Schwarzschild-Couder Telescope for the Cherenkov Telescope Array Observatory: Status and Progress

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ABSTRACT

The 9.7m aperture Schwarzschild-Couder Telescope (SCT) is being developed as an alternative advanced design of the medium-sized telescope for the Cherenkov Telescope Array Observatory (CTAO). The novel aplanatic dual-mirror optics of the SCT makes it possible to simultaneously achieve a wide 8-degree field of view and unprecedented 0.068° imaging resolution of the telescope camera, which is instrumented with 11,328 silicon photomultiplier (SiPM) detectors. The SCT project, with the goal to demonstrate capabilities of this new design, is advancing at the Fred Lawrence Whipple Observatory in Arizona, USA. The positioning and optical systems of the SCT have achieved design specifications and enabled the detection of the Crab Nebula with a statistical significance of 8.6 sigma using a partially instrumented 1,536-pixel prototype camera. An SCT camera upgrade is currently underway to fully populate it with advanced SiPMs and high-density electronics. Once completed by the end of 2025, the project is expected to verify SCT performance end-to-end and to provide the foundation for SCT subarray deployment during the enhancement phase of the CTAO construction. The sub-array of SCTs in the CTAO installation would offer improved sensitivity and unprecedented angular resolution. These technology advances would significantly boost the observatory's scientific output for detection of multi-messenger transients, mapping the morphology of gamma-ray sources with large angular extent, and conducting galactic plane sky surveys with improved limit on source confusion. This poster highlights the SCT project achievements and its transformative science-enabling potentials in the enhanced CTAO configuration.

The SCT Overview

- The SCT design is motivated by the goal of achieving the ultimate performance of the atmospheric Cherenkov light detection technology in the context of the CTAO installation.
- Compact wide 8° FoV is combined with a high-resolution camera of 11328 pixels.
- The aplanatic optical system of SCT has demonstrated design specification, which enabled the detection of the Crab Nebula at 8.6σ using a partially populated camera[1] (2.7°x 2.7°) in 2019 .
- The US-led SCT project (14 US institutes) is delivered in collaboration with institutes in Germany (3), Italy (5), Japan (1) and Mexico (1).

