Science with the ASTRI Mini-Array and prototype

Andrea Giuliani

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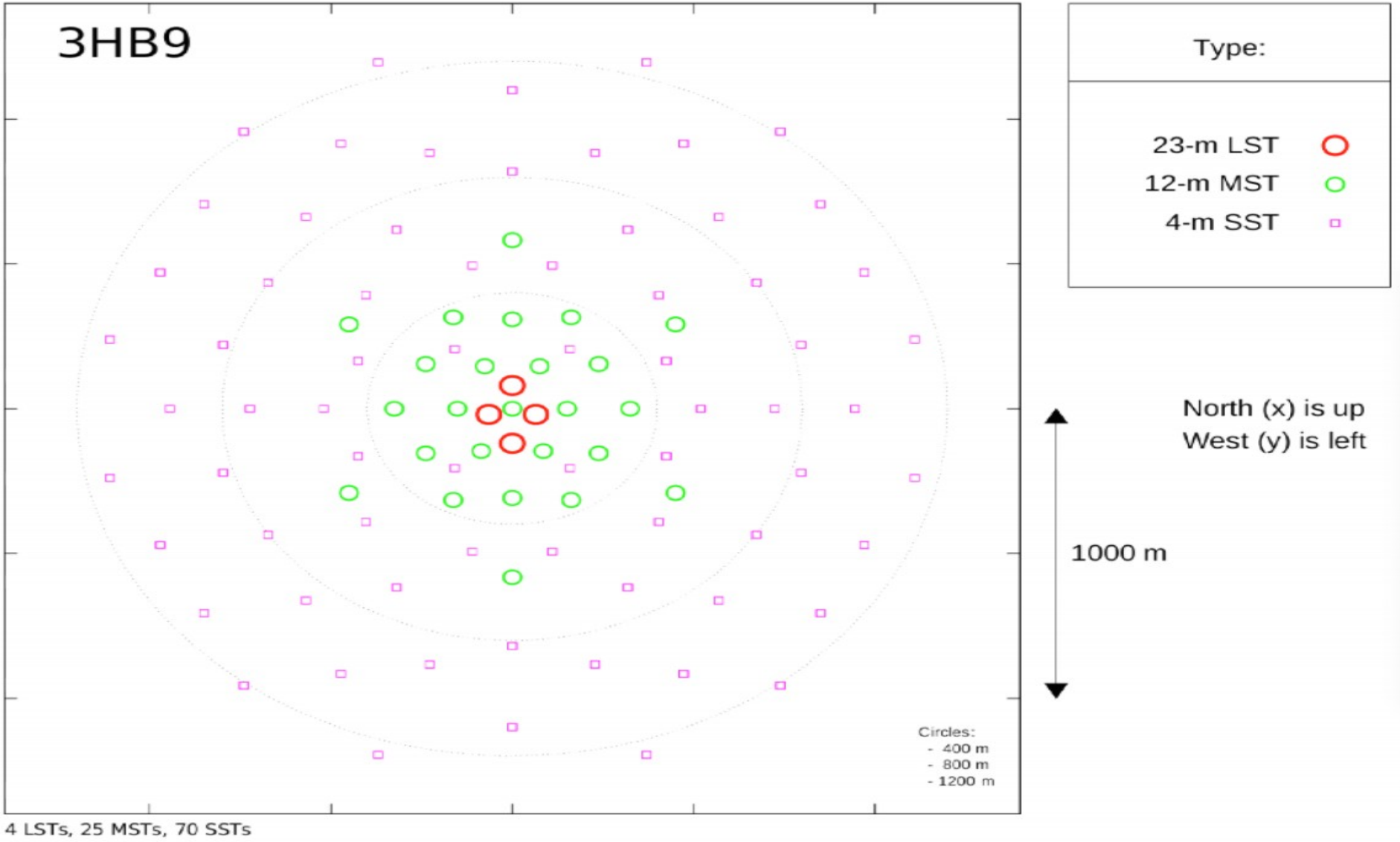
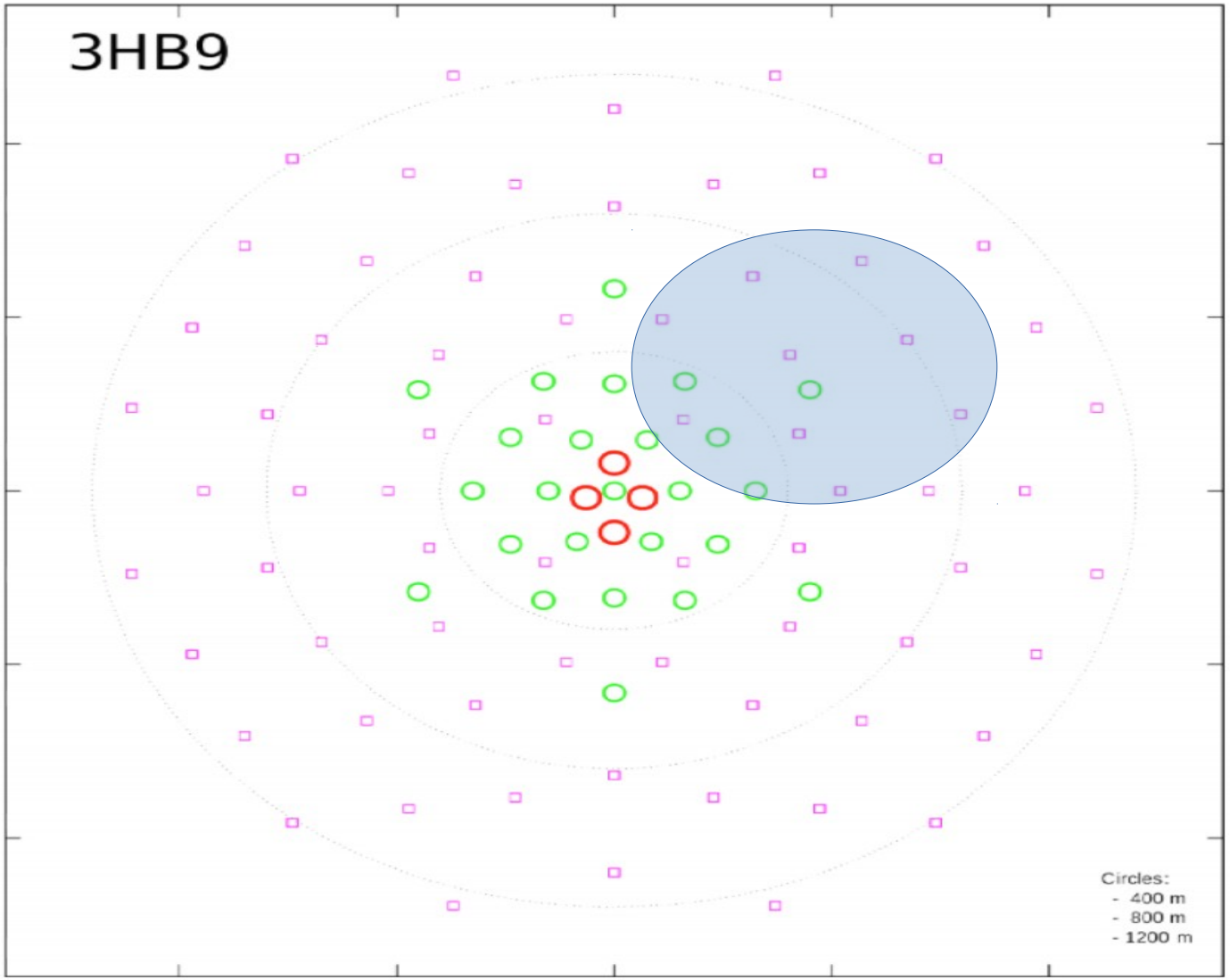
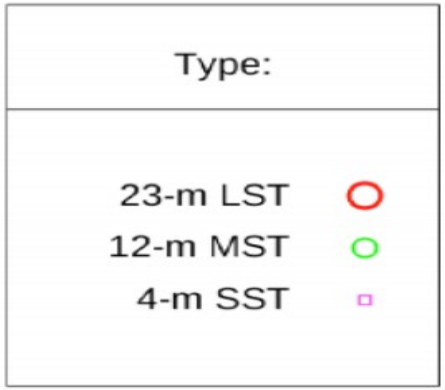
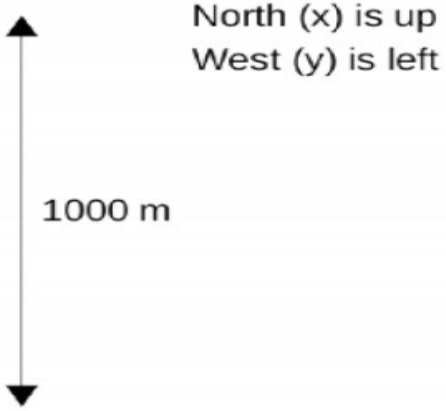
The ASTRI Project and CTA



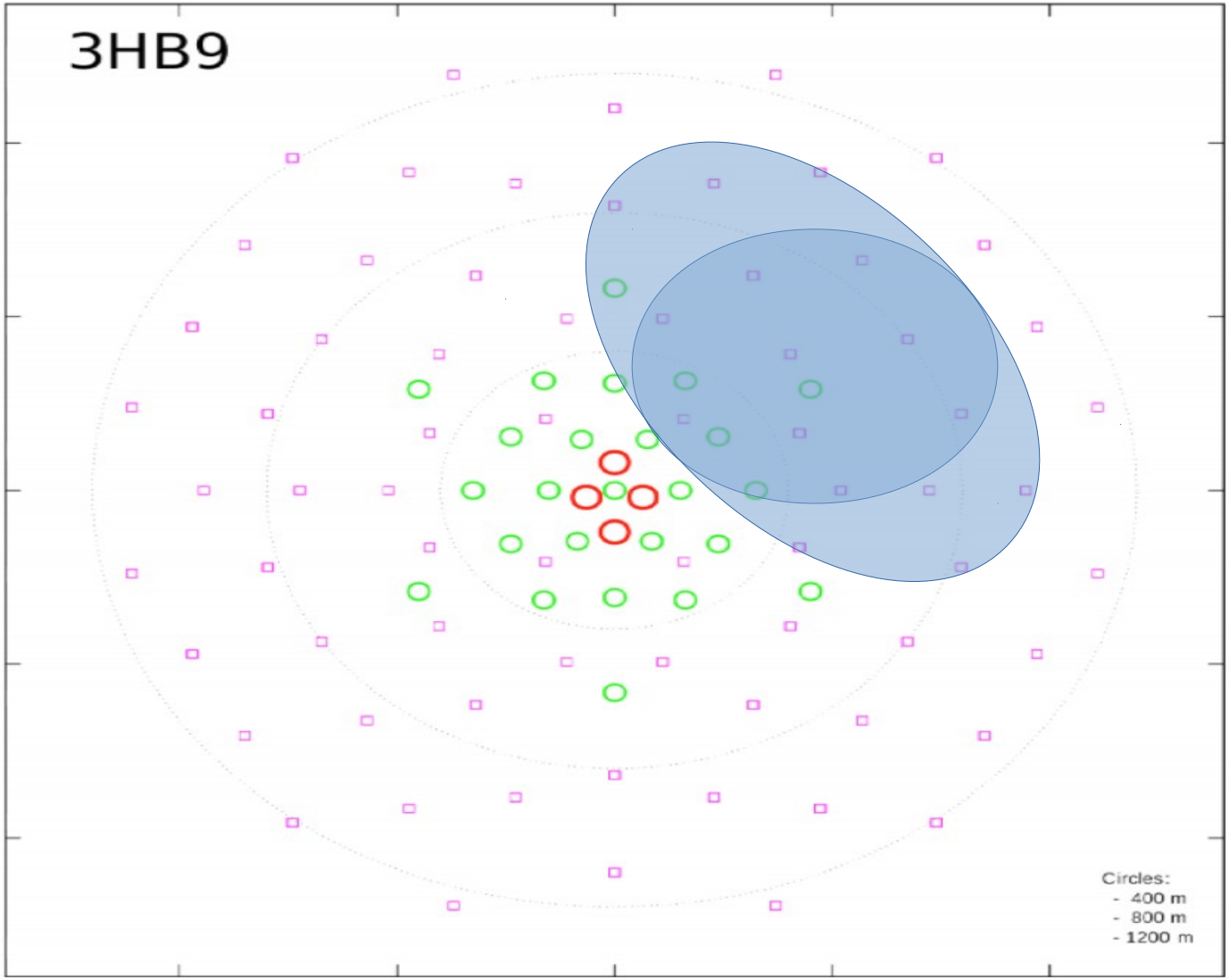
The ASTRI MiniArray (9 SST)







The ASTRI MiniArray (15 SST)



Type:

23-m LST
12-m MST
4-m SST

North (x) is up
West (y) is left

1000 m

The ASTRI SST-2M E2E prototype

We expect to detect
1 Crab flux level sources at 5-sigma in a few hours at E > 1 TeV

More information:
Vercellone et al., 2015, arXiv:1508.00799 (and references therein)

ASTRI SST-2M **innovative solutions**:

Dual-mirror optical layout
first time for VHE IACTs;
reduces the plate-scale;
optimal PSF across the entire FoV.

