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

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日本天文学会 2017 年 秋季年会

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# Cherenkov Telescope Array (CTA)

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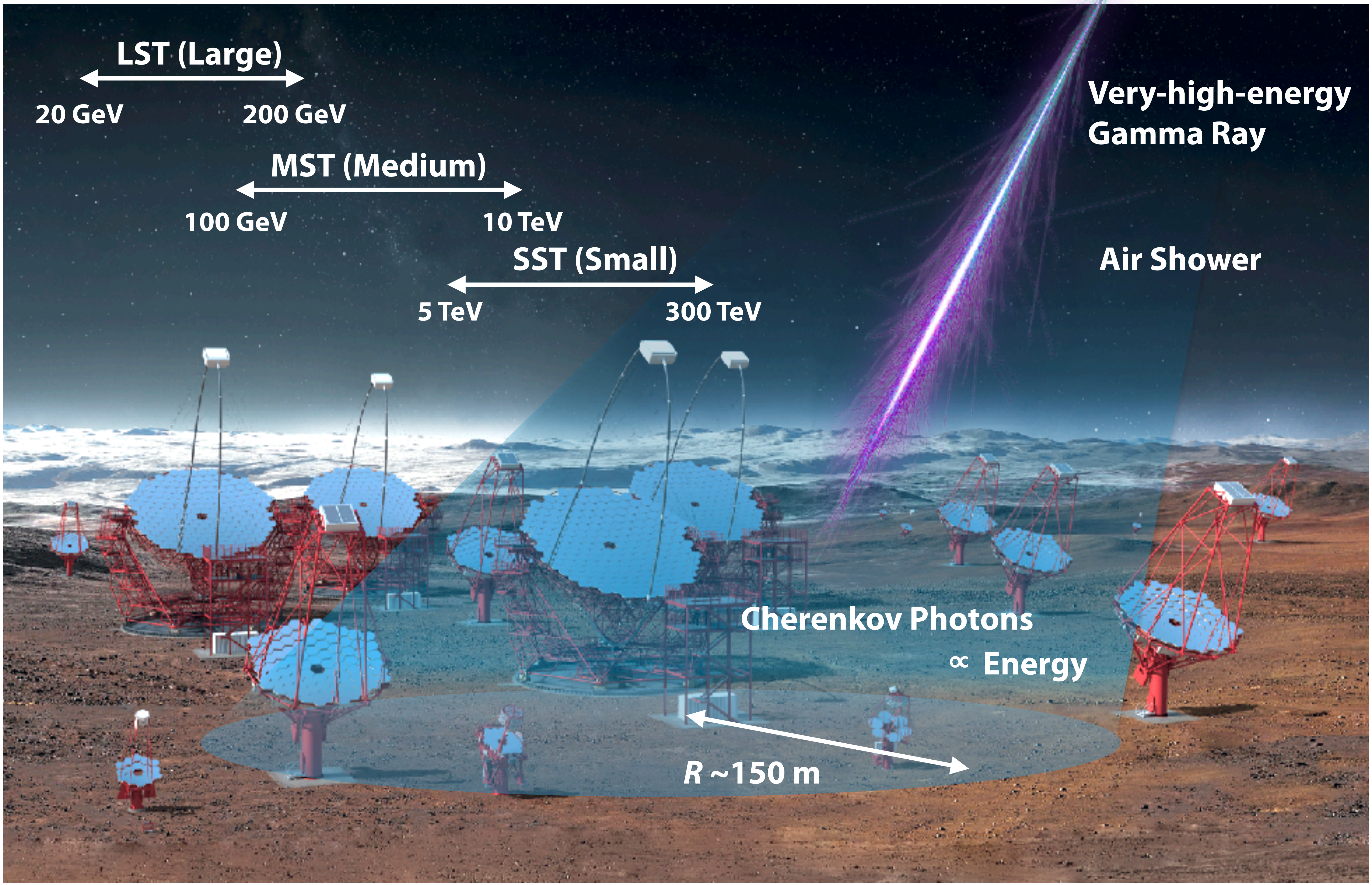

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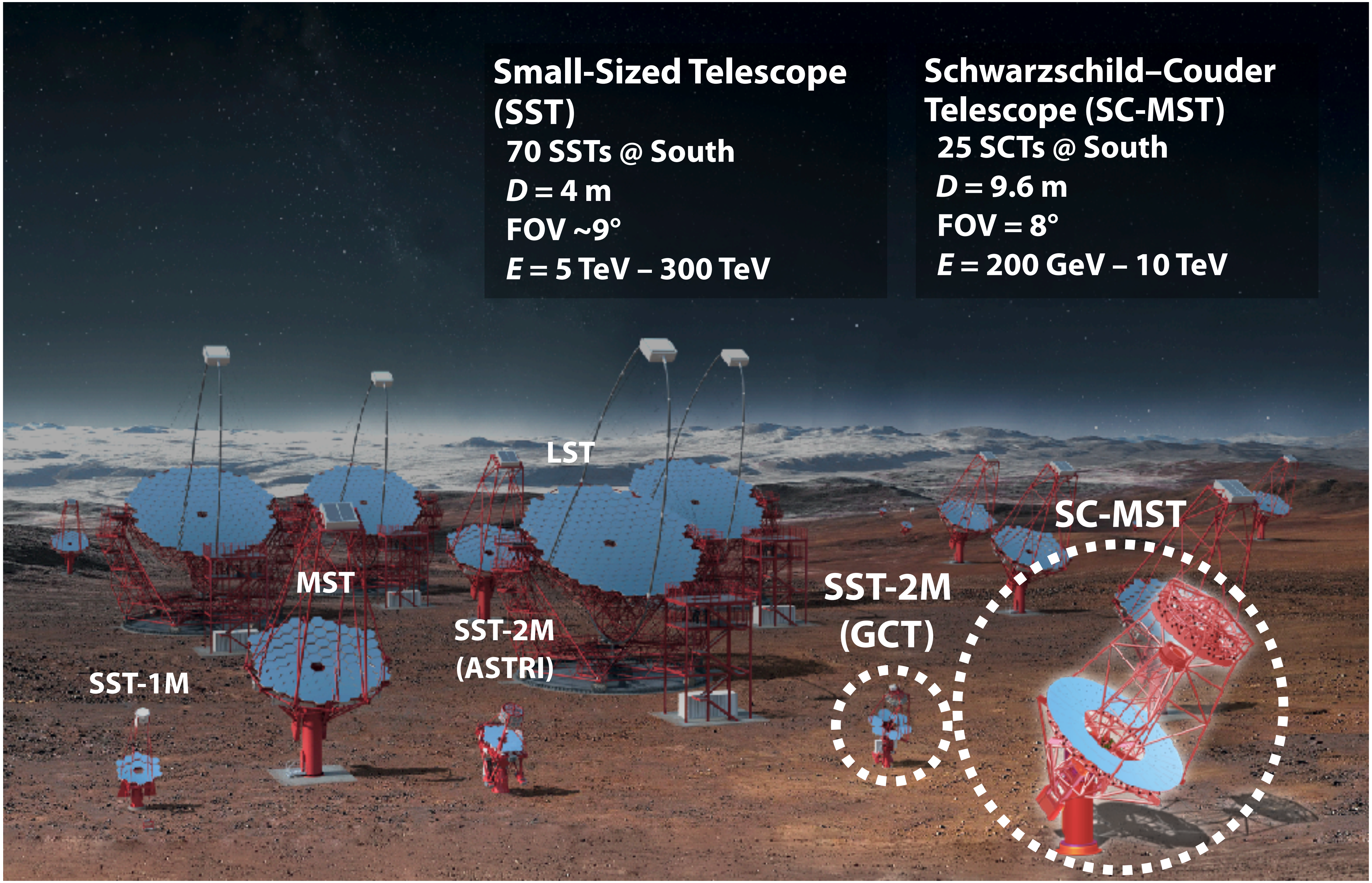
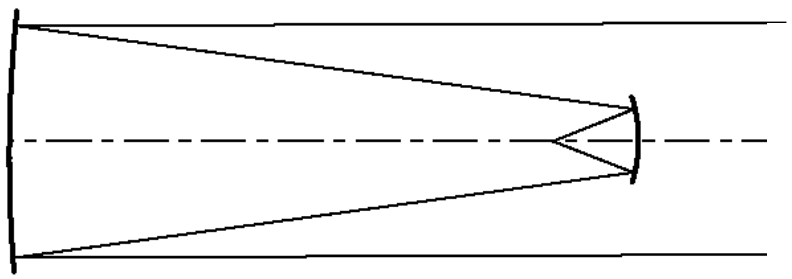
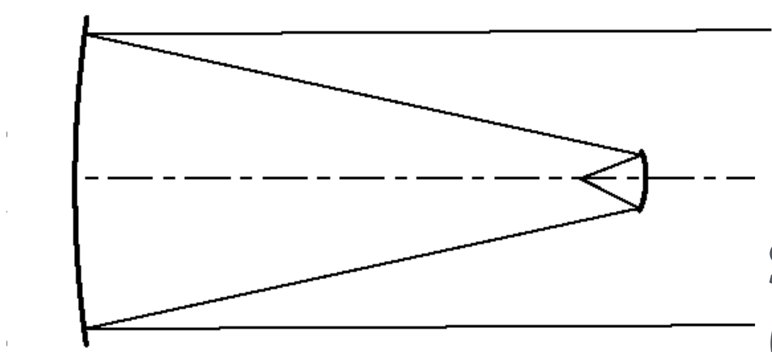