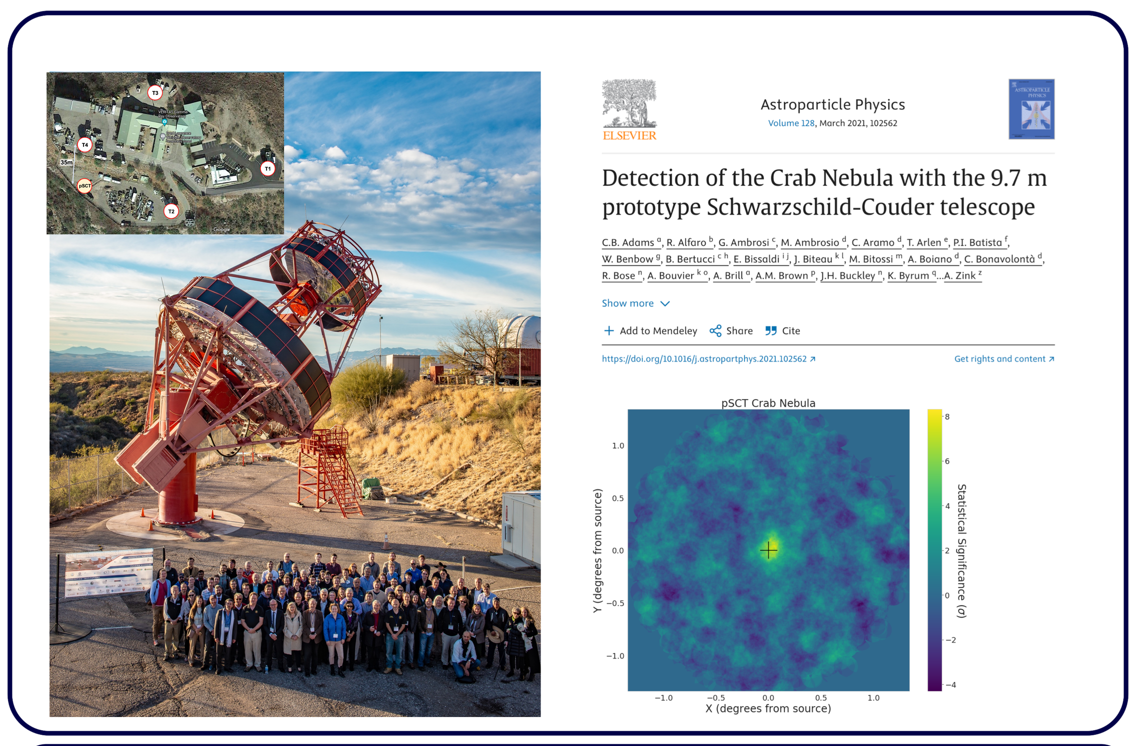

Fig. 1: The prototype SCT on-site at the Fred Lawrence Whipple Observatory (FLWO) in Arizona (left). SCT detected Crab Nebula in 2019 (right).

The SCT Optical System (OS)

- Dual-mirror aplanatic design. Fully corrects spherical and comatic aberrations.
- Field of View (FoV): 8° [78 cm diameter].
- Angular pixel size: 0.067°.
- Dec 2019, on-axis optical alignment completed at 2.6′ [2] .
- July 2022, off-axis alignment completed [3].

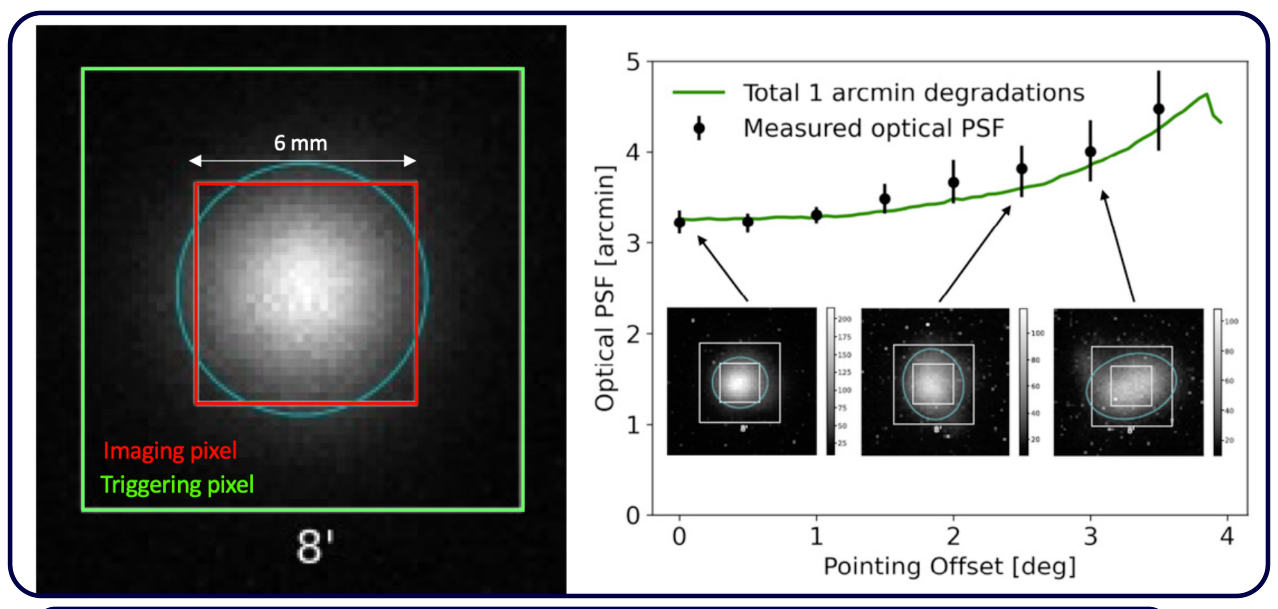

Fig. 2: Optimized on-axis PSF (left) and validation of the off-axis PSF (right).