SiPMs photo-detectors
small pixel-size;
can work during moonlight;
fast front-end and control electronics;

Wide field-of view (9.6°)
excellent for:
extended sources, surveys;
allows to extend the energy range above 100 TeV.

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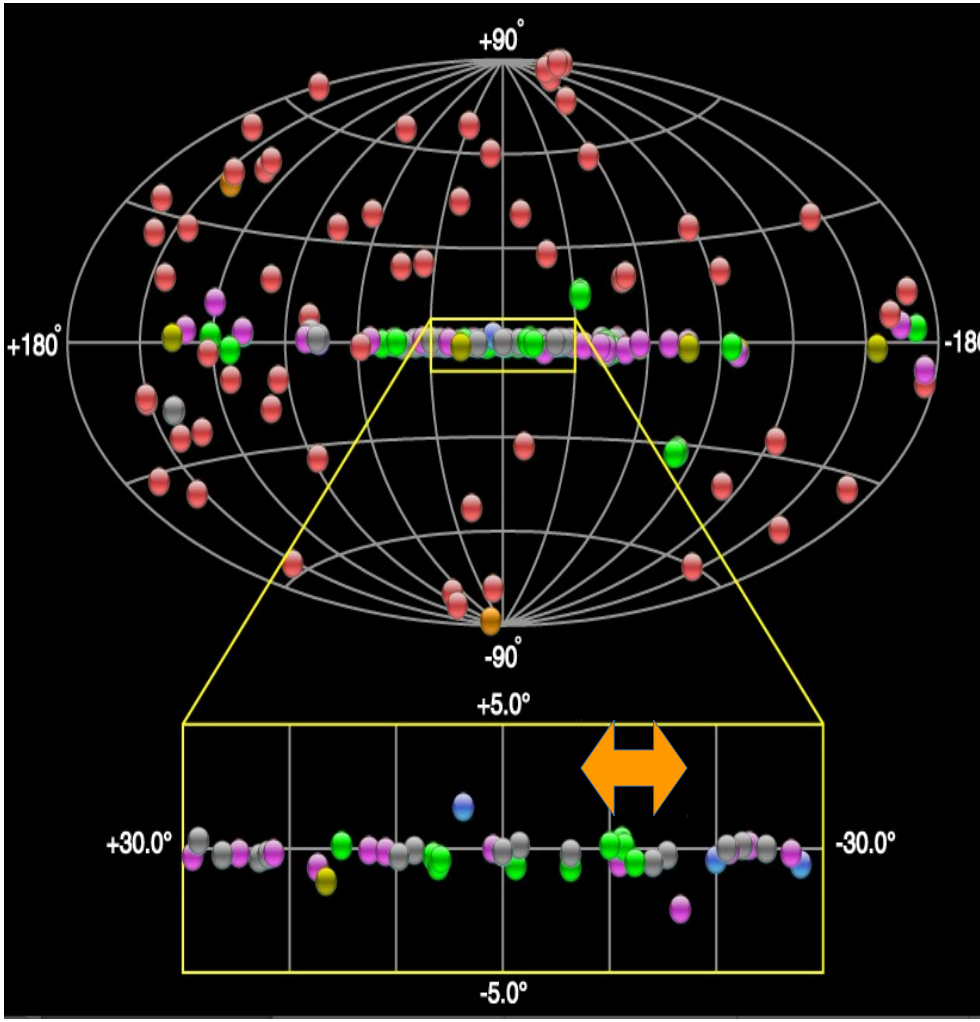
GALACTIC SCIENCE