# The Schwarzschild–Couder (SC) Design

**"Handbook of Optics"**

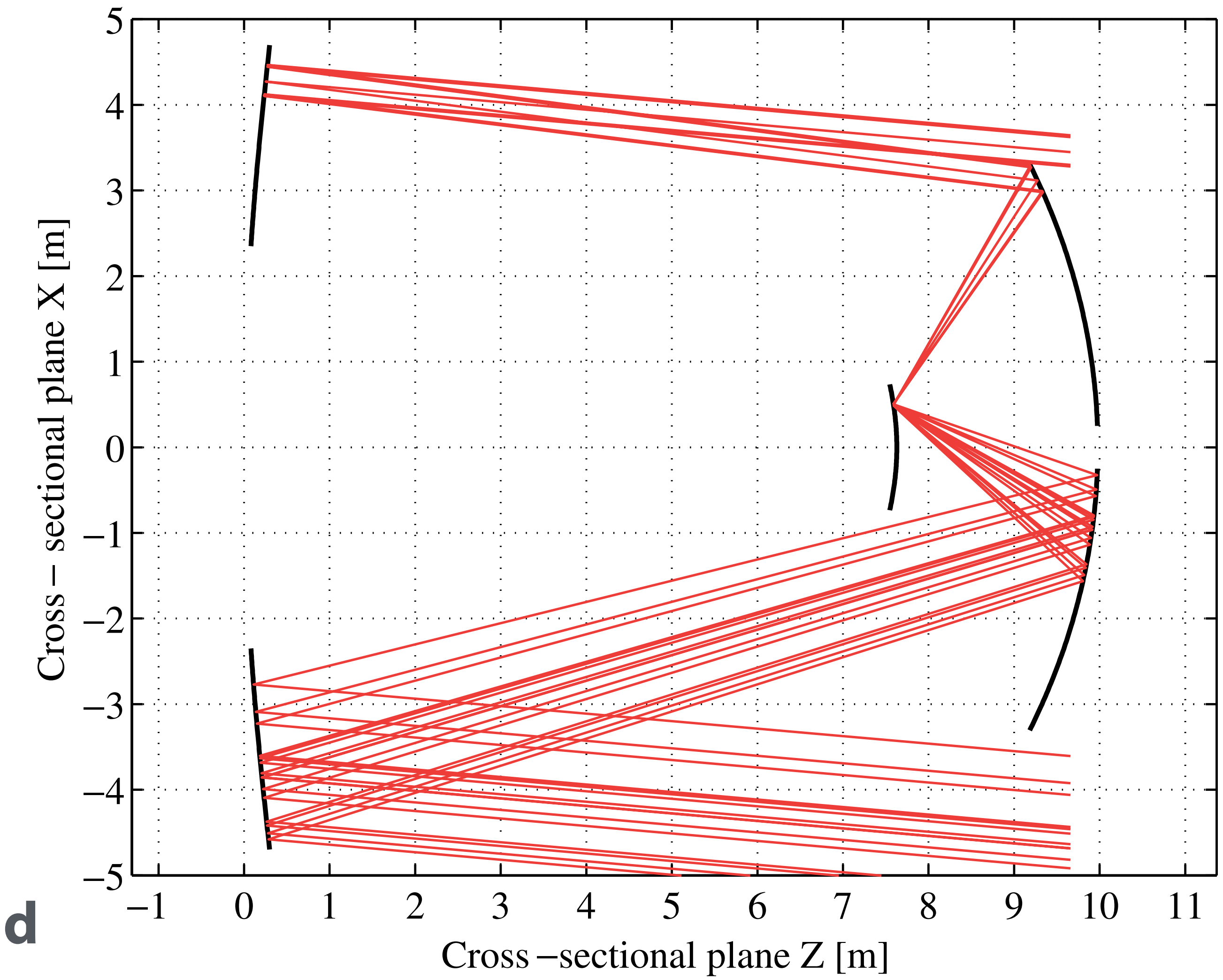


**Couder (1926)**



**Schwarzschild (1905)**

**Vassiliev *et al*. (2007)**



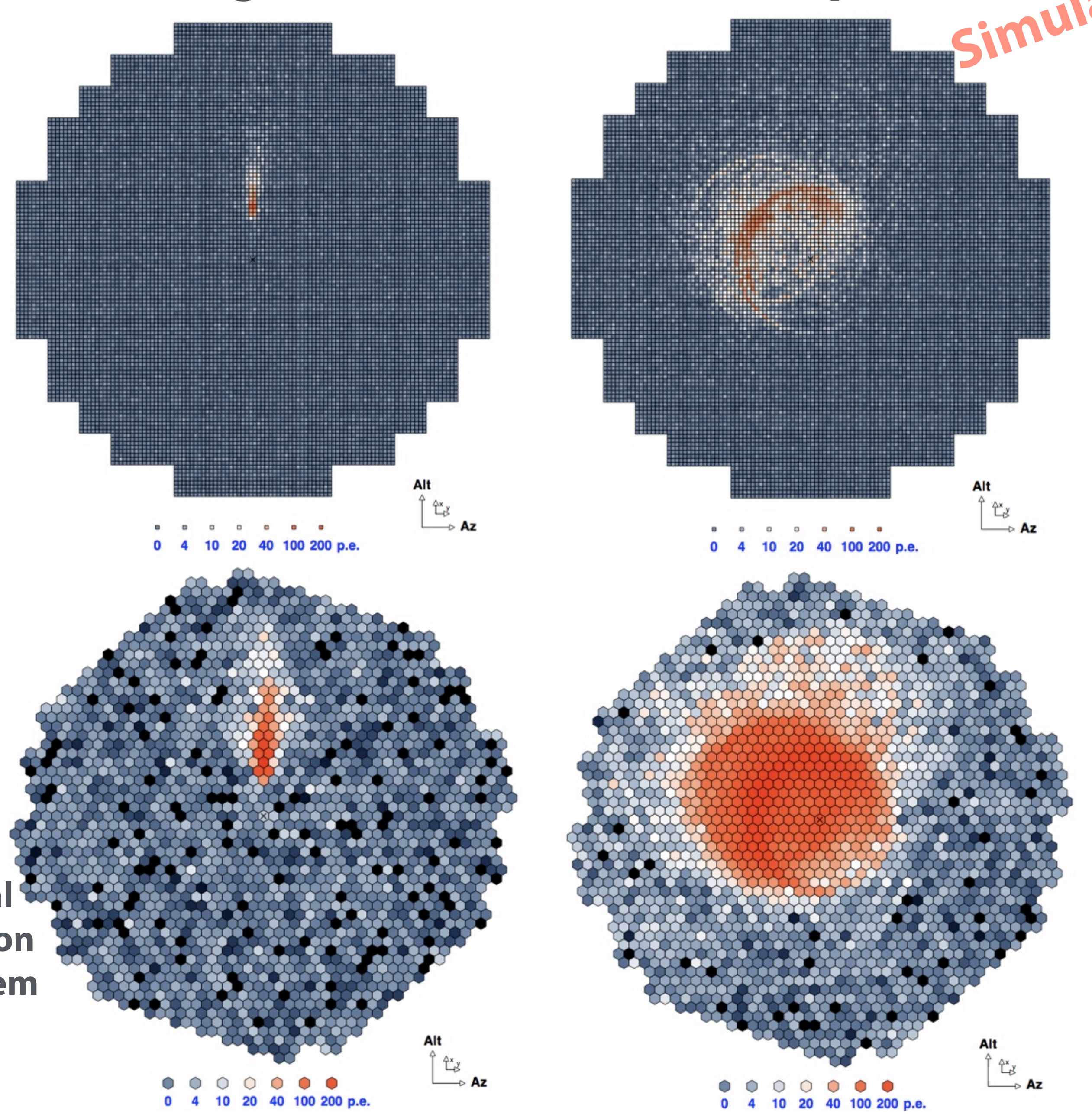

- Wide FOV aplanatic design with primary and secondary mirrors, invented by Schwarzschild (1905) and Couder (1926)
- Proposed for ground-based gamma-ray telescopes in 2007
- Will achieve **wider FOV (~8°)** and **higher resolution (< ~0.04°)** with a compact camera