2019 Prototype SCT Camera [4]

- Partially instrumented camera with central sector (25 modules, 1536 pixels of silicon photomultipliers (SiPMs), 2.7°x2.7°).
- Photon detectors: Hamamatsu MPPC FBK (USA)+ FBK NUV-HD3 (Italy).

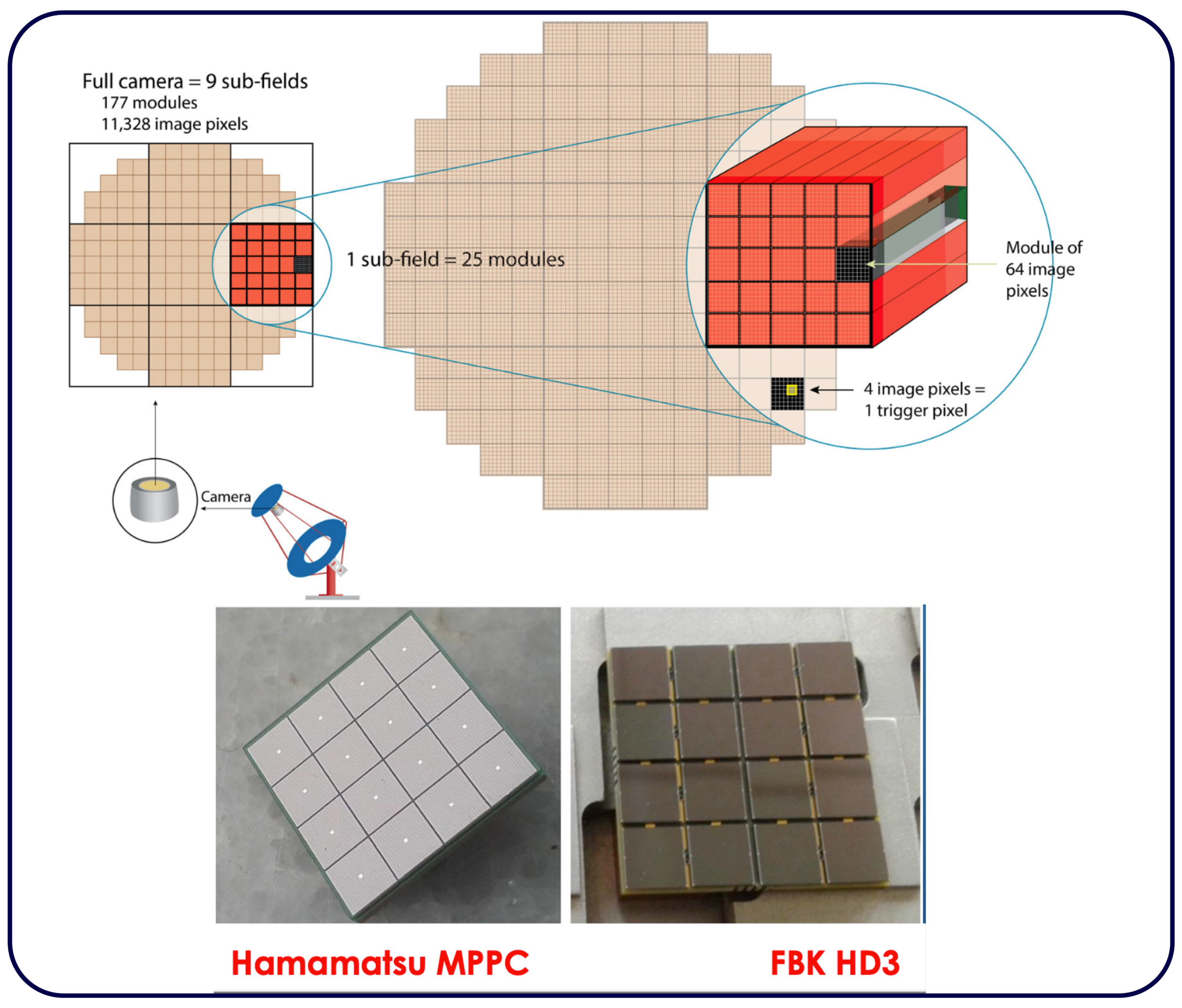

Fig. 3: SCT camera and SiPMs.