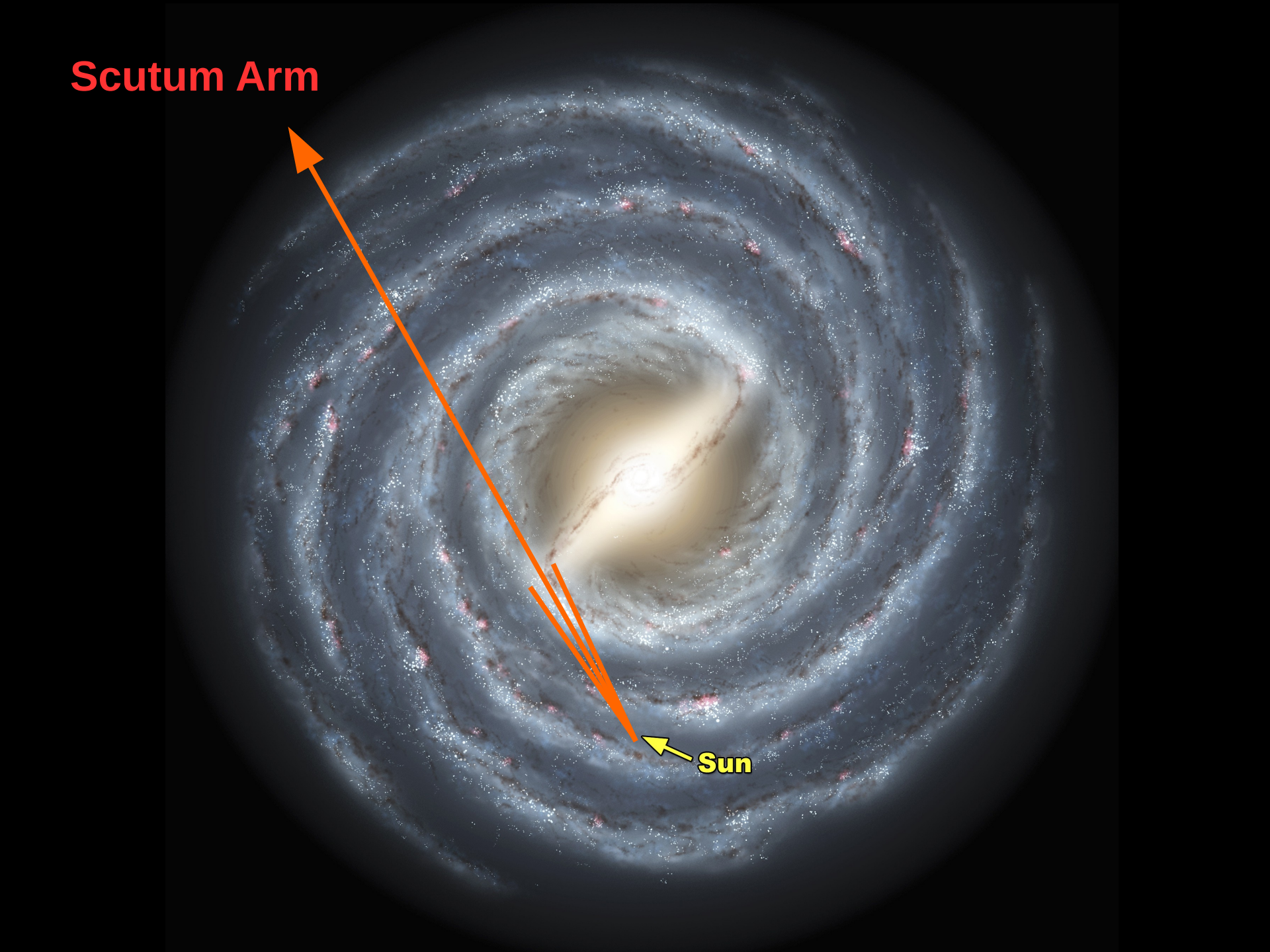
Large Field of View

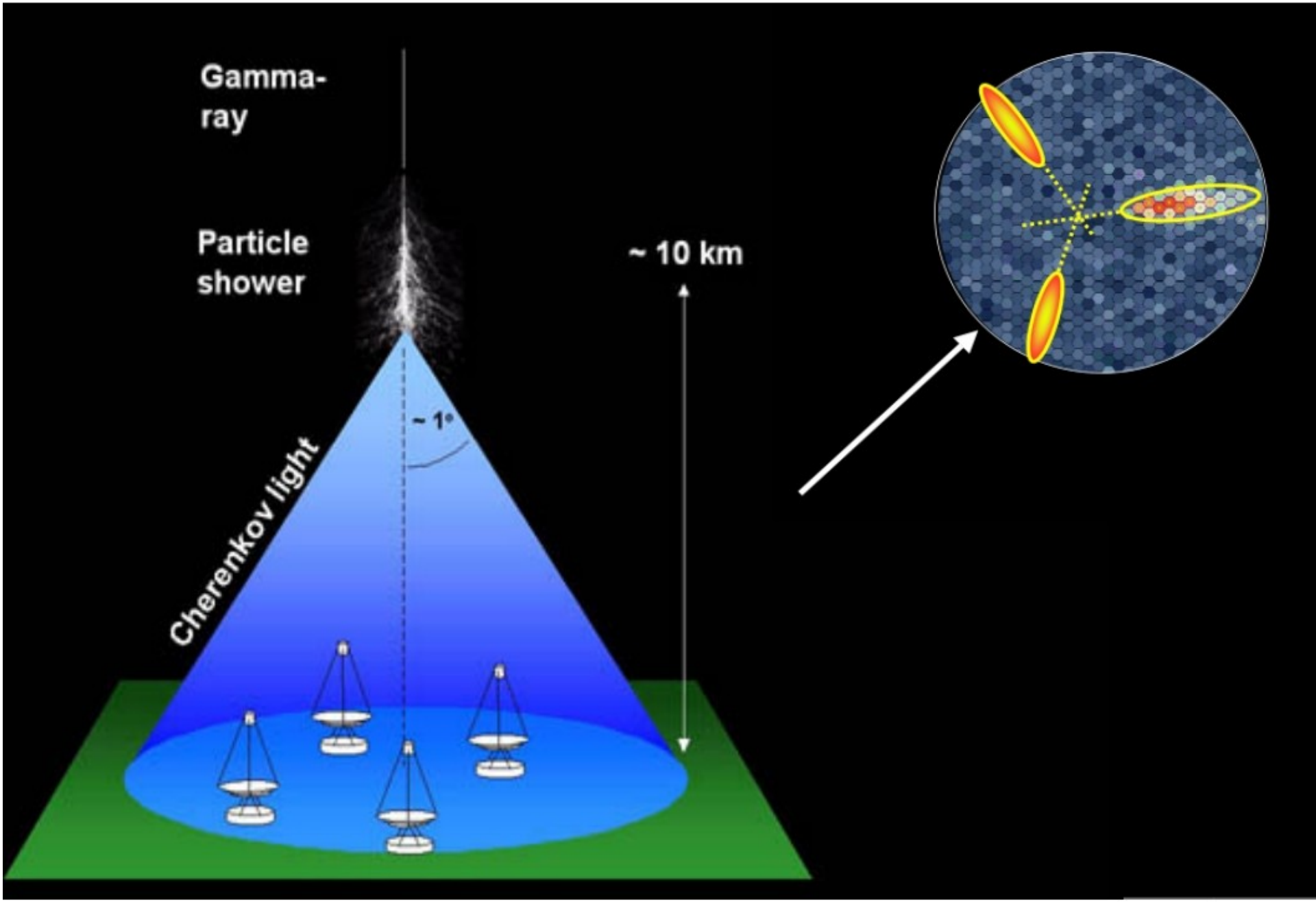
Large exposure of the Galactic plane

Multiple source observations

Transient and serendipitous sources




Scutum Arm
Sun


Gamma-ray
Particle shower
~ 10 km
~ 1°
Cherenkov light

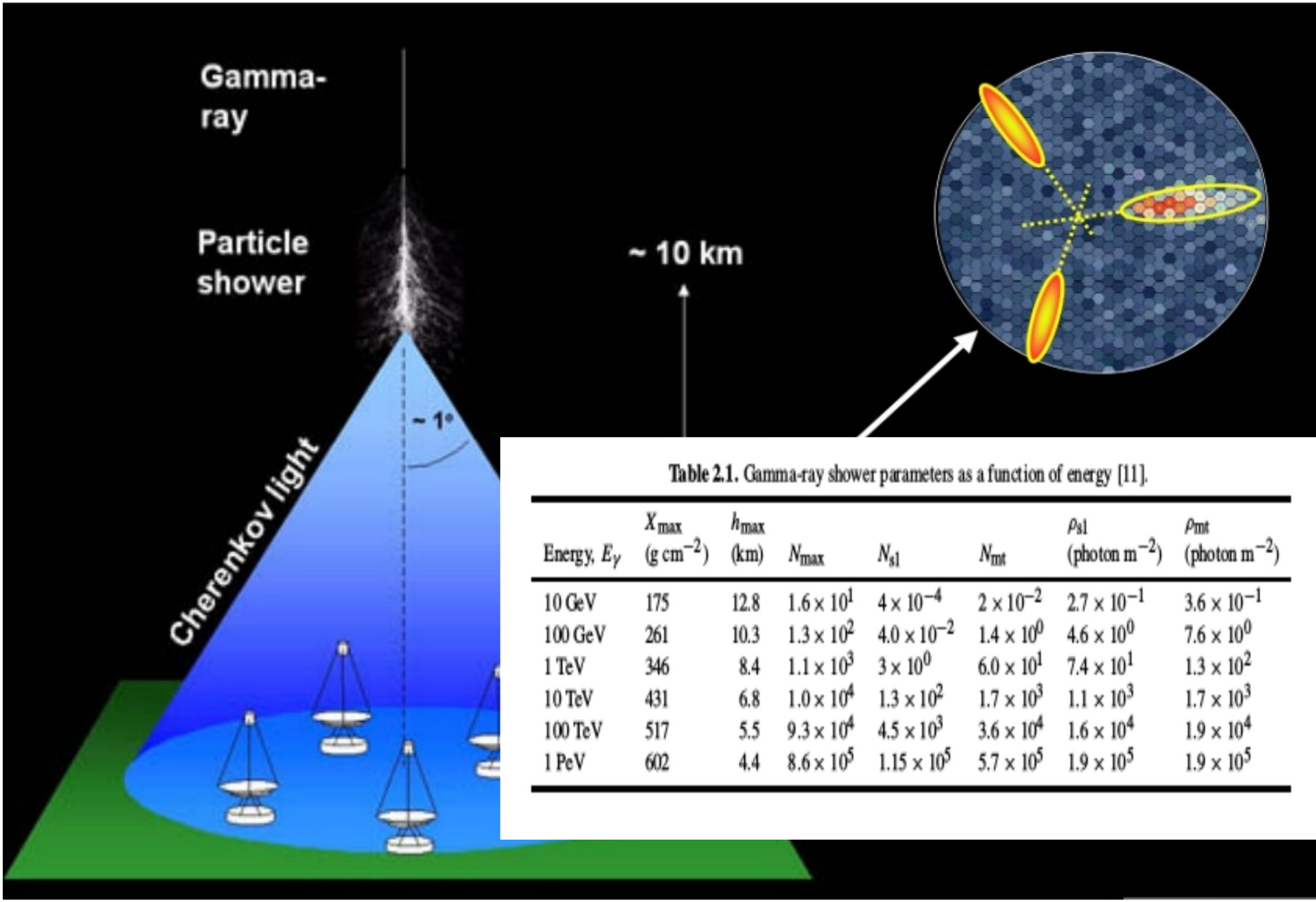
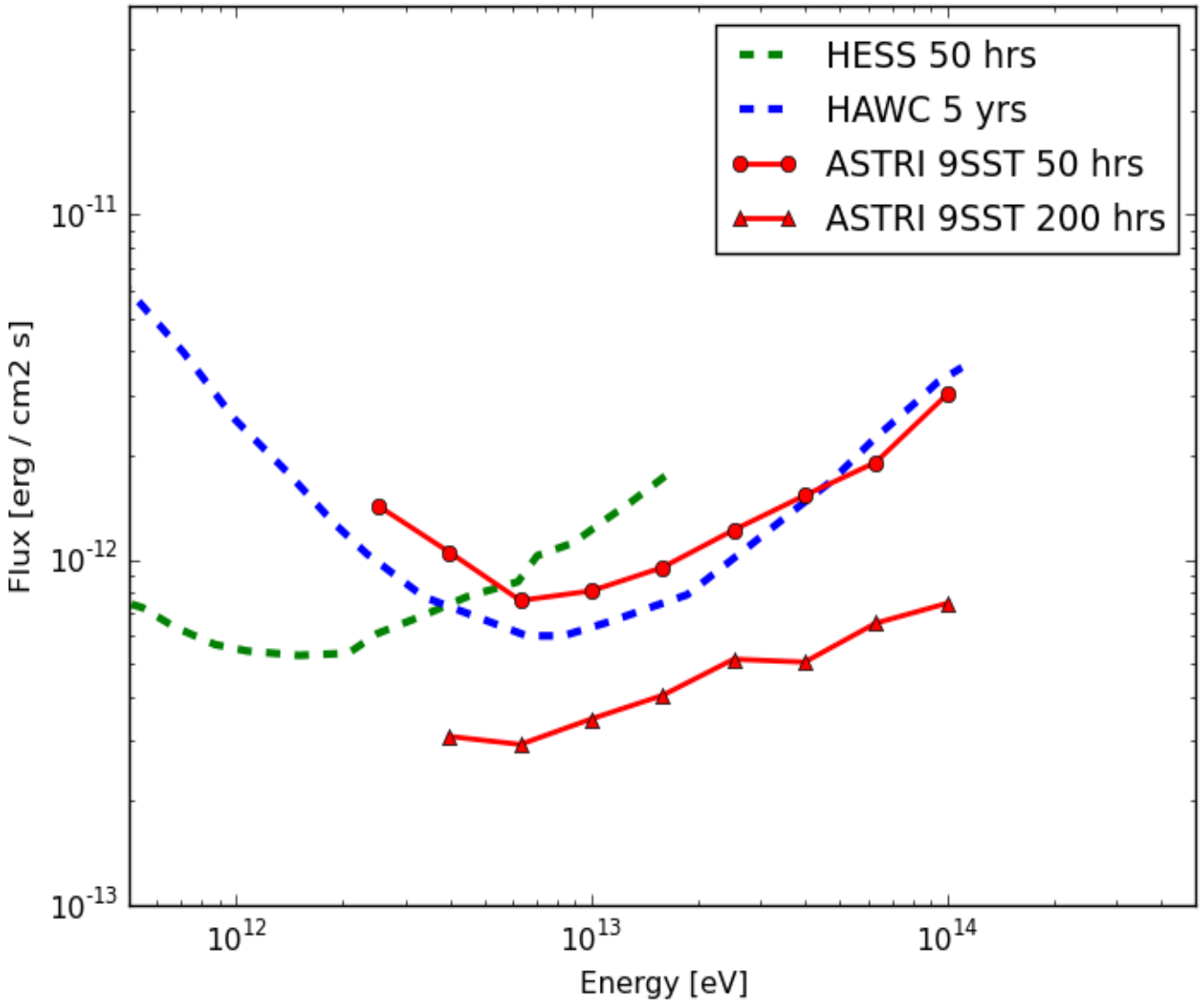


Table 2.1. Gamma-ray shower parameters as a function of energy [11].

Energy, E_γ	X_{max} (g cm^{-2})	h_{max} (km)	N_{max}	N_{sl}	N_{mt}	ρ_{sl} (photon m^{-2})	ρ_{mt} (photon m^{-2})
10 GeV	175	12.8	1.6×10^{1}	4×10^{-4}	2×10^{-2}	2.7×10^{-1}	3.6×10^{-1}
100 GeV	261	10.3	1.3×10^{2}	4.0×10^{-2}	1.4×10^{0}	4.6×10^{0}	7.6×10^{0}
1 TeV	346	8.4	1.1×10^{3}	3×10^{0}	6.0×10^{1}	7.4×10^{1}	1.3×10^{2}
10 TeV	431	6.8	1.0×10^{4}	1.3×10^{2}	1.7×10^{3}	1.1×10^{3}	1.7×10^{3}
100 TeV	517	5.5	9.3×10^{4}	4.5×10^{3}	3.6×10^{4}	1.6×10^{4}	1.9×10^{4}
1 PeV	602	4.4	8.6×10^{5}	1.15×10^{5}	5.7×10^{5}	1.9×10^{5}	1.9×10^{5}

HESS and Astri M.A. Sensitivity



Science with the ASTRI MA

The aim is to **test both the SST-2M technological and scientific performance** at energies above a few TeV by means of **prolonged pointings.**

Galactic science ➔ choose sky regions containing multiple targets.

Extra-galactic science ➔ select a few promising targets.

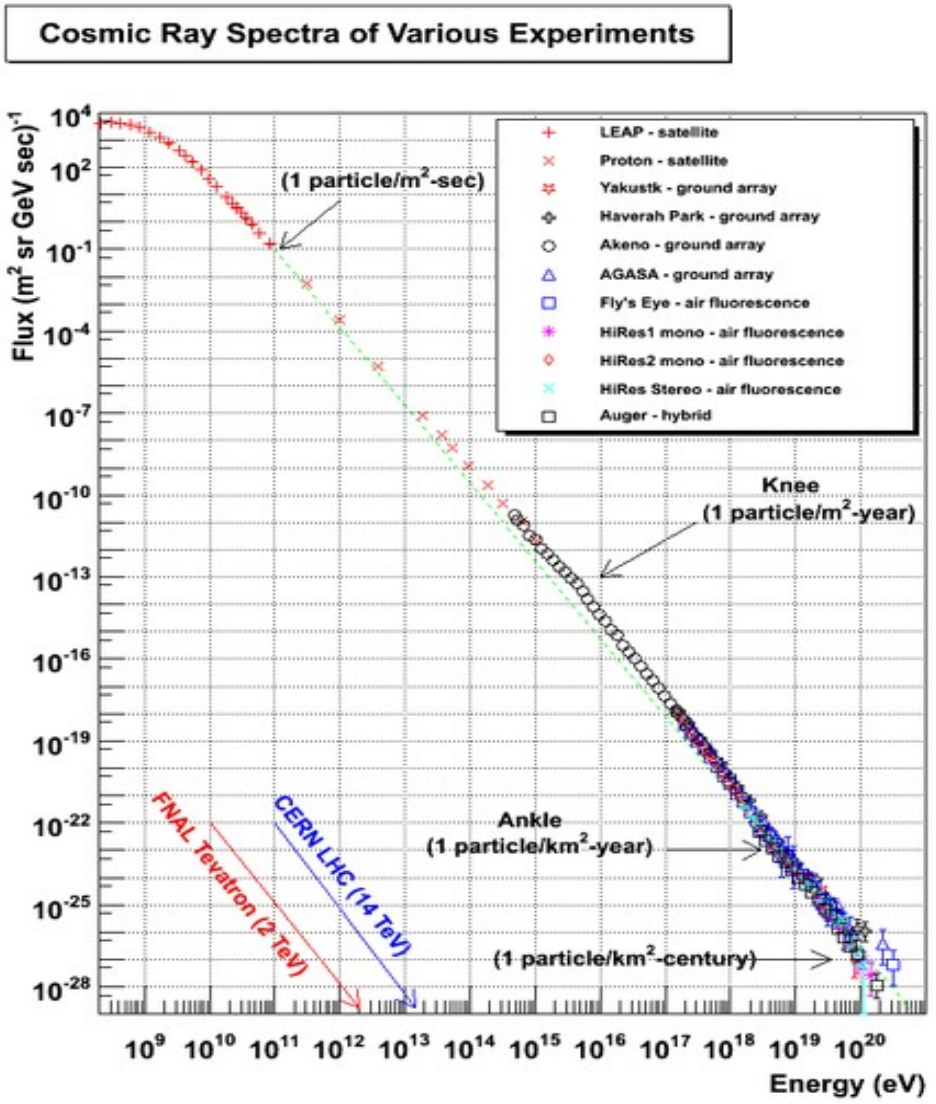
Fundamental Physics ➔ nearby blazars, GC, and dSphs.