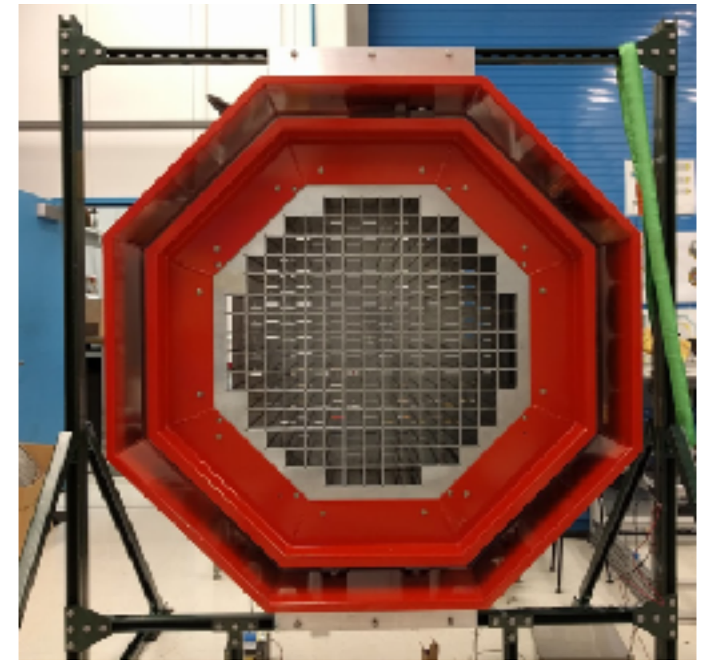
# Improved Optical Resolution

1-TeV gamma | 3.16-TeV proton | Simulation

SC-MST

MST
Conventional
Davies–Cotton
Optical System



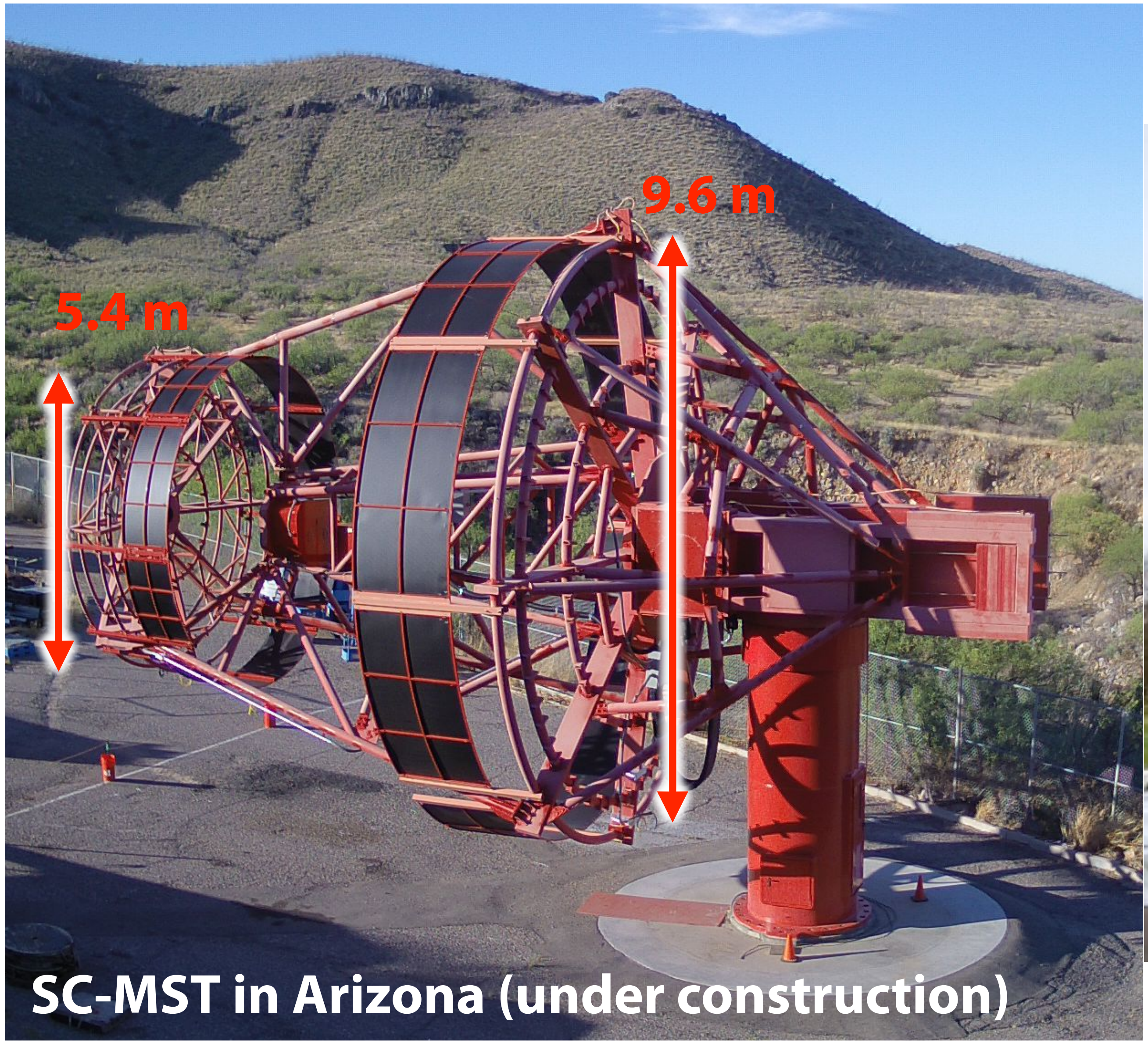



0.8 m

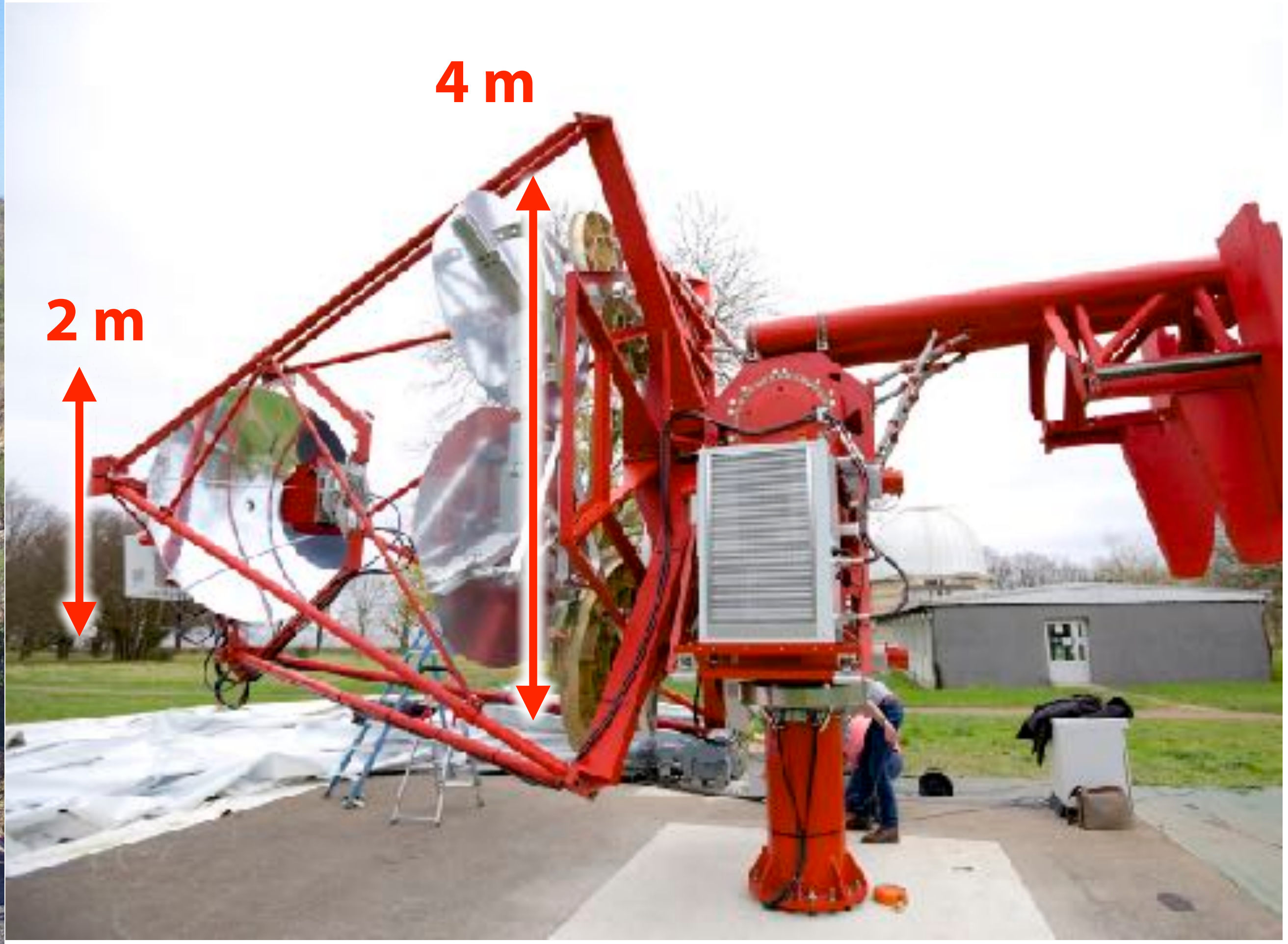

2 m

- 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



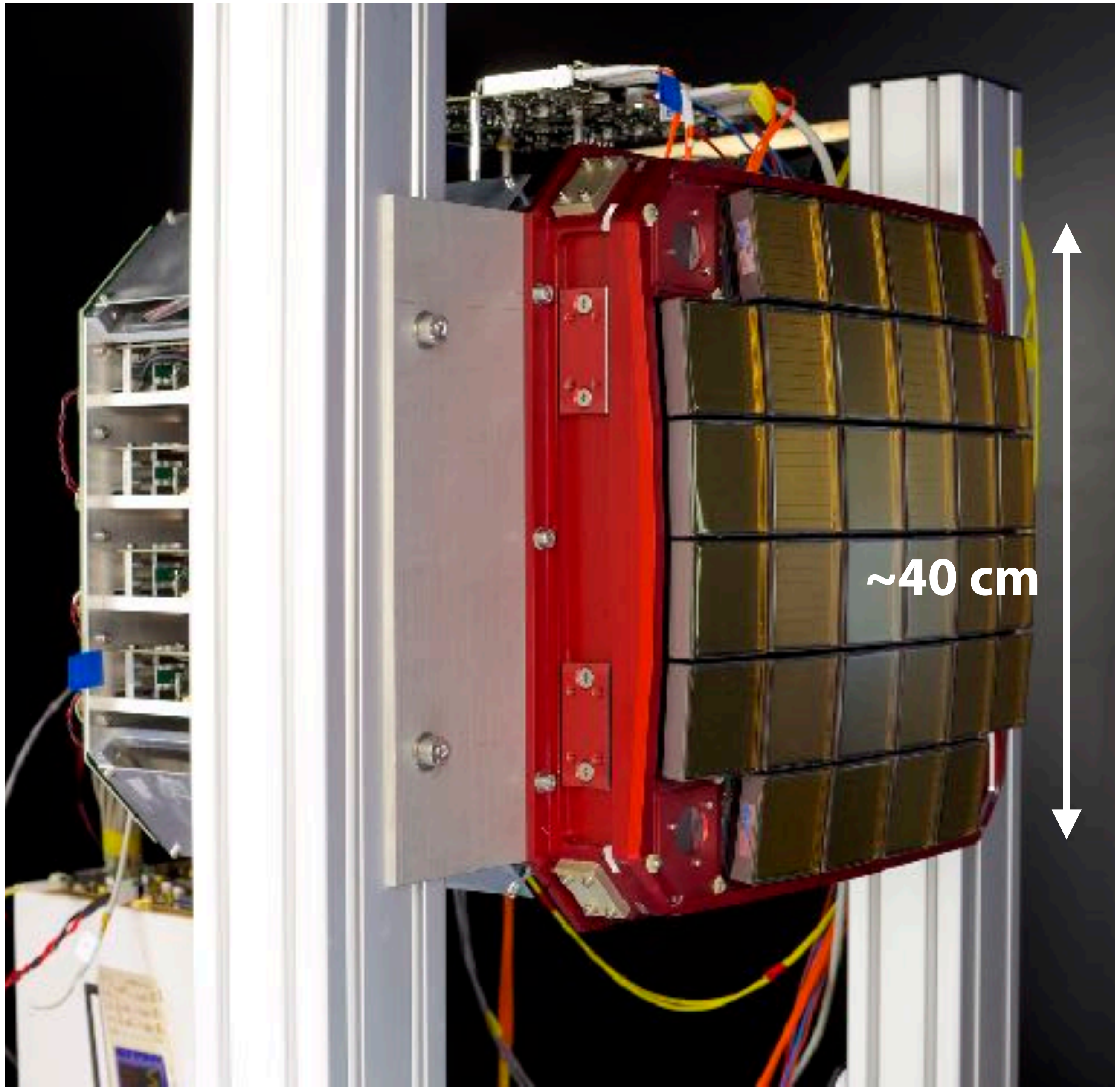

SC-MST in Arizona (under construction)