SCT Camera Upgrade (T.B.C. 2025)

- Full-scale implementation of the SCT camera (11328 pixels).
- FBK SiPMs with enhanced NUV photon detection efficiency with reduced optical cross-talk and afterpulsing.
- New front-end electronics to reduce electronic noise and dedicated pulse-shaping and preamplification ASIC (SMART).

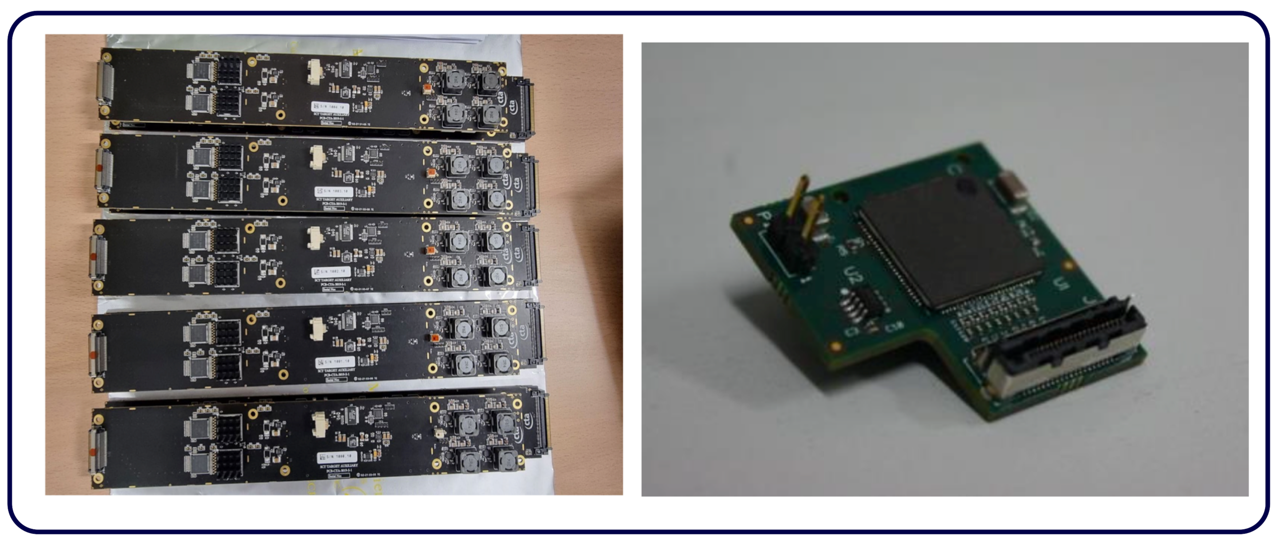

Fig. 4: front-end electronic modules (left) and SMART ASIC (right).

The SCT Mechanical and OS Upgrade

- Making an effort to move the SCT OS towards industrial procurement and fabrication.

SCT Science

- All key science projects of CTAO will benefit from the deployment of SCTs during the enhanced phase of CTAO construction.
- Examples include:
  - Galactic plane sky survey.
  - Morphology-resolved spectroscopic study of gamma-ray sources with large angular extent.
  - Multi-messenger gamma-ray transients with poorly defined initial localization (e.g. gravitational wave and astrophysical neutrino events).