Synergies with facilities dedicated to transient follow-ups are of paramount importance.

Pevatrons : Why ?

The simple shape of the spectrum suggests a common origin for CRs up to (at least) 10^{15} eV

→ Pevatrons



Pevatrons : What ?

Accelerators of protons (or nuclei) up to 1 PeV
(spectrum without cut-offs up to 1 PeV)

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Interaction with ISM gives gammas with energy up to ~ 10 % E_p

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Accelerators of protons (or nuclei) up to 1 PeV
(spectrum without cut-offs up to 1 PeV)

Interaction with ISM gives gammas with energy up to ~ 10 % E_p

→ *Hadronic gamma-ray emission,*
<u>with without cut-offs</u> up to ~ 100 TeV

Pevatrons : Where ?

SN Remnants ? *can accelerate of CRs !*

but still no evidence SNR = Pevatron

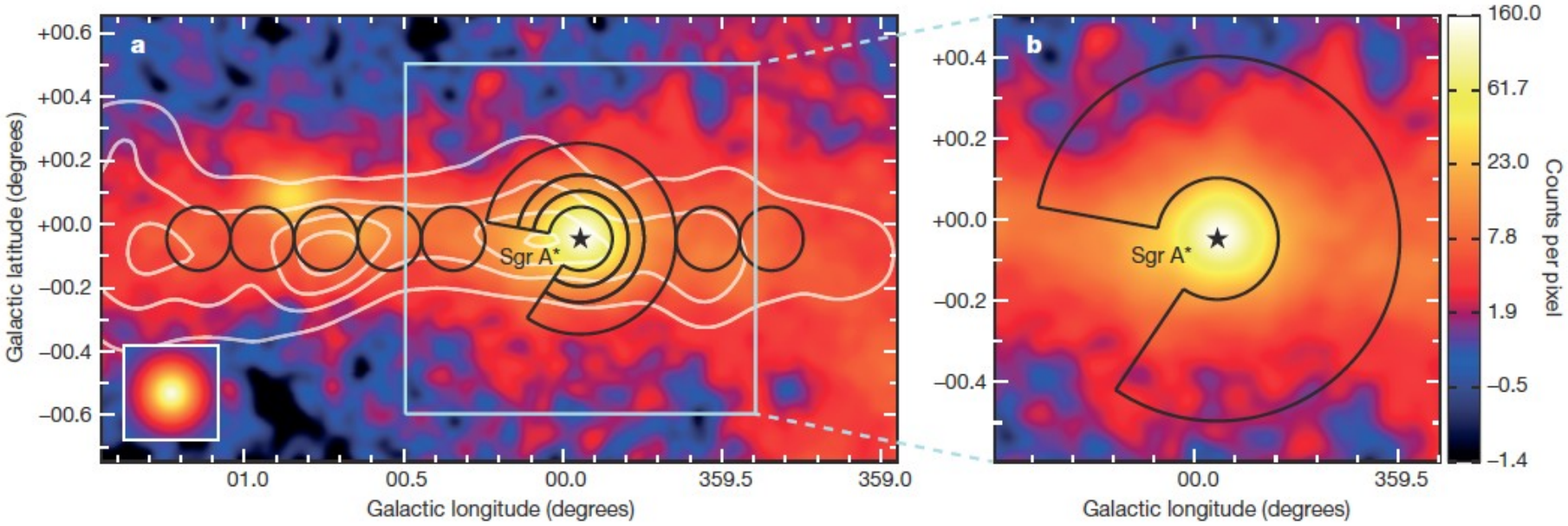
Hot result !

LETTER

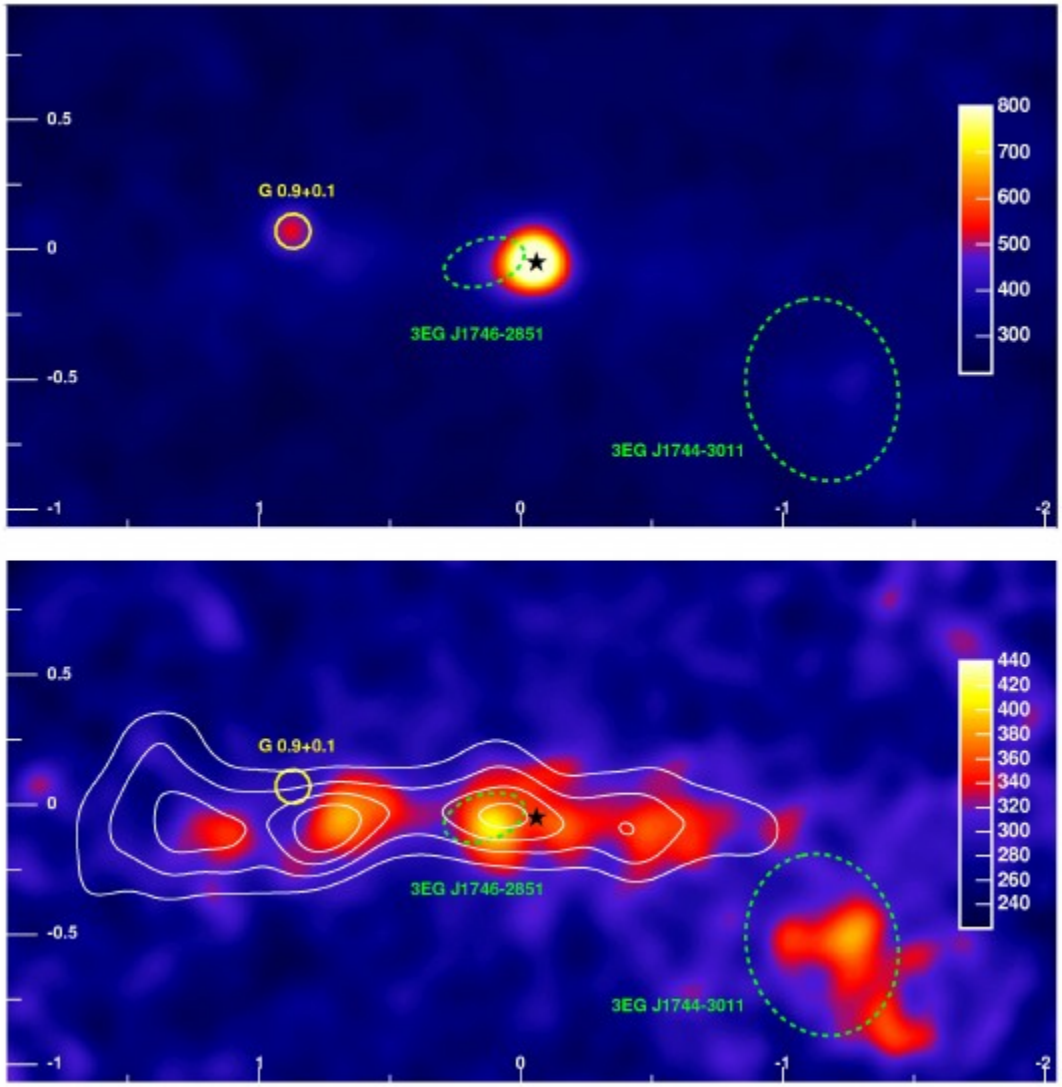
doi:10.1038/nature17147

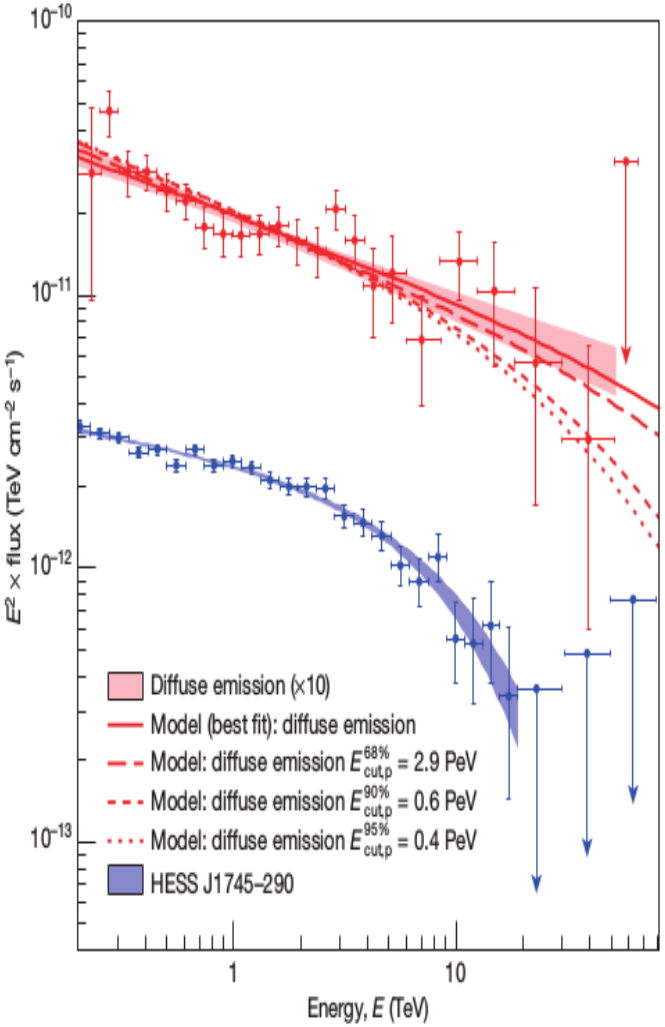
Acceleration of petaelectronvolt protons in the Galactic Centre

