al., telescope structure, GA-IN-370  
K. Seweryn et al., optical system, GA-IN-773
CAMERA

E. Schioppa et al, PDP, GA-IN-65
P. Rajda et al., DAQ and Trigger (DigiCam), GA-IN-78
CAMERA PERFORMANCE

Charge resolution with different NSB
660 MHz = ½ moon at 5° from camera.
22 MHz: dark night
Next step is the deployment of a mini-array of 9 SST-2M and the production will contribute 21 more telescopes.

Initial operations with prototype are ongoing.
MINI-ARRAY PERFORMANCE

Simulations indicate that the mini array sensitivity will be already better than H.E.S.S. above 1 TeV
ASTRI CAMERA

Photon Detection Modules (PDM)

Auxiliary Devices

Voltage Distribution Boards

PDMs Support Structure

Thermal Control System

Back-End Electronics

Hamamatsu: Low-Crosstalk LCT1-B
THE GAMMA-RAY CHERENKOV TELESCOPE (GCT)

- Schwarzschild-Couder optics.
- Alt-Az mount.
- Designed for ease of manufacture, assembly and maintenance.
- Compact camera with full waveform readout and low cost.
- Overall width × height 5.4 m × 8 m.
- Total mass 7.8 tons.
GCT CAMERA

- 2048 pixels of size 6 × 6 mm²...7 × 7 mm² (0.15°...0.2°).
- Readout/front end trigger TARGET ASIC (1 Gs/s, 12 bits), 32 modules.
- Camera trigger via Backplane PCB/FPGA.
- Dimensions 0.35 × 0.35 × 0.5 m³.
- Mass 45 kg.
- Power 450 W.
- MAPM/SiPM versions (CHEC-M/CHEC-S) under test/construction.
- Incorporates LED calibration flasher units.
TARGET MODULE

- Samtec 40 pin connector to the backplane carrying raw data, trigger and sync signals and power
- Xilinx Spartan 6 FPGA (on reverse of PCB)
- Samtec individually shielded coaxial ribbon cables for analogue signals and preamplifier power
- Front-end buffer module consisting of 4 x 16 channel preamplifier boards
- Front-most front-end buffer PCB forming the interface to the focal plane plate
- Mechanical standoff with threaded hole for securing the TARGET module to the backplane
- High Voltage supply (12 V in, 0 - 1200 V out)
- TARGET ASIC providing 16 channels of digitisation and triggering
- Individual amplifier circuit
- High Voltage connection to the MAPM (cable secured and pins insulated during normal operation)
- MAPM (Hamamatsu H10966B)
The SST array will operate in the discovery region above 50 GeV with unprecedented sensitivity. It is extremely powerful for VHE surveys.

Multiple SST designs increase prototyping effort which is a very instructive process and essential for first implementations of new technologies (dual mirror and SiPM).

Projects will provide > 20 telescopes each to CTA.

Develop as many common systems as possible.
- Similar foundations for all SSTs
- Common HW and SW Drives
- Cameras can be interchanged between ASTRI and GCT SST-2M
- Working towards common telescope control hardware and software.

Strategy will minimize SST infrastructure and operation cost.
CTA CONSORTIUM

- 31 Countries
- 194 Institutes
- >1200 Members