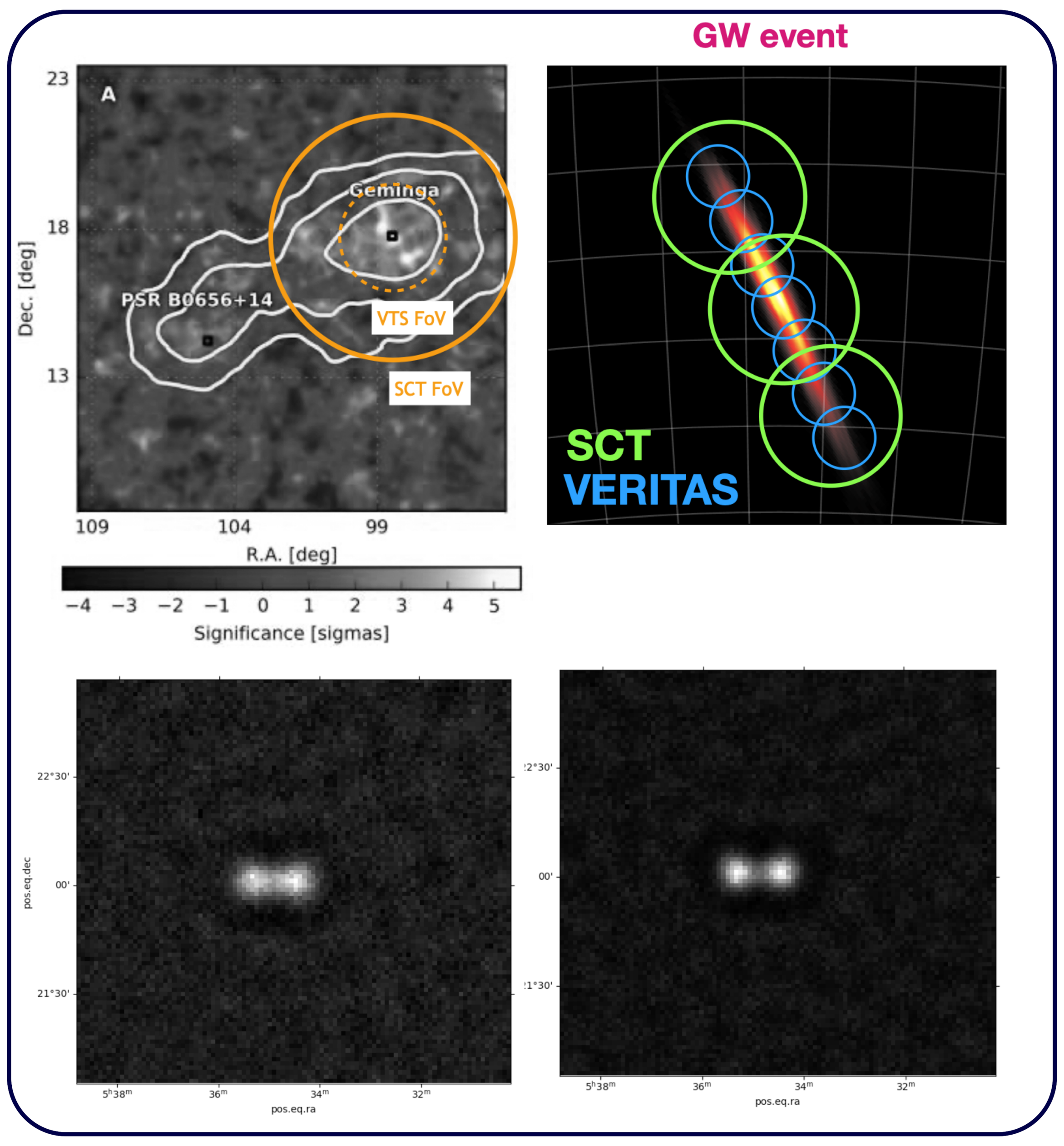

Fig. 5: SCT FoV superimposed on Geminga (T.L.) and GW event (T.R.). The image of two simulated sources obtained by the 14 MSTs configuration after the deconvolution (B.L.), the image obtained by 14 MSTs + 11 SCTs configuration after the deconvolution (B.R.).

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