HESS Collaboration*

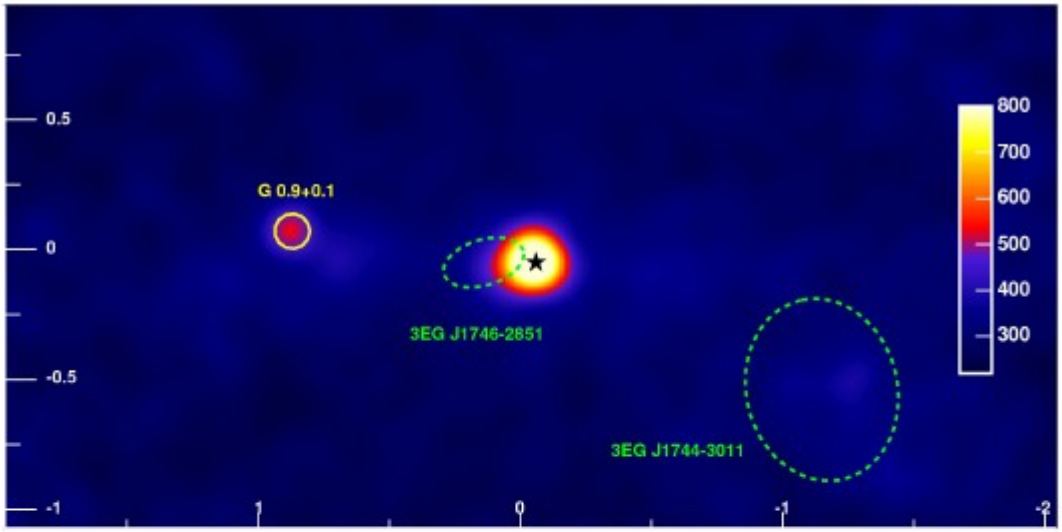


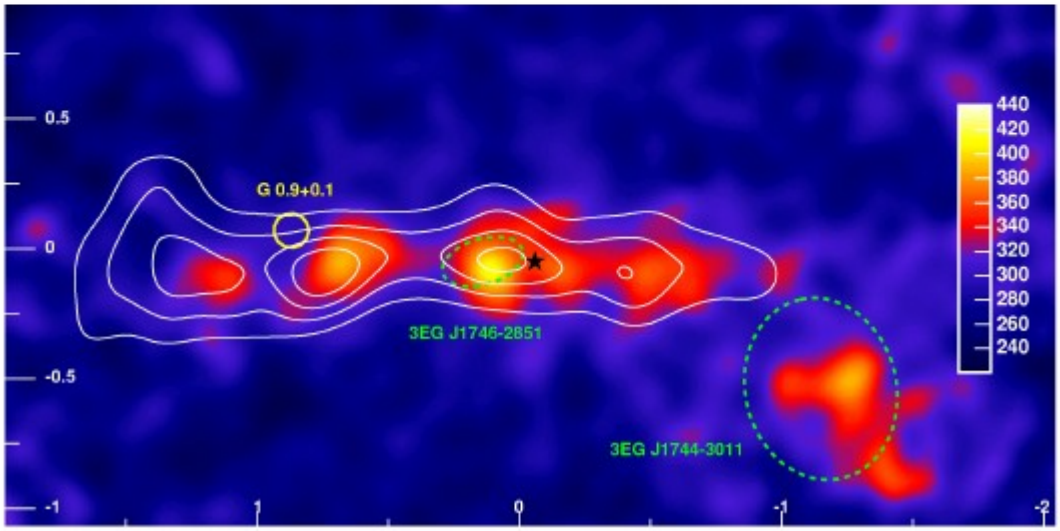
GALACTIC SCIENCE

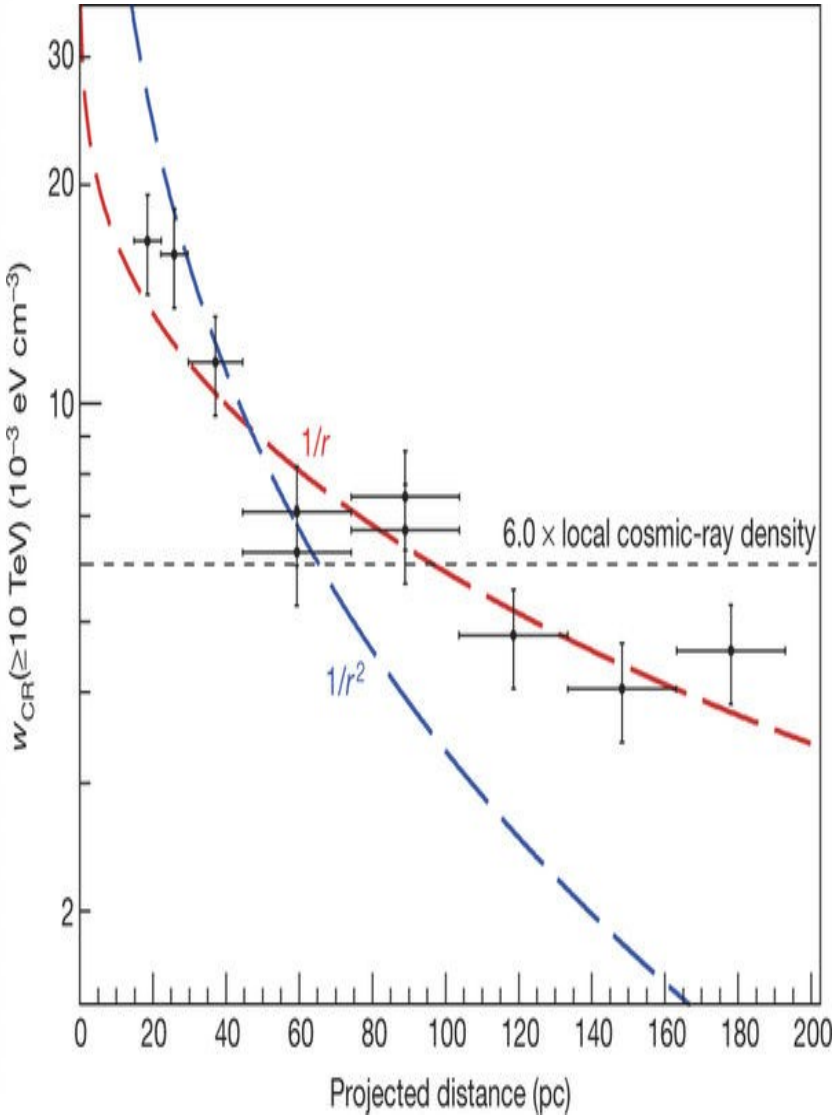




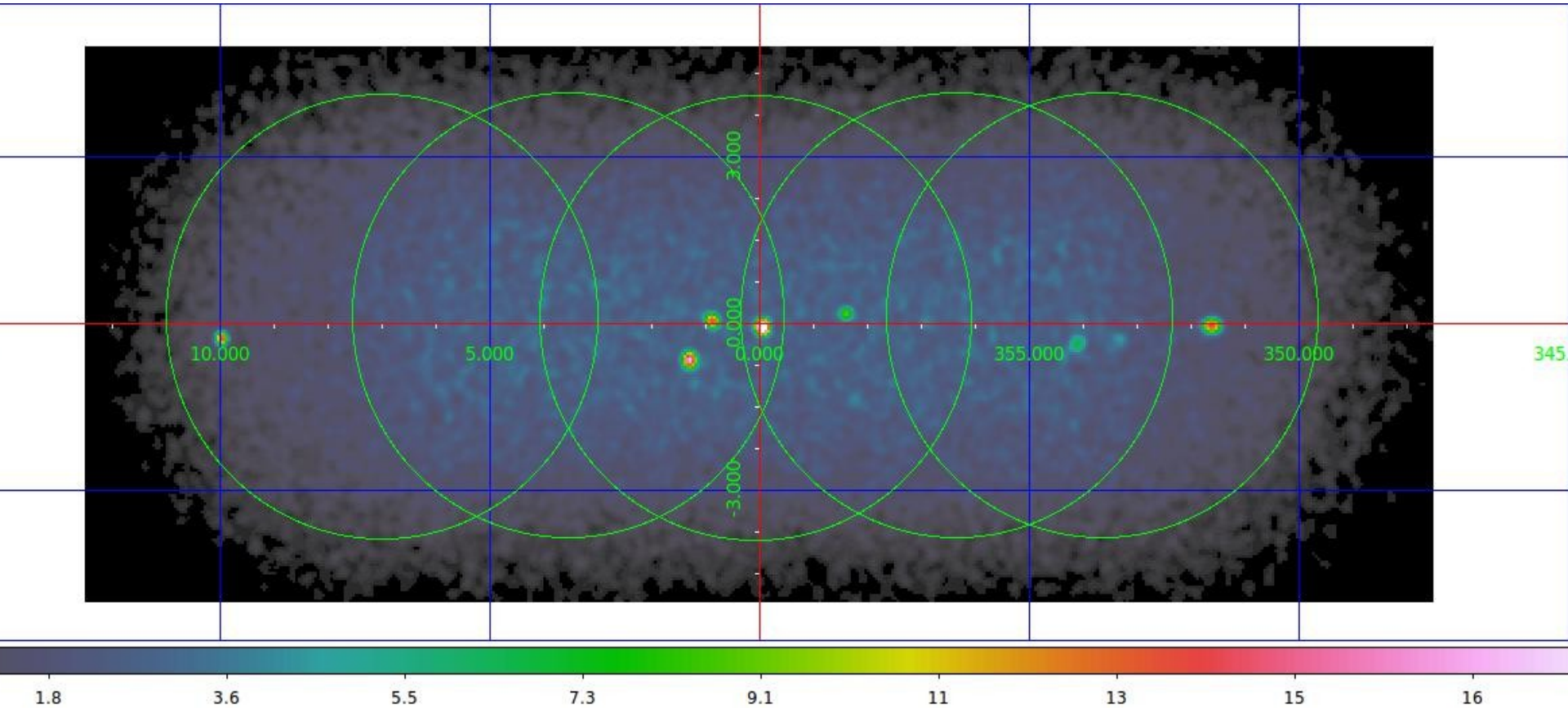
GALACTIC SCIENCE







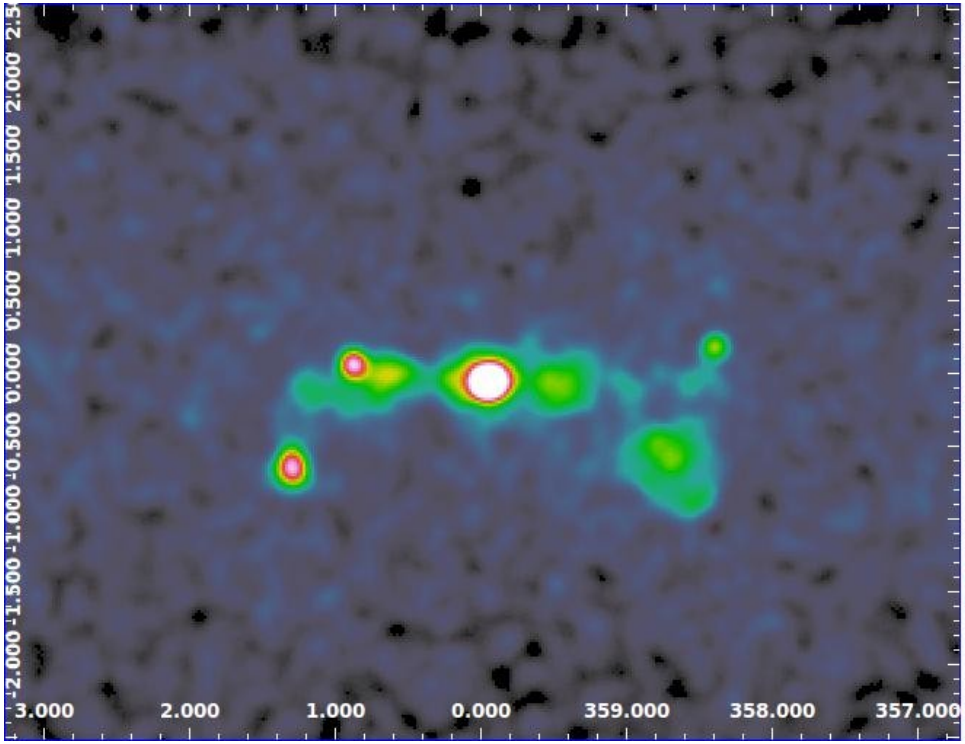
Galactic Center Simulation



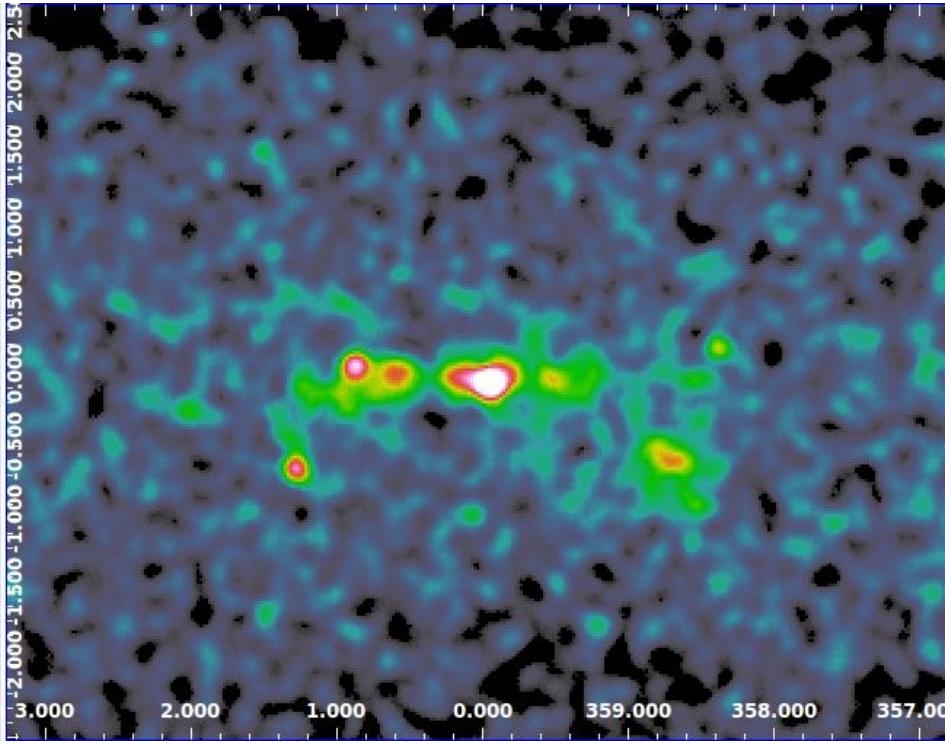
ASTRI mini-array simulation of the Galactic Center