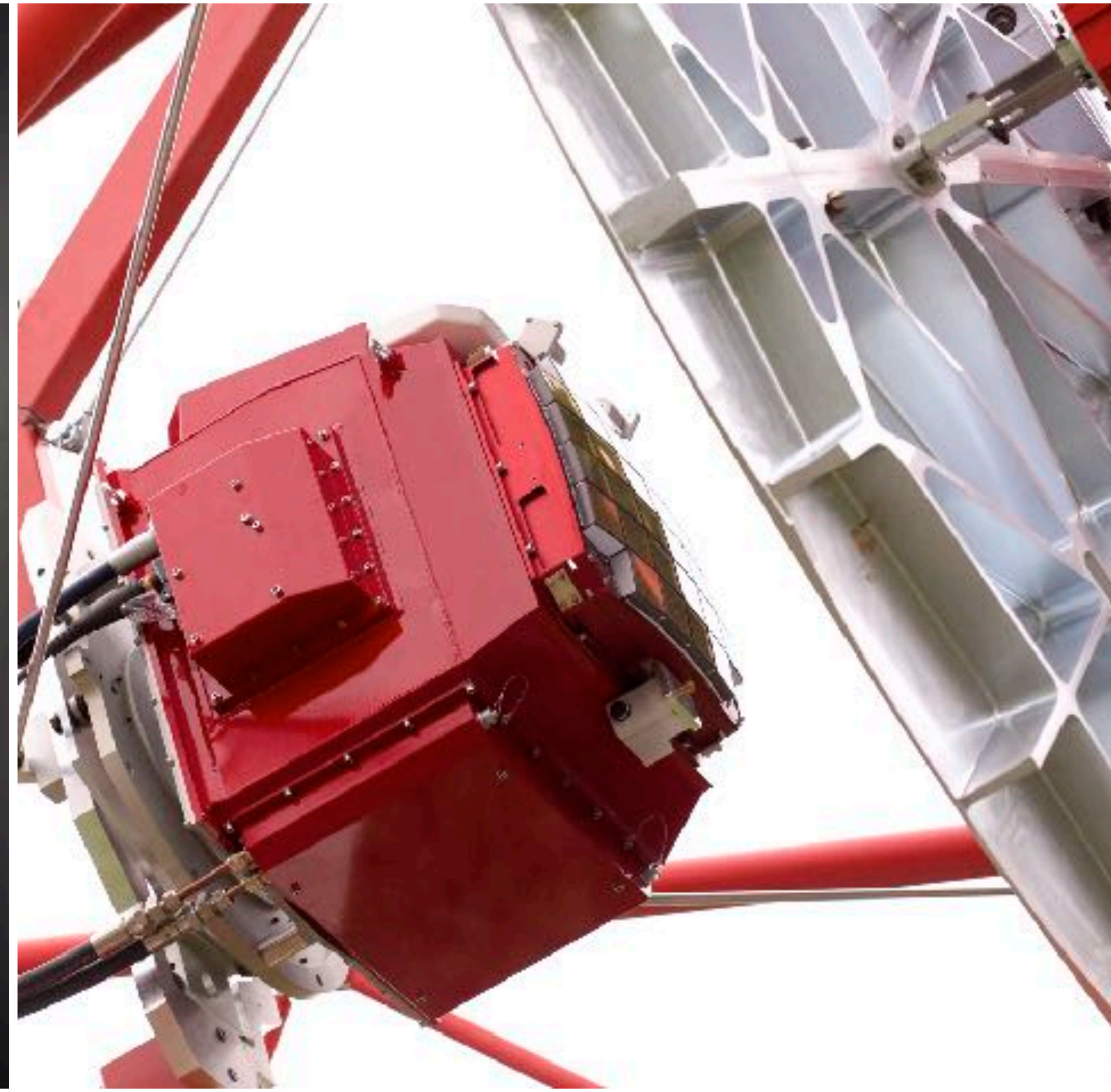



SST-2M (GCT) in Paris

- 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

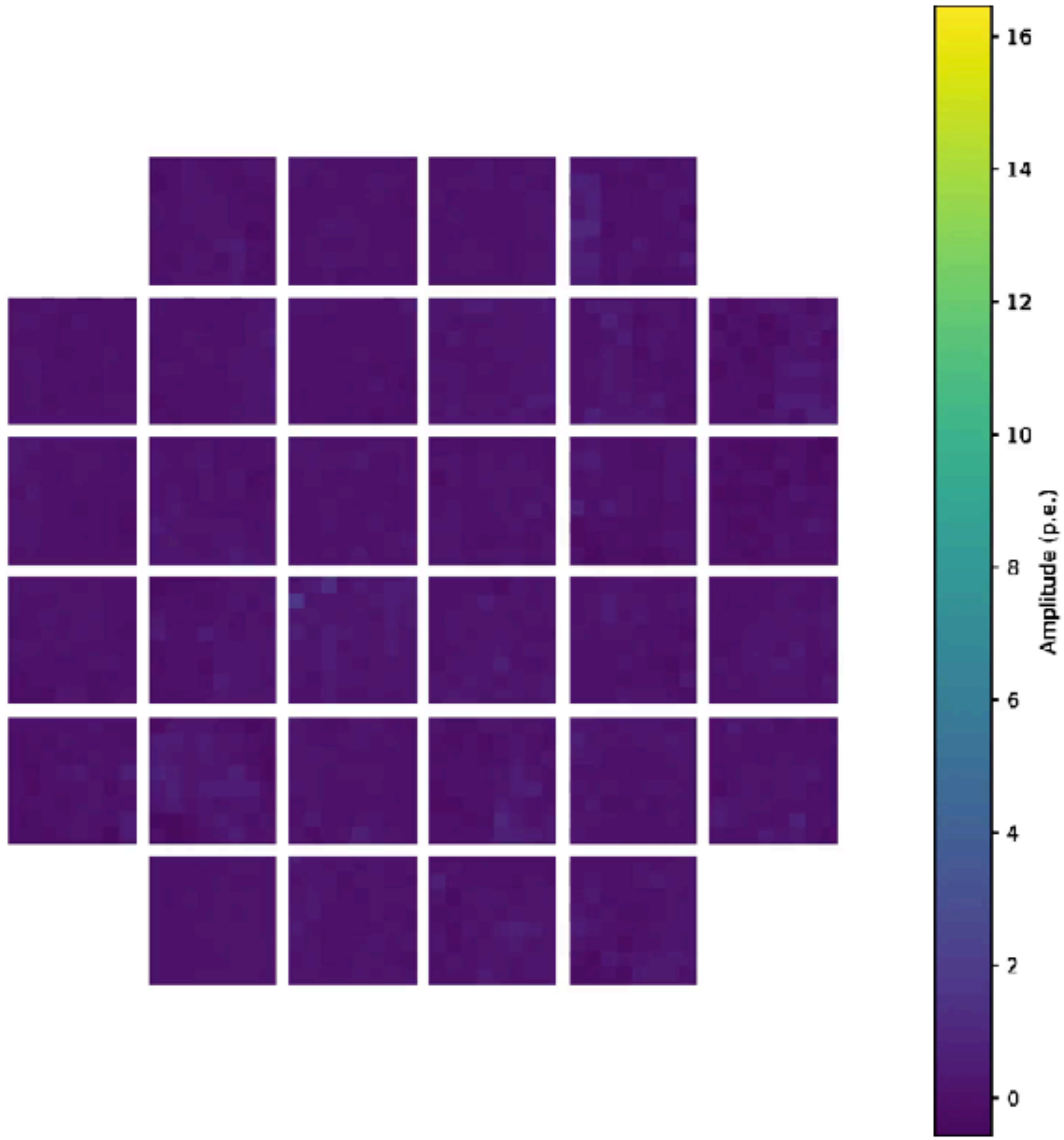
# Camera Prototype for 2M-SST (GCT)



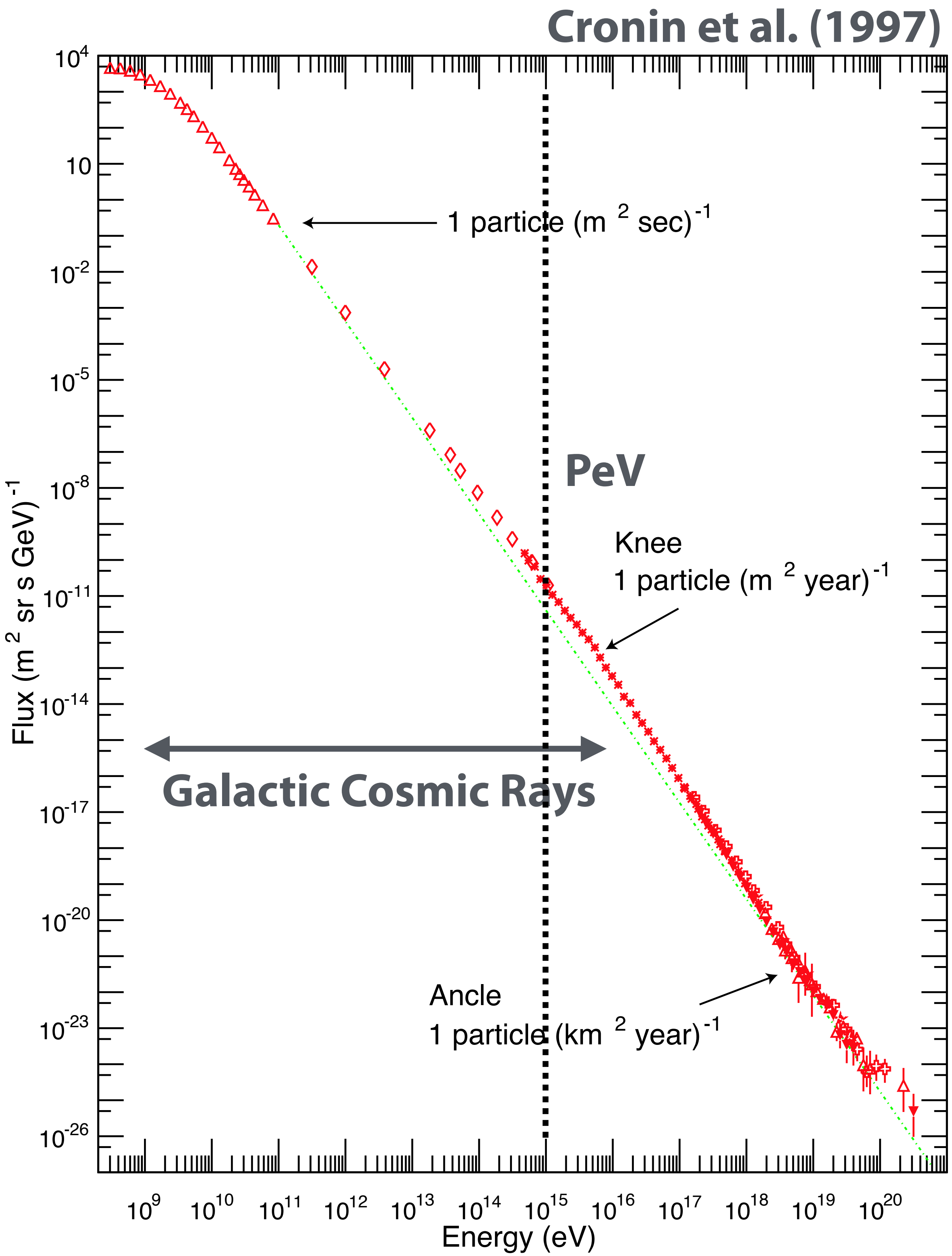
- 2048 pixels with multi-anode PMTs (to be updated to silicon photomultipliers)
- Capable of 1-ns frame "video" recording (i.e., 1 GHz) for Cherenkov flashes (~10 ns)
- Installed on the prototype telescope in Nov 2015

