Schwarzschild–Couder 光学系を用いた CTA 小・中口径望遠鏡の開発

奥村 暼¹、朝野彰¹、田島宏康¹、中村裕樹¹、山根暢仁¹
片桐秀明²、重中茜²、他 CTA Consortium

¹名古屋大学 宇宙地球環境研究所（ISEE）
²茨城大学理学部

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Cherenkov Telescope Array (CTA)
Cherenkov Telescope Array (CTA)

LST (Large)
20 GeV
200 GeV

MST (Medium)
100 GeV
10 TeV

SST (Small)
5 TeV
300 TeV

Very-high-energy Gamma Ray

Air Shower

Cherenkov Photons \( \propto \) Energy

\( R \sim 150 \text{ m} \)
Cherenkov Telescope Array (CTA)

Small-Sized Telescope (SST)
- 70 SSTs @ South
- $D = 4\, m$
- FOV $\sim 9^\circ$
- $E = 5\, \text{TeV} - 300\, \text{TeV}$

Schwarzschild–Couder Telescope (SC-MST)
- 25 SCTs @ South
- $D = 9.6\, m$
- FOV $= 8^\circ$
- $E = 200\, \text{GeV} - 10\, \text{TeV}$
The Schwarzschild–Couder (SC) Design

- Wide FOV aplanatic design with primary and secondary mirrors, invented by Schwarzschild (1905) and Couder (1926)
- Proposed for ground-based gamma-ray telescopes in 2007
- Will achieve **wider FOV (~8°)** and **higher resolution (< ~0.04°)** with a compact camera
Improved Optical Resolution

- Optical resolution will be improved (0.1° → < 0.05°)
- Compact and less expensive camera with small pixels (~2000 → > 10000 pixels)
CTA Prototypes of Schwarzschild–Couder

- SC-MST and 2M-SST (GCT) are being developed by ISEE (Nagoya), US, and Europe
- Camera development, optics simulation, and software development by ISEE
- 2M-SST (ASTRI) is also being developed by Italy
Camera Prototype for 2M-SST (GCT)

- 2048 pixels with multi-anode PMTs (to be updated to silicon photomultipliers)
- Capable of 1-ns frame “video” recording (i.e., 1 GHz) for Cherenkov flashes (~10 ns)
- Installed on the prototype telescope in Nov 2015
Cherenkov Showers

- Achieved the first light at Paris Observatory in 2015
- The first Cherenkov images (proton events) ever in CTA
PeV Cosmic Rays

Galactic cosmic rays up to ~PeV energies

Galactic Center and SNRs are leading candidates of PeVatrons

Figure 2.1: The spectrum of cosmic rays observed at the top of the Earth's atmosphere (Cronin et al., 1997). All cosmic-ray species are plotted together.
CTA Science and the Key Science Projects (KSPs)

- Dark matter
- **KSP: Galactic Center** *(525 + 300 hours)*  
  - Sgr A* + Halo
- **KSP: Galactic Plane Survey** *(1020 + 600 hours)*  
  - South + North
  - Typical obs. time ~50 hours per object
- **KSP: LMC Survey** *(340 + 150 hours)*
- **KSP: Extragalactic Survey**
- **KSP: Transients**
- **KSP: Cosmic Ray PeVatrons** *(250 + 50 hours)*  
  - Candidates from GPS + RX J1713
- **KSP: Star Forming Systems**
- **KSP: Active Galactic Nuclei**
- **KSP: Clusters of Galaxies**
- **Non-Gamma-ray Science**

"Science with CTA" will be published soon
Point Source Sensitivity

5 bins per decade, point source, high Gal. lat.

Energy Frontier
30–300 TeV

×5 @ ~100 GeV

×10 @ 1–10 TeV
The energy spectrum of the diffuse Galactic Centre, which show the expected tracer of the presence believed to supply most Galactic cosmic rays—has shown the contains petaelectronvolt accelerators ('PeV atrons'), but all proposed outflow from the Galactic Centre.

However, none of the currently known accelerators—

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Thus, at distances

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The diffusion coefficient and radius, respectively. For timescales

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Angular Resolution

Note: Further improvement is expected by using telescope multiplicity cut, etc.
H.E.S.S. Galactic Plane Survey (as of 2012)
CTA View of the Galactic Plane (Simulation)
CTA View of RX J1713.7–3946 (Simulation)

Nakamori et al. (2015)

(a) CTA leptonic dominant case (A2/A1=0.01)
DEC (J2000) [degree]

(b) CTA hadronic dominant case (A2/A1=100)
DEC (J2000) [degree]

R.A.: 17:13:17.1
DEC: -39° 46′ 36.7″

-40.5  -40.0  -39.5
-40.5   -40.0   -39.5
-40.5   -40.0   -39.5
-40.5   -40.0   -39.5

\( \frac{d^2N}{dE\,d\Omega} \) (erg cm\(^{-2}\) s\(^{-1}\))

Energy (TeV)

-40.5  -40.0  -39.5
-40.5   -40.0   -39.5
-40.5   -40.0   -39.5
-40.5   -40.0   -39.5

\( \frac{d^2N}{dE\,d\Omega} \) (erg cm\(^{-2}\) s\(^{-1}\))

Energy (TeV)

\( \frac{d^2N}{dE\,d\Omega} \) (erg cm\(^{-2}\) s\(^{-1}\))

Energy (TeV)
CTA telescopes with Schwarzschild–Couder designs are being prototyped for MSTs and SSTs

Succeeded in imaging Cherenkov showers for the first time ever in CTA

Wider FOV, higher angular resolution, and ~100 telescopes will extend the view of very-high-energy sky

- Galactic plane survey and PeVatron search
- Detailed study of SNRs
- Galactic Center