Galactic Center Simulation

E > 5 TeV



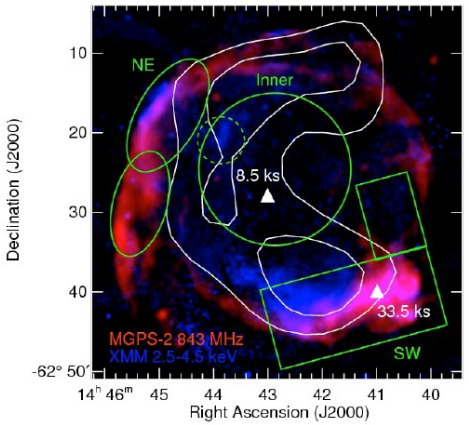
E > 15 TeV

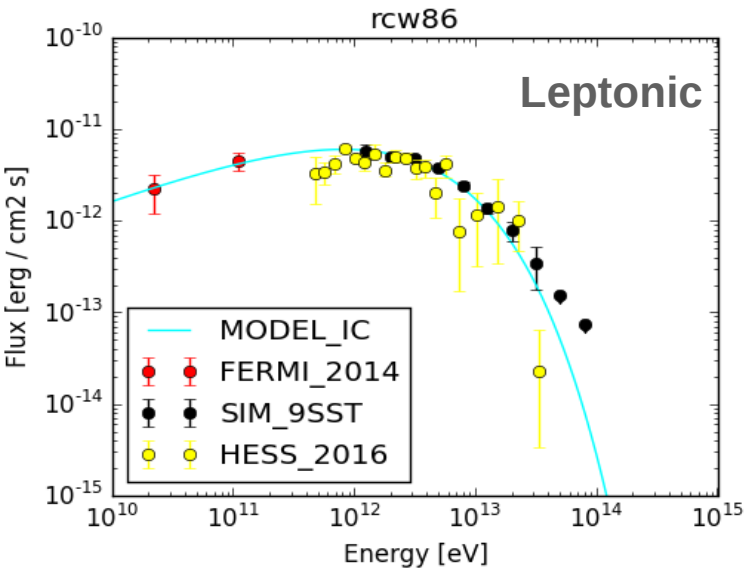


SNR RCW 86

Fairly young SNR (2000 yrs)

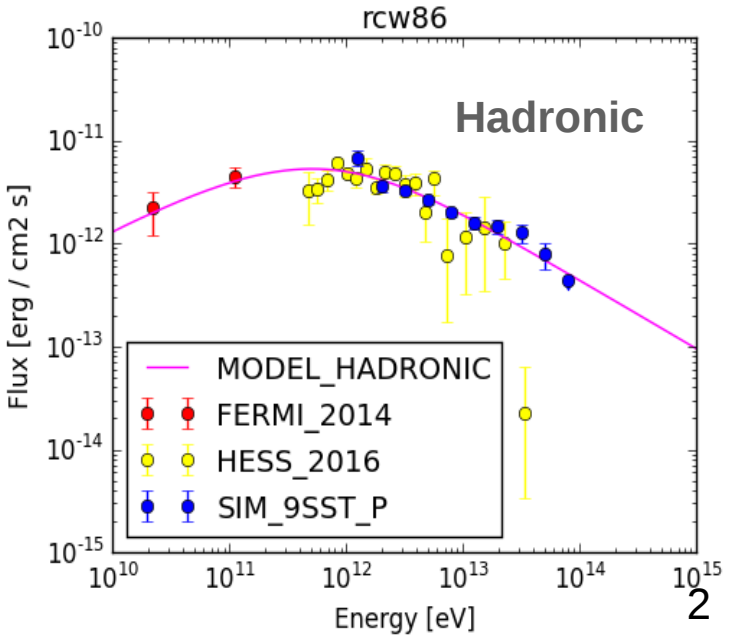
Seen in Radio, X, GeV (*Fermi*), TeV (H.E.S.S.)





Debated origin:
interacting source with molecular clouds or RX J1713-like source ?

ASTRI mini-array (black/blue points, simulated data) can discriminate between hadronic and leptonic scenario and (if hadronic) look for VHE(~5x10^{14} eV) CRs



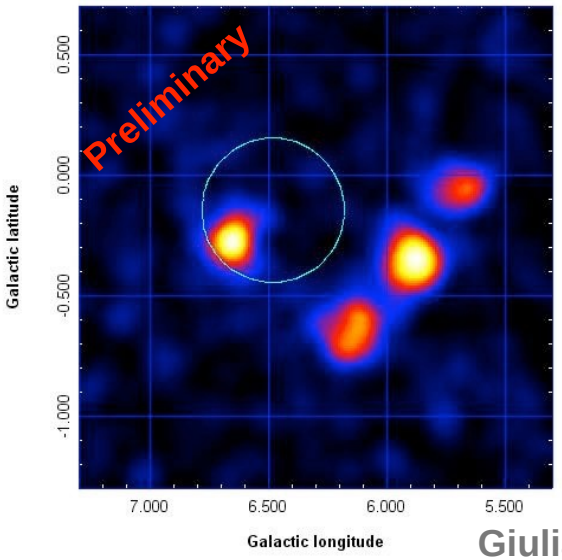
SNR W28

Evolved SNR interacting with a giant molecular cloud (MC), very bright at TeV energies

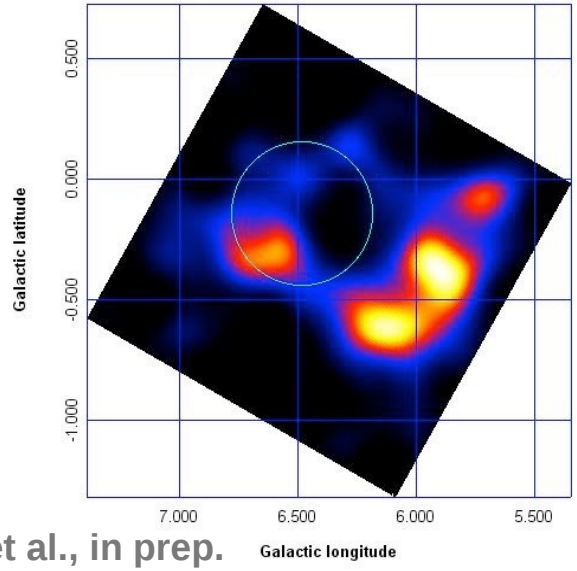
H.E.S.S. resolved this source in almost 4 point-like sources near the MC

ASTRI mini-array can better resolve the source and study the diffusion of CR far from the SNR shell (blue circle)

ASTRI mini-array simulation



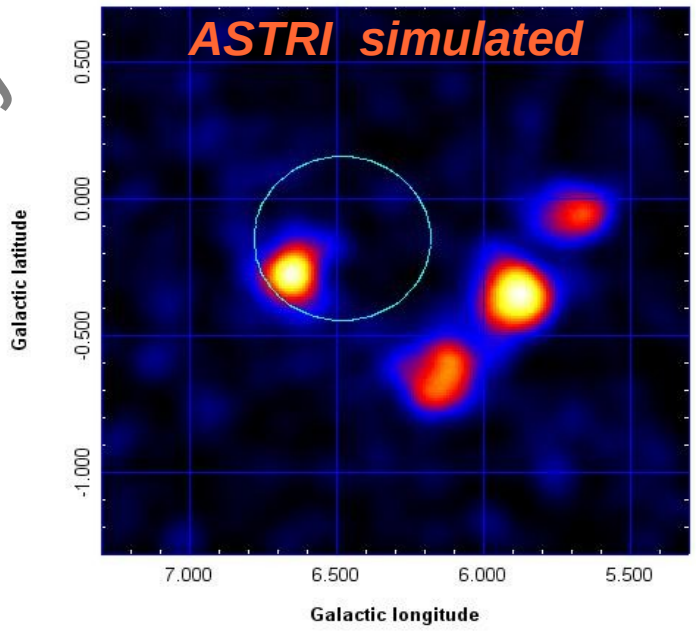
H.E.S.S. data

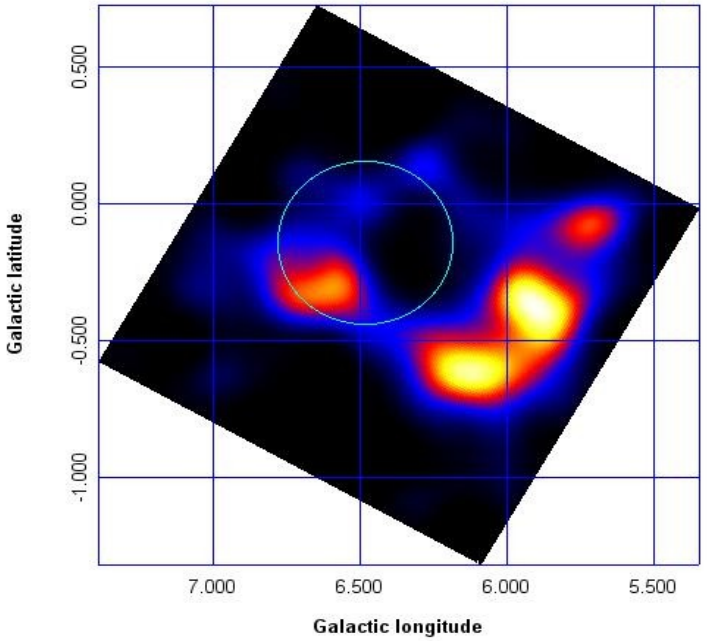


Giuliani et al., in prep.