# Cherenkov Showers




- Achieved the fist 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**

# CTA Science and the Key Science Projects (KSPs)

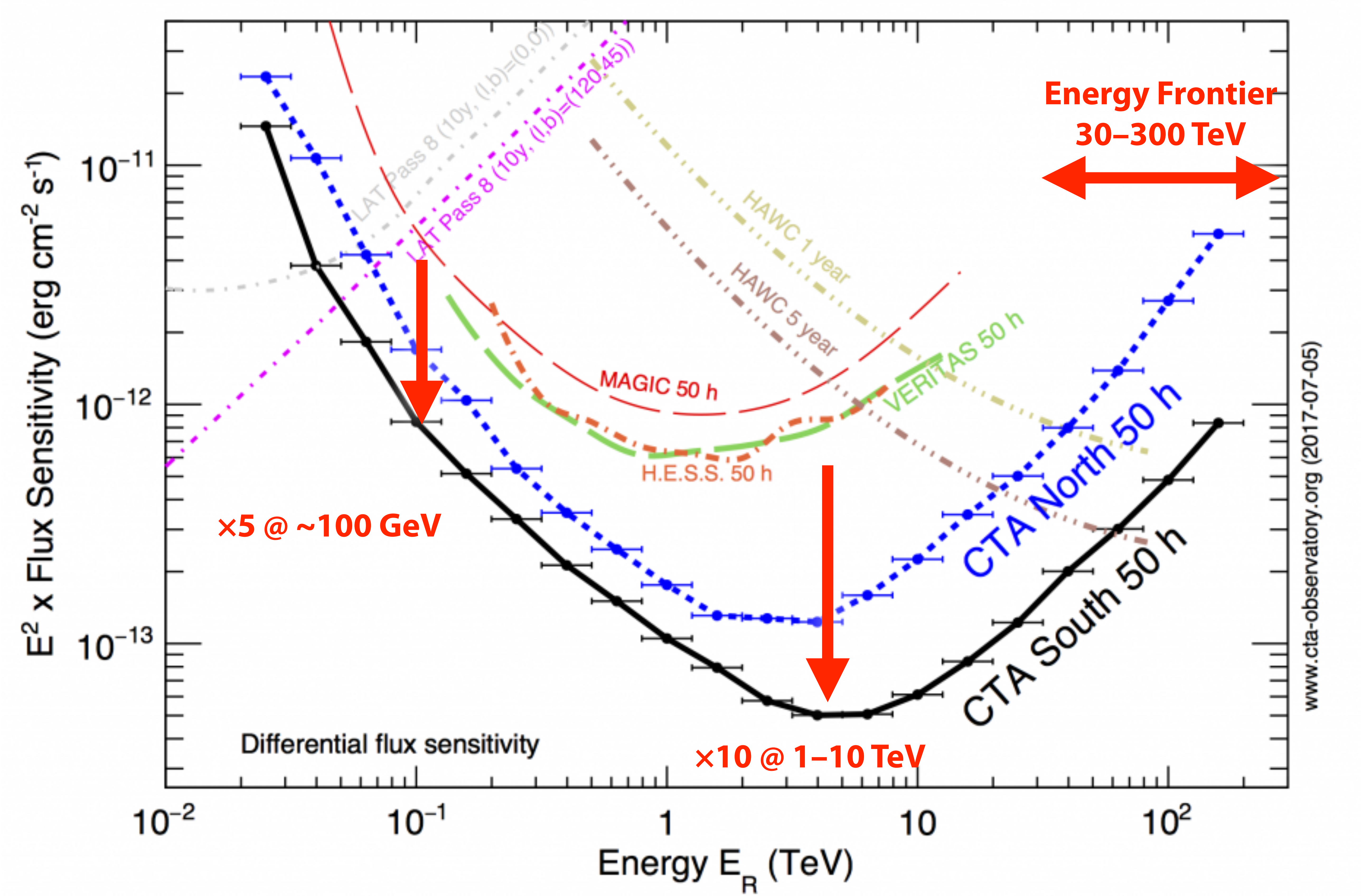
- Dark matter
- **KSP: Galactic Center (525 + 300 hours)**
  Sgr A* + Halo
- **KSP: Galactic Plane Survey (1020 + 600 hours)**
  South + North
- KSP: LMC Survey (340 + 150 hours)
- KSP: Extragalactic Survey
- KSP: Transients
- **KSP: Cosmic Ray PeVatrons (250 + 50 hours)**
  Candidates from GPS + RX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

**Typical obs. time ~50 hours per object**

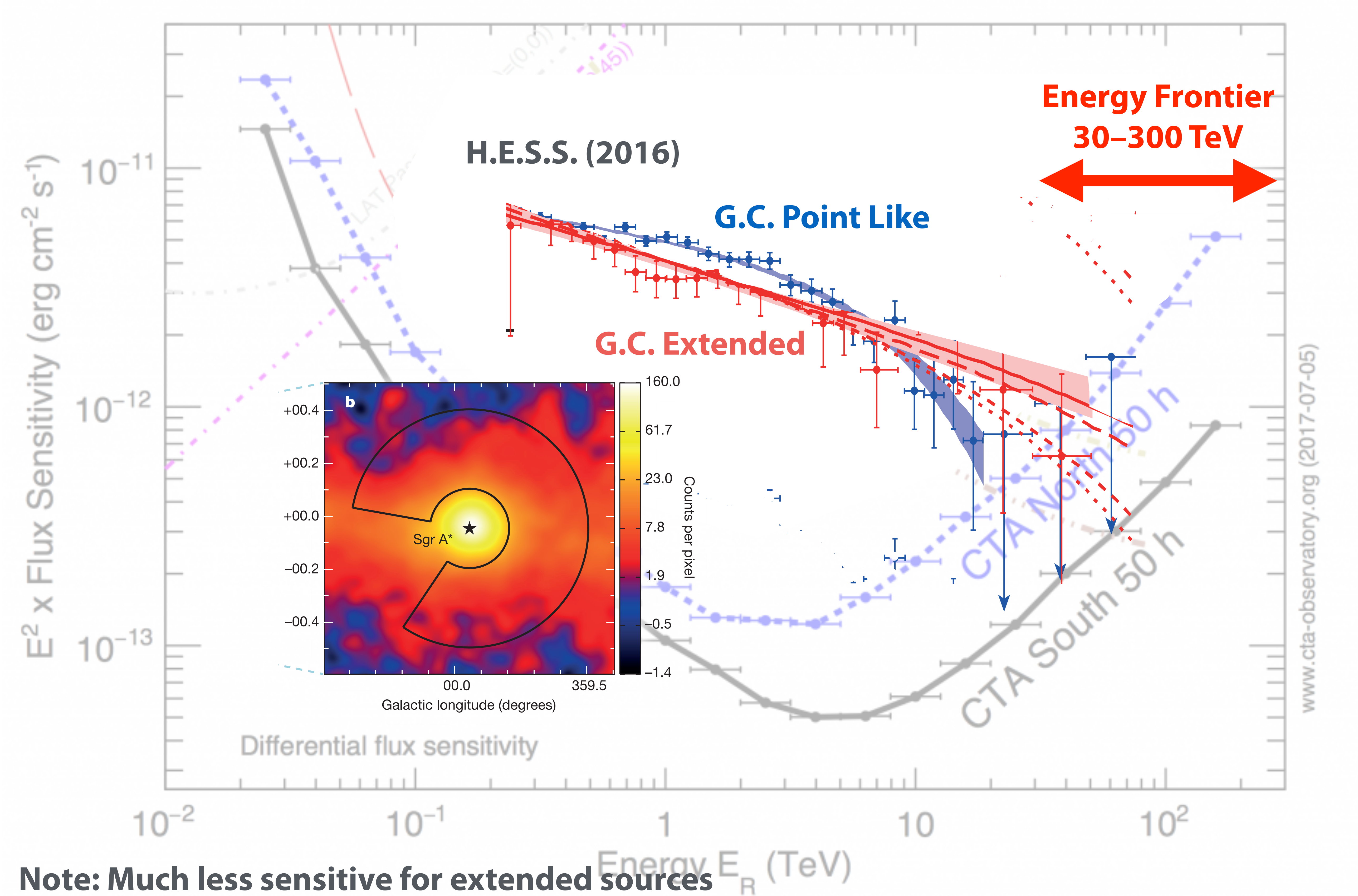
**"Science with CTA" will be published soon**