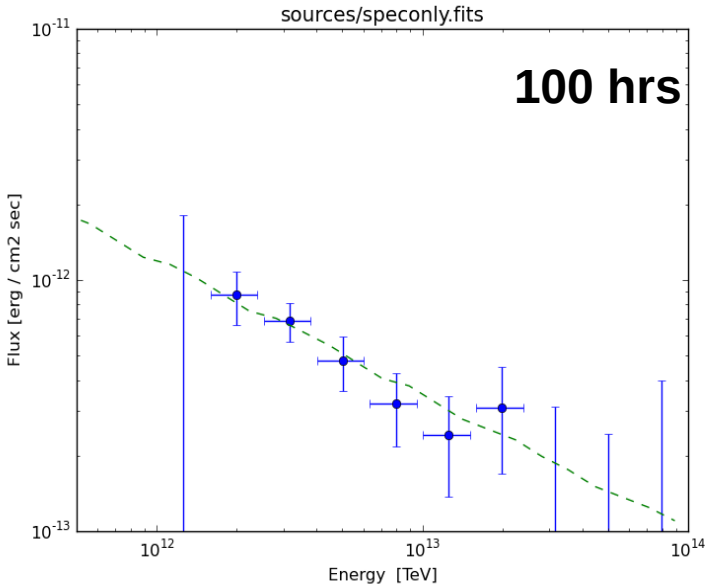
SNR W28

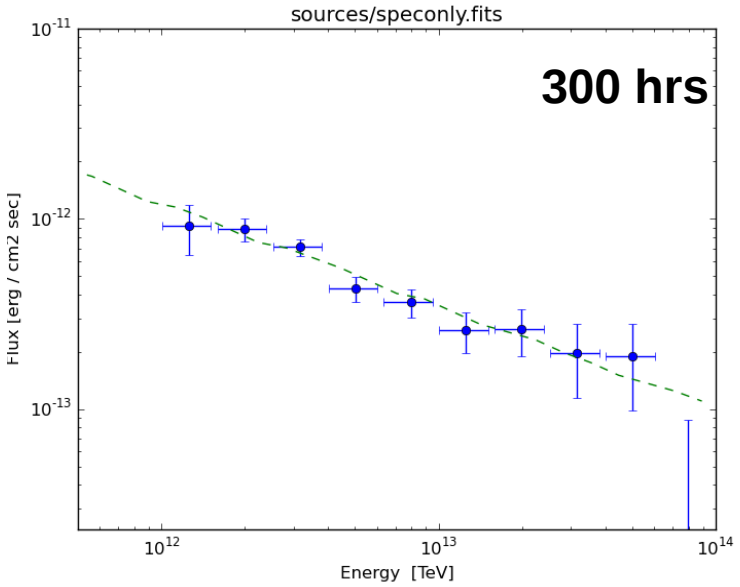
Morphology



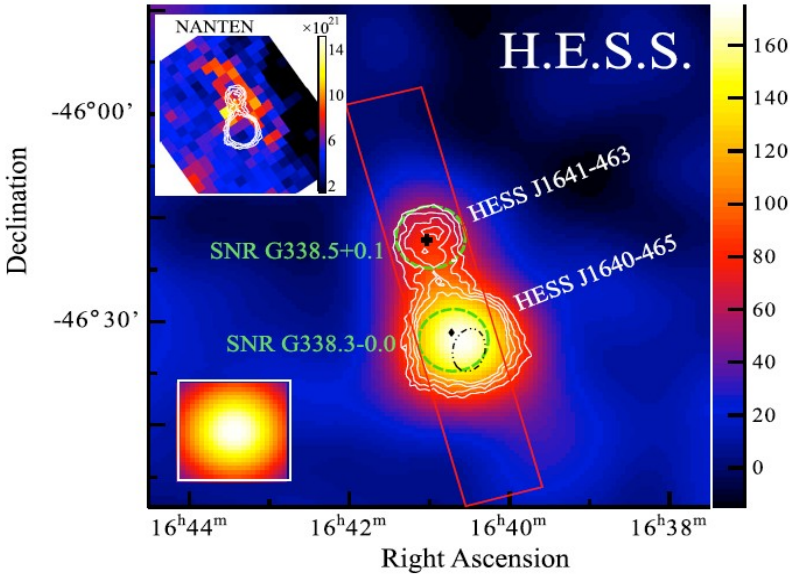


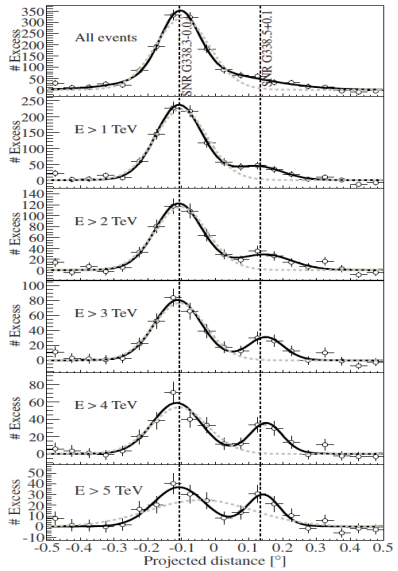
Spectrum





Un ID Sources : HESS J1641-463

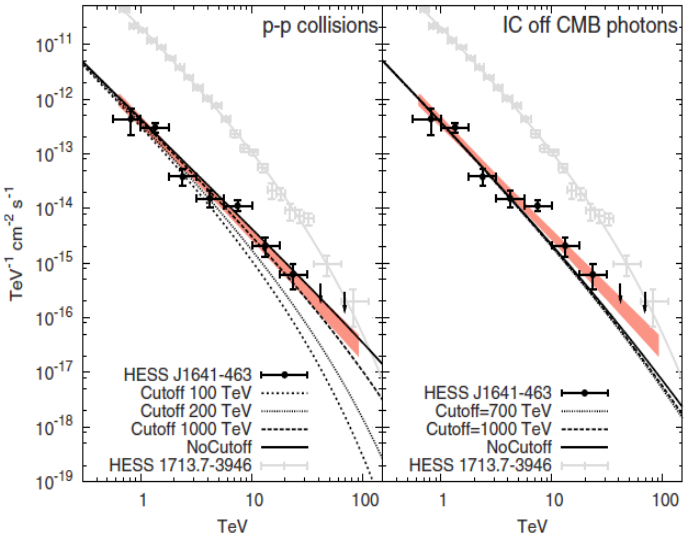




Hard source Ph. Index~2.1
Uncertain nature

Simulations by the ASTRI Science Team

Abramowski +14



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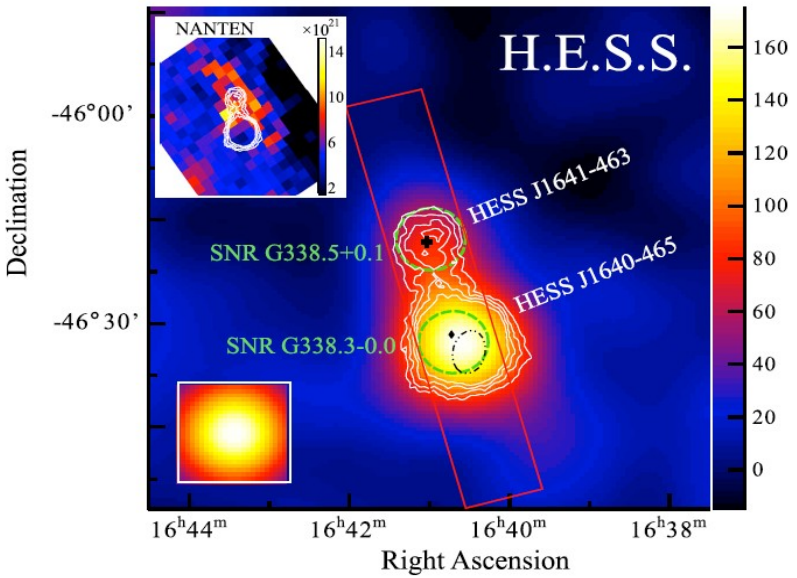
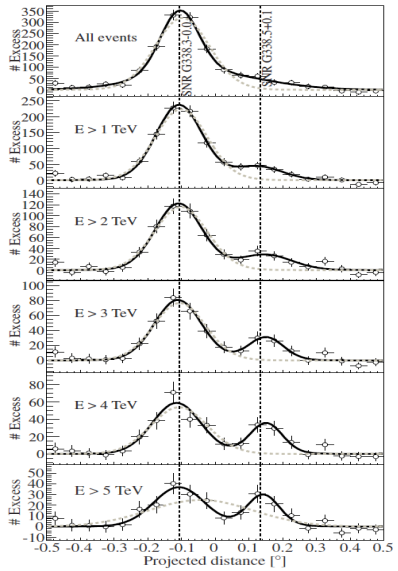
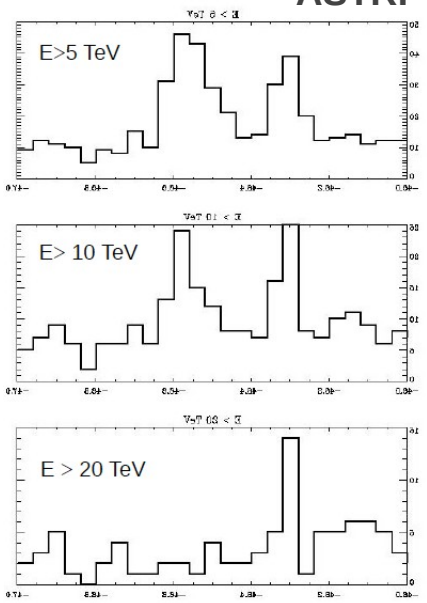




ASTRI



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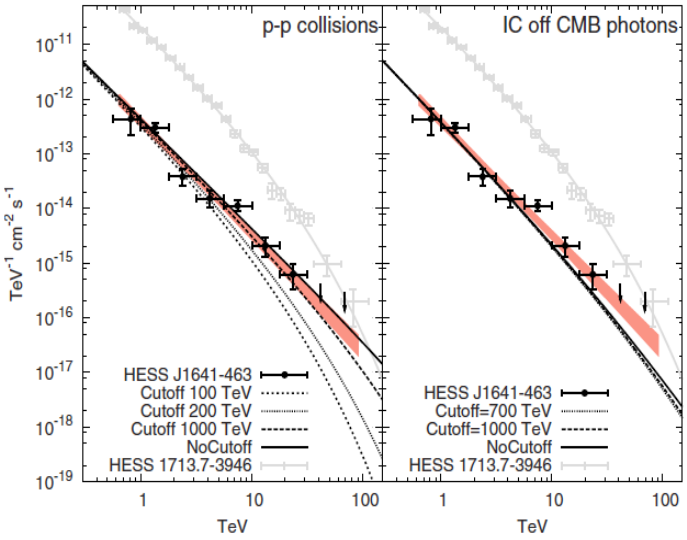
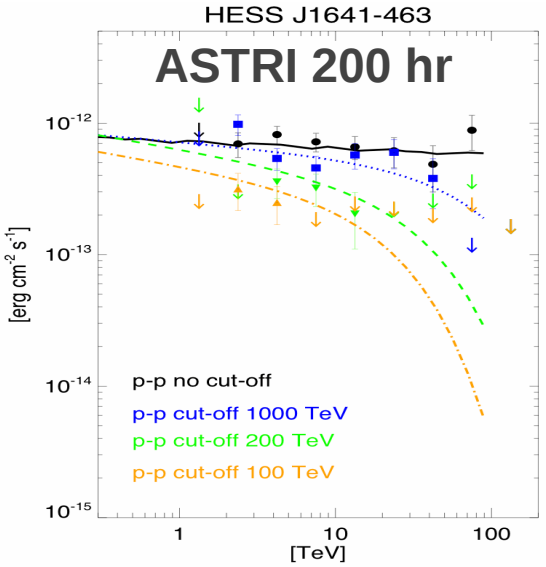
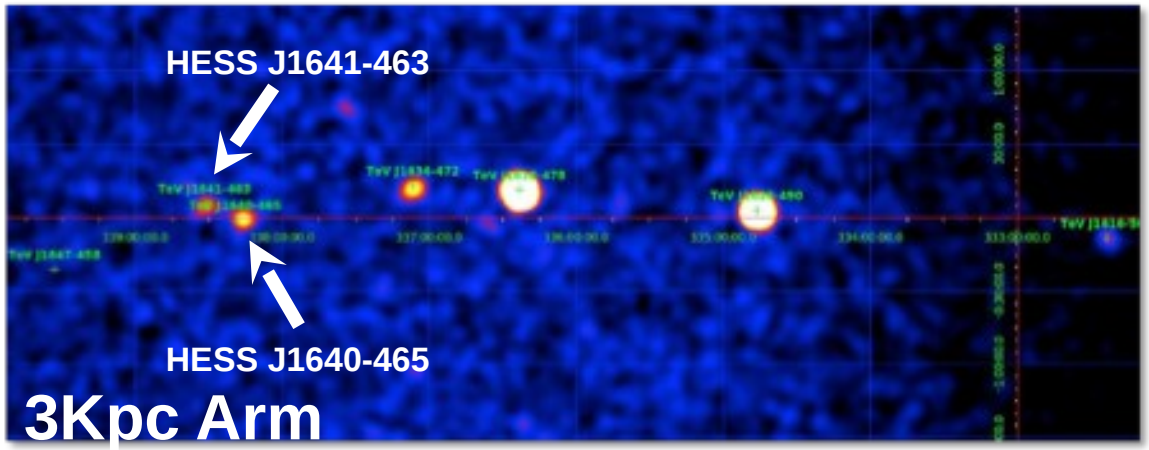
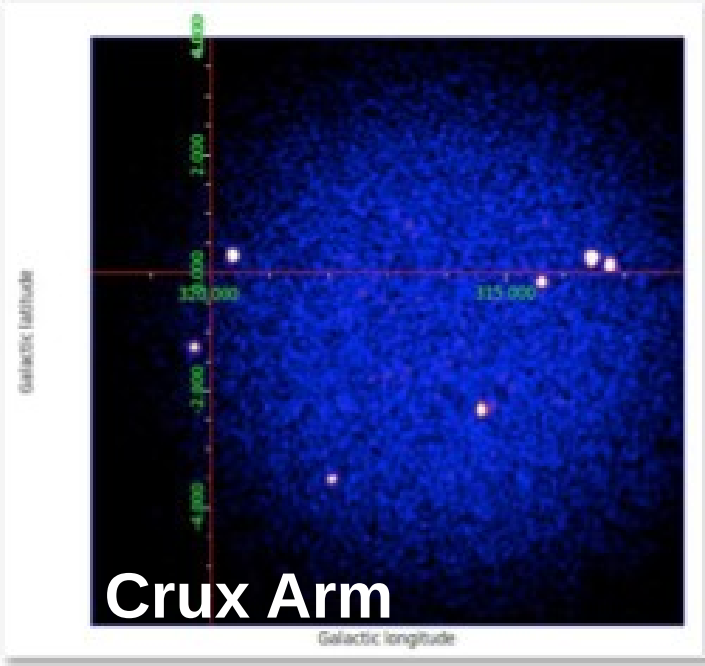
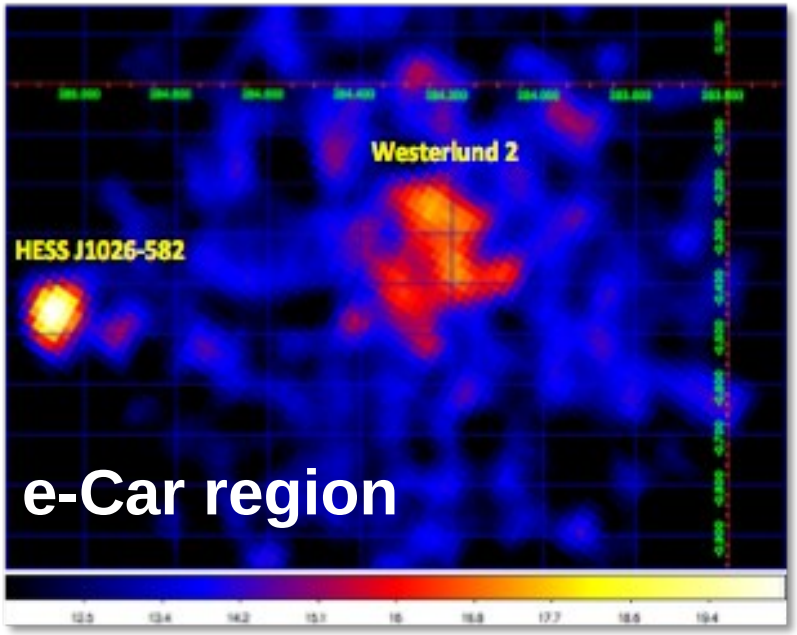