# Point Source Sensitivity

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

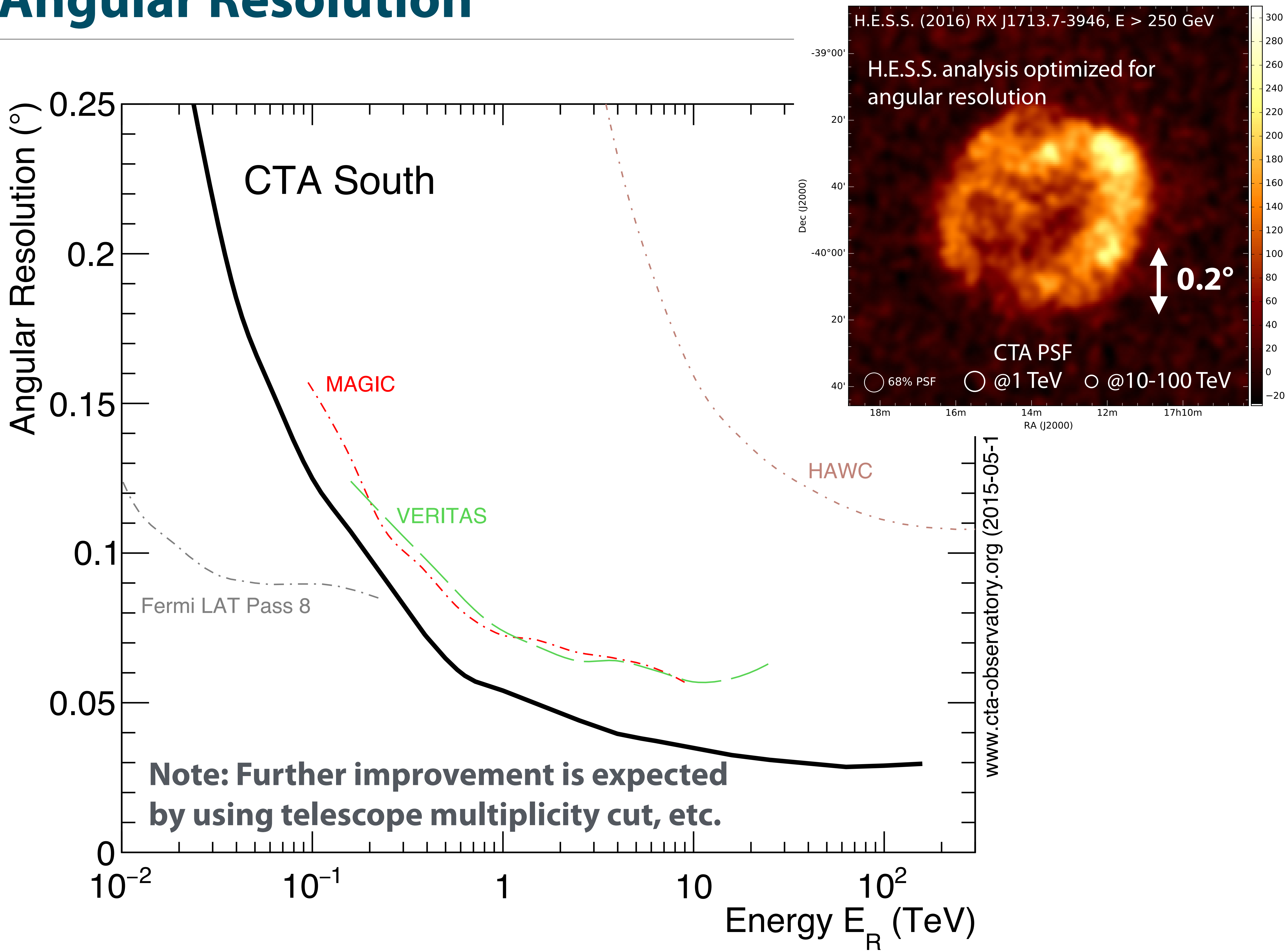


# Point Source Sensitivity

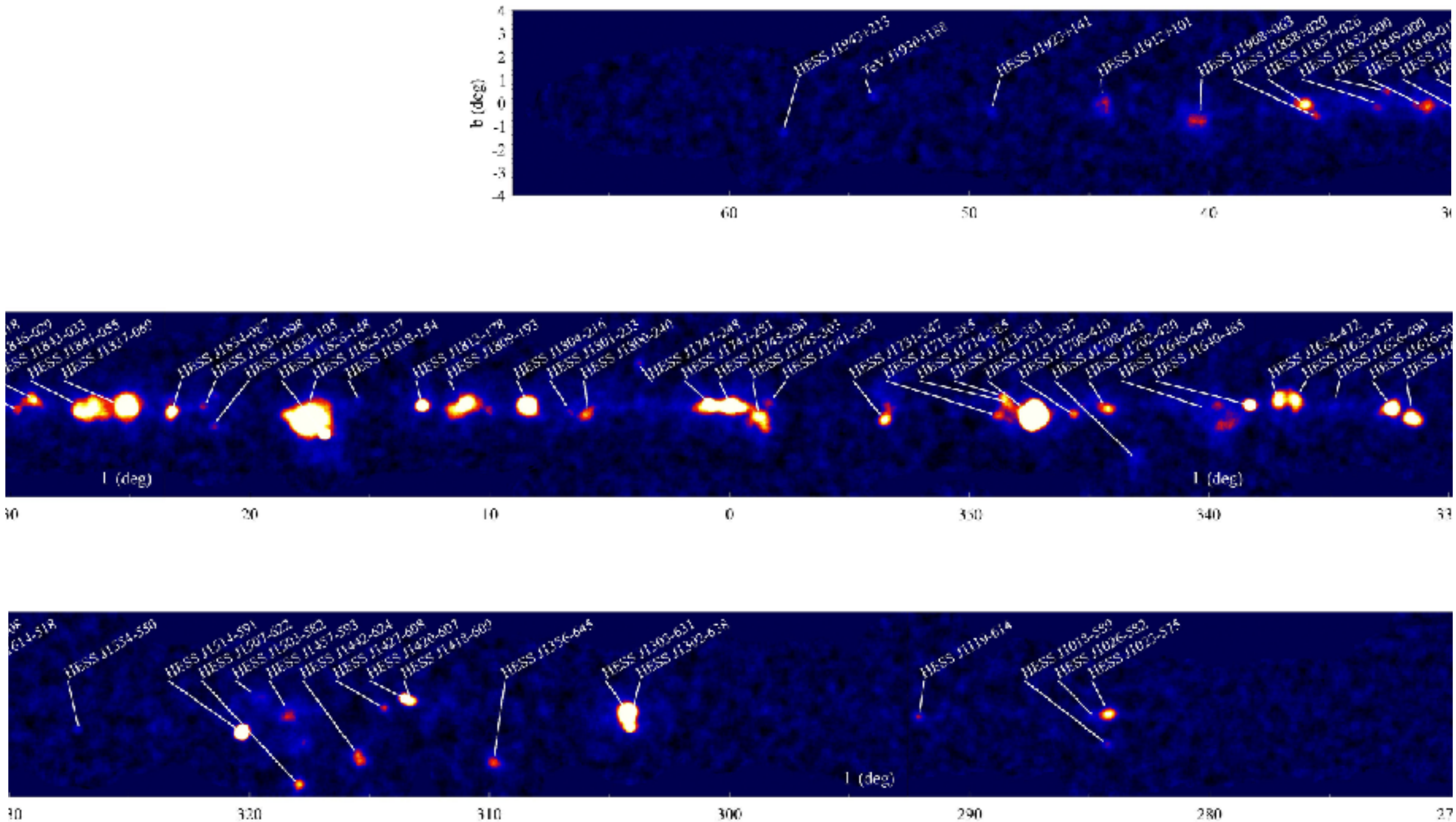



Note: Much less sensitive for extended sources

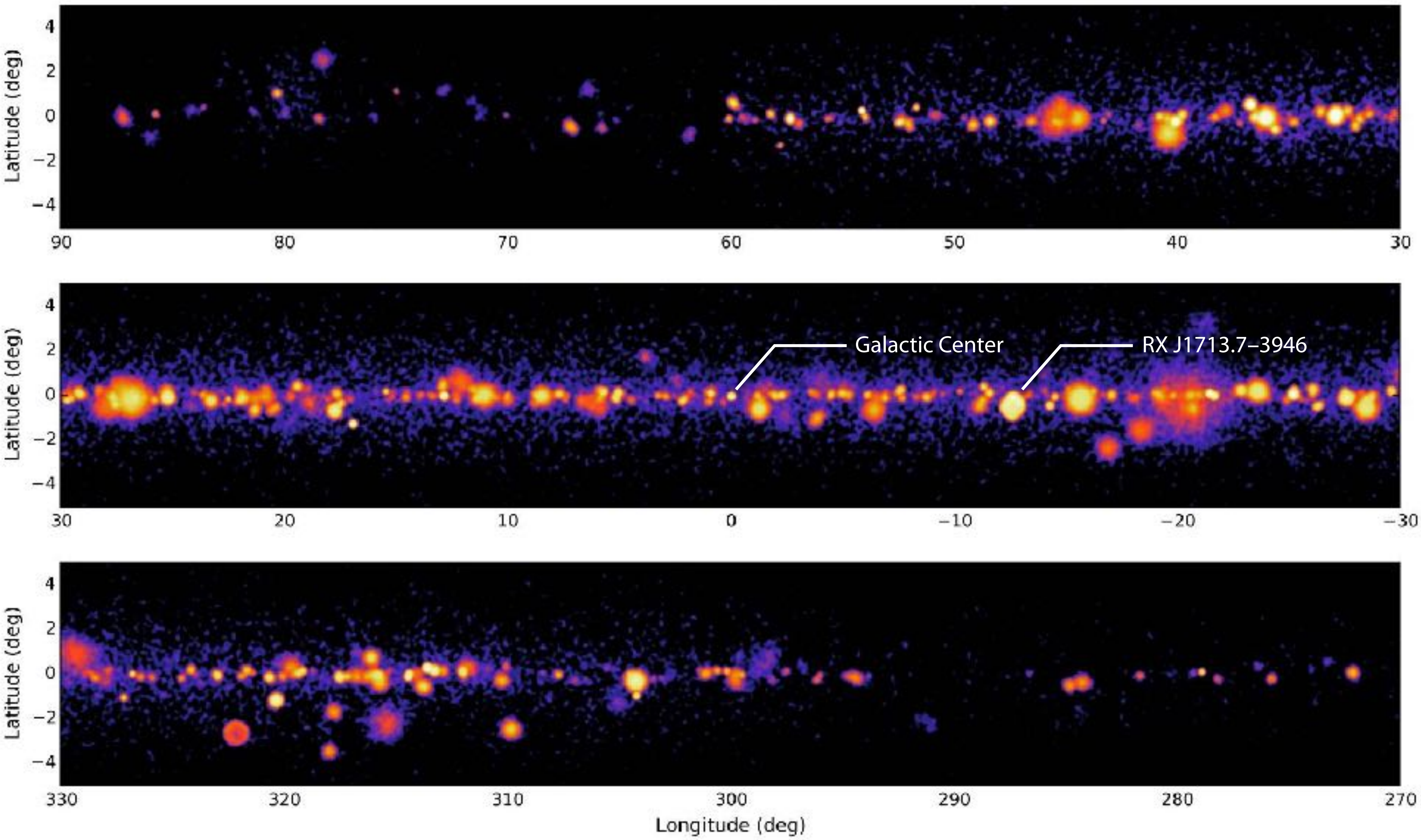
# Angular Resolution



# H.E.S.S. Galactic Plane Survey (as of 2012)

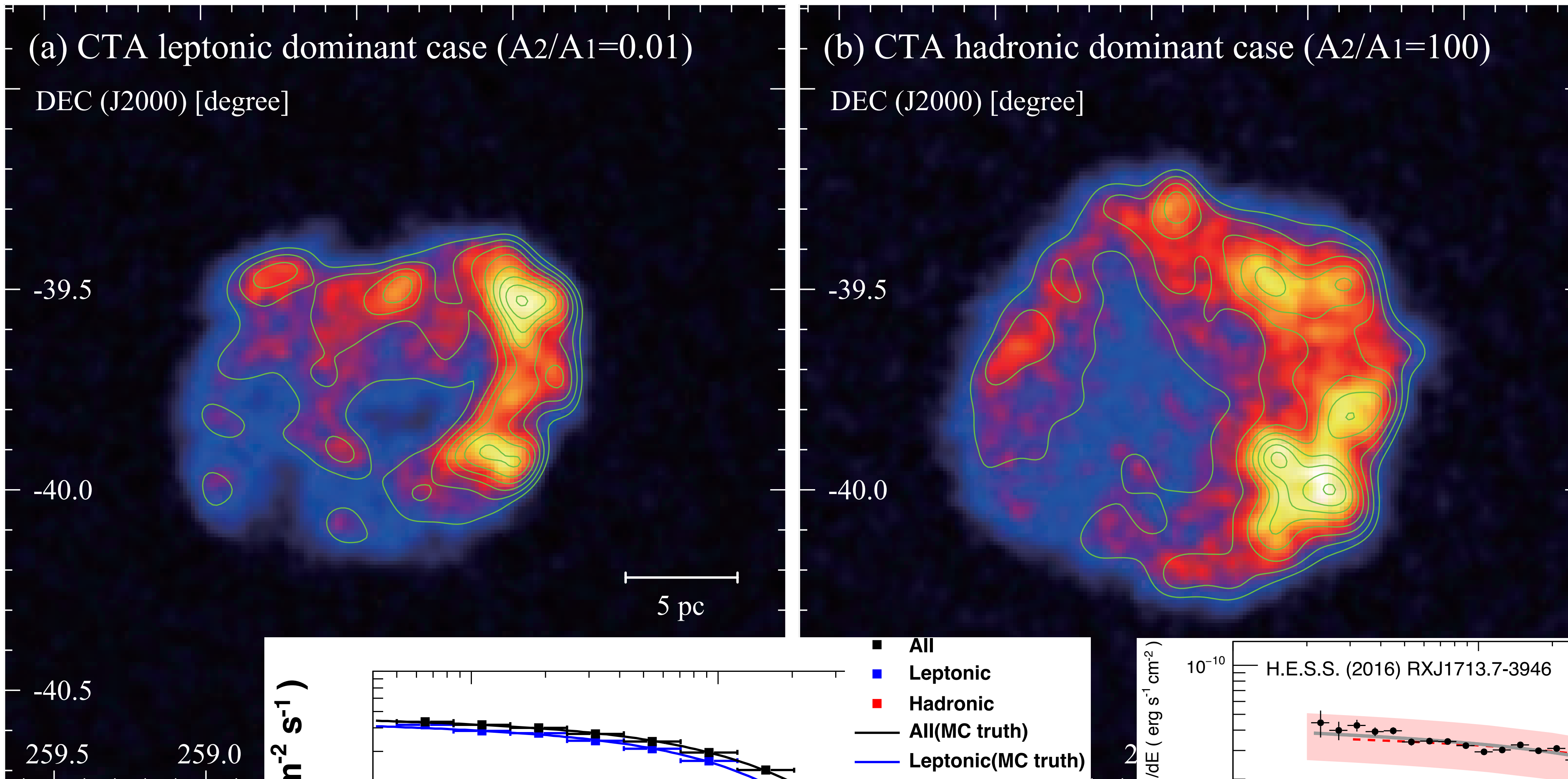


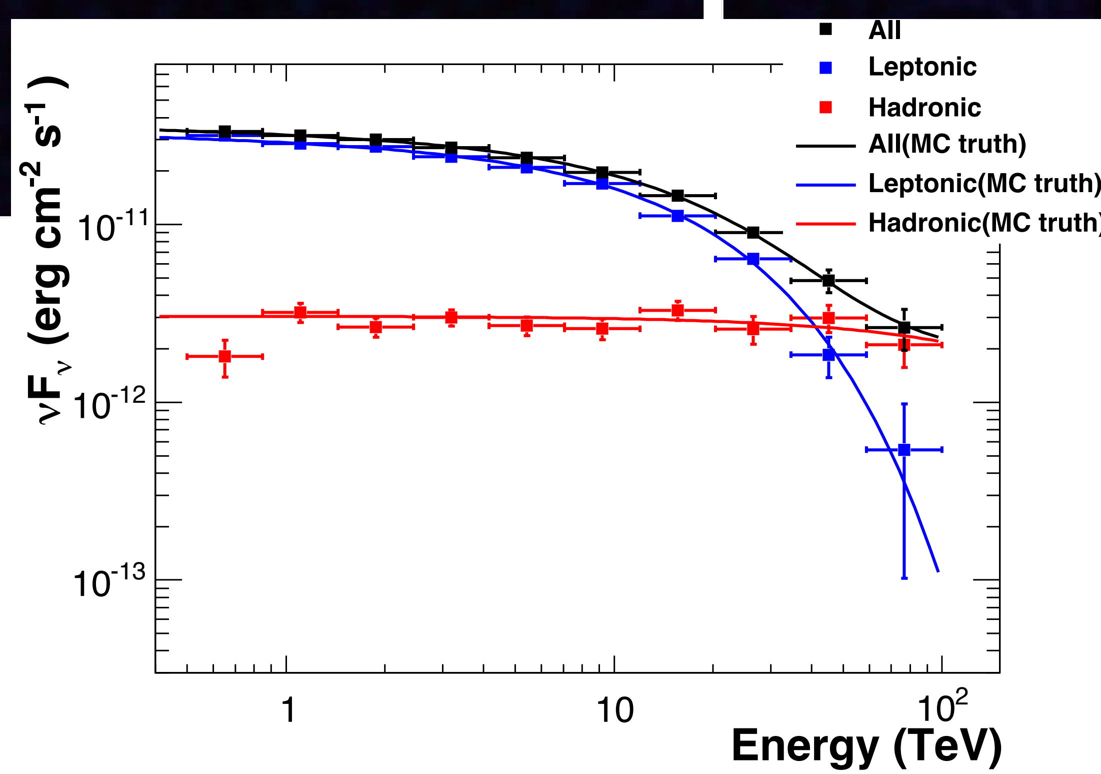
# CTA View of the Galactic Plane (Simulation)

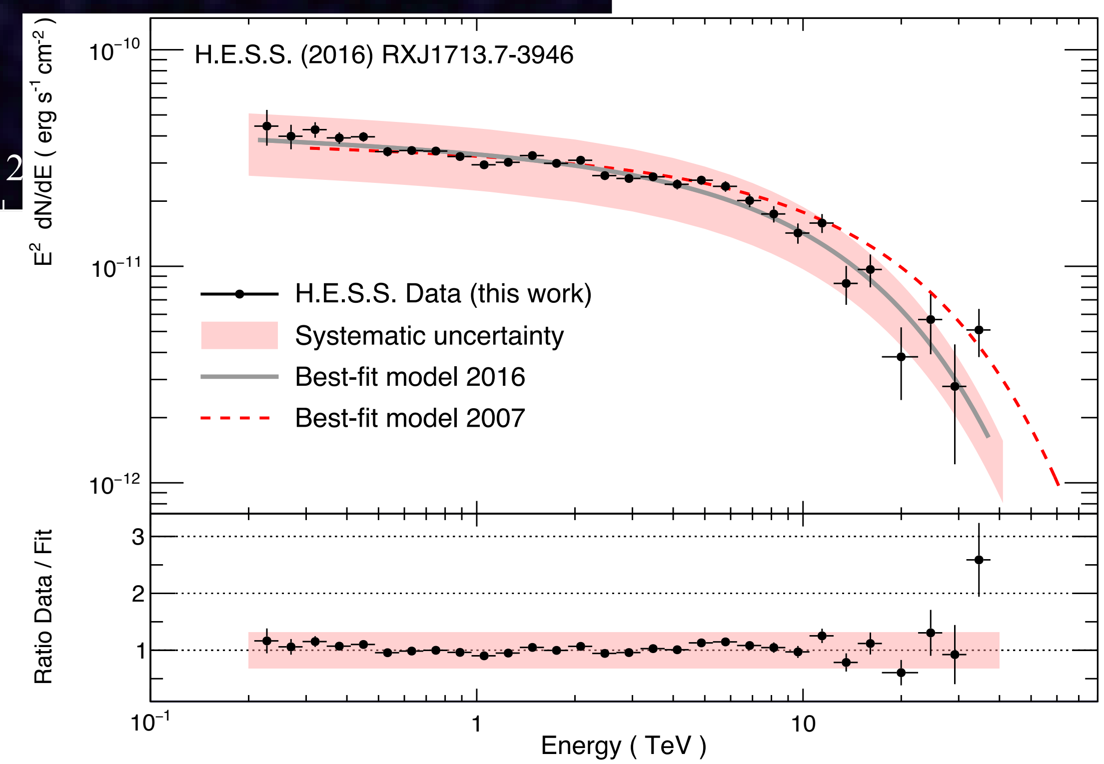


# CTA View of RX J1713.7–3946 (Simulation)

Nakamori *et al.* (2015)



# Summary

- 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