e wide field of view and our Galaxy







Deep observations of Galactic Arms

Simulation based on the current performance of the ASTRI mini-array of pre-production CTA telescopes (by means of a dedicated SW).

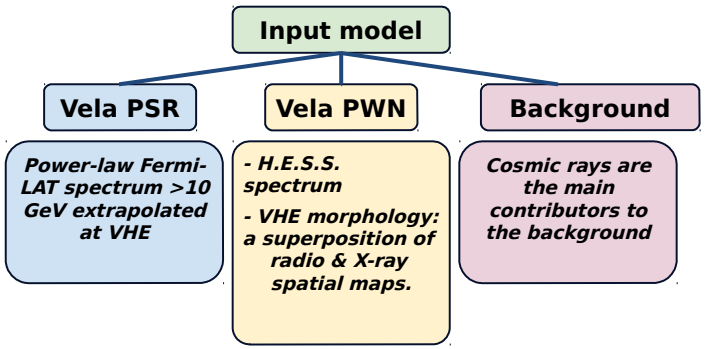
Imaging the Vela X region with ASTRI

I. Simulation of the VHE emission

- To simulate extended emission from the Vela PWN, we created radio and X-ray templates, adopting archival high-resolution observations of MOST and ROSAT telescopes

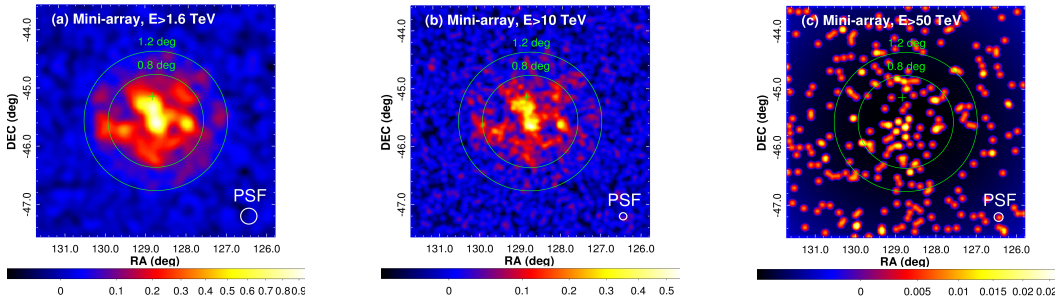
II. Configuration

-. ASTRI mini-array [*9 ASTRI SST-2M*]

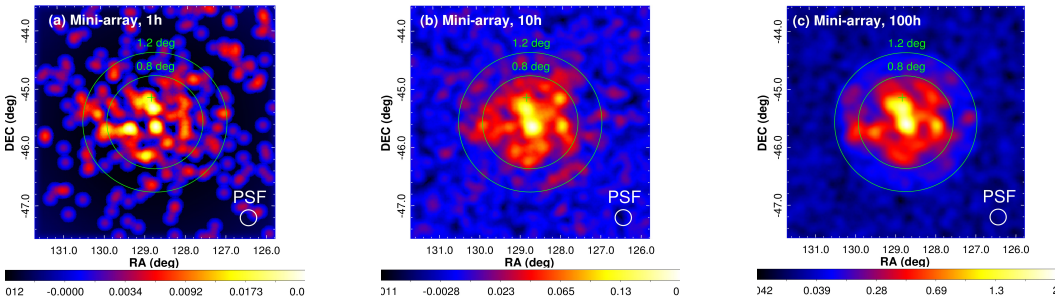


III. Simulated residual maps of the Vela X region

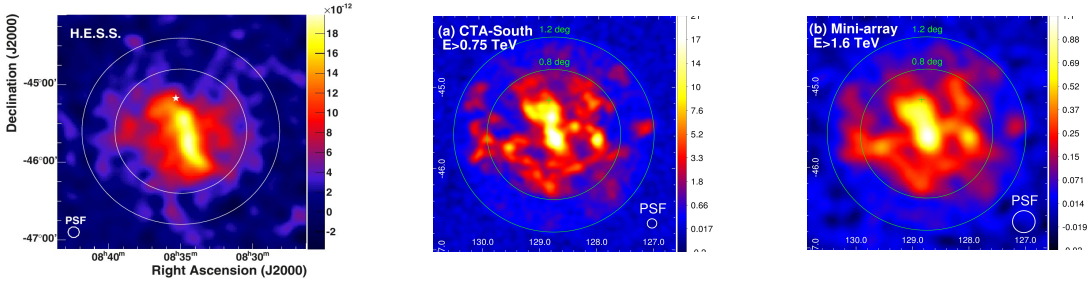
- for the ASTRI mini-array (50h):



- for the ASTRI mini-array (*E*>1.6 TeV):



- H.E.S.S. vs CTA-South vs ASTRI mini-array (~50h):



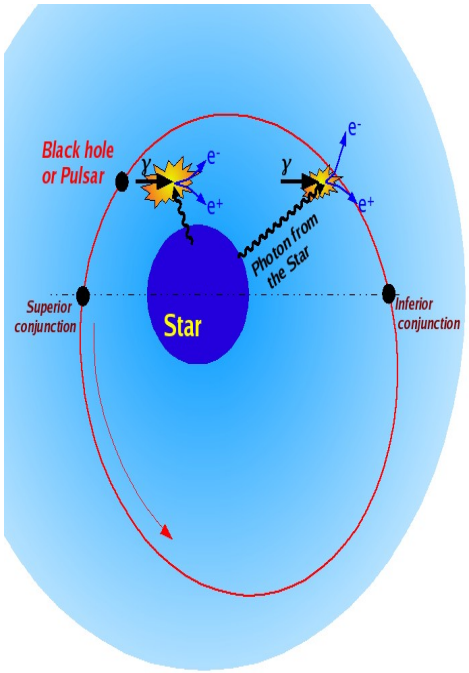
Notes. *The cross/star marks to the Vela PSR position.*
ASTRI simulations are performed using ASTRIsim software.

IV. Results

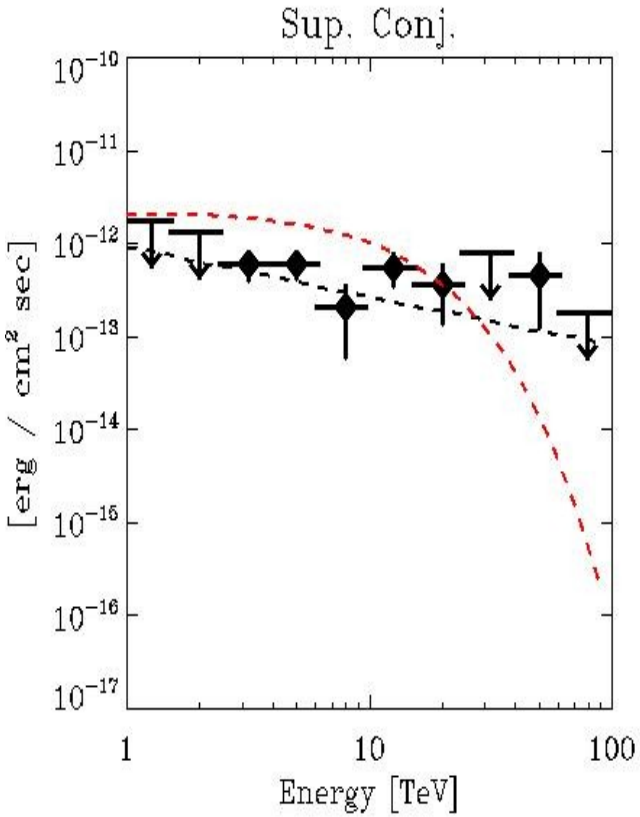
- **Using *ASTRIsim*, we simulated the VHE Vela X diffuse emission**
  - → ASTRI mini-array will be able to determine the contributions of the radio and X-ray populations with an accuracy of a several percent (for 50h, >1.6 TeV)
  - → We obtained that the radio-like and X-ray-like components can be distinguished with ASTRI, if the contribution from either the radio or X-ray population is more than 10% of the total VHE flux of Vela X (for 50h, >1.6 TeV)
- **The Vela PWN will be detected (5σ) with the ASTRI mini-array in several hours**
- **Within 50-100 hours it will be possible to perform detailed morphological and spectral studies with the ASTRI mini-array at 1-100 TeV energies**

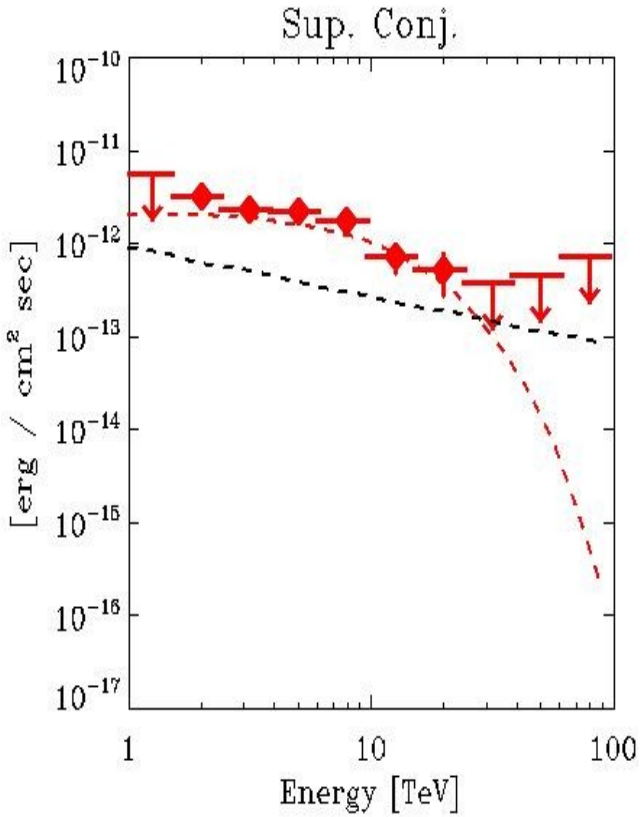
A. Burtovoi, L. Zampieri, A. Giuliani

LS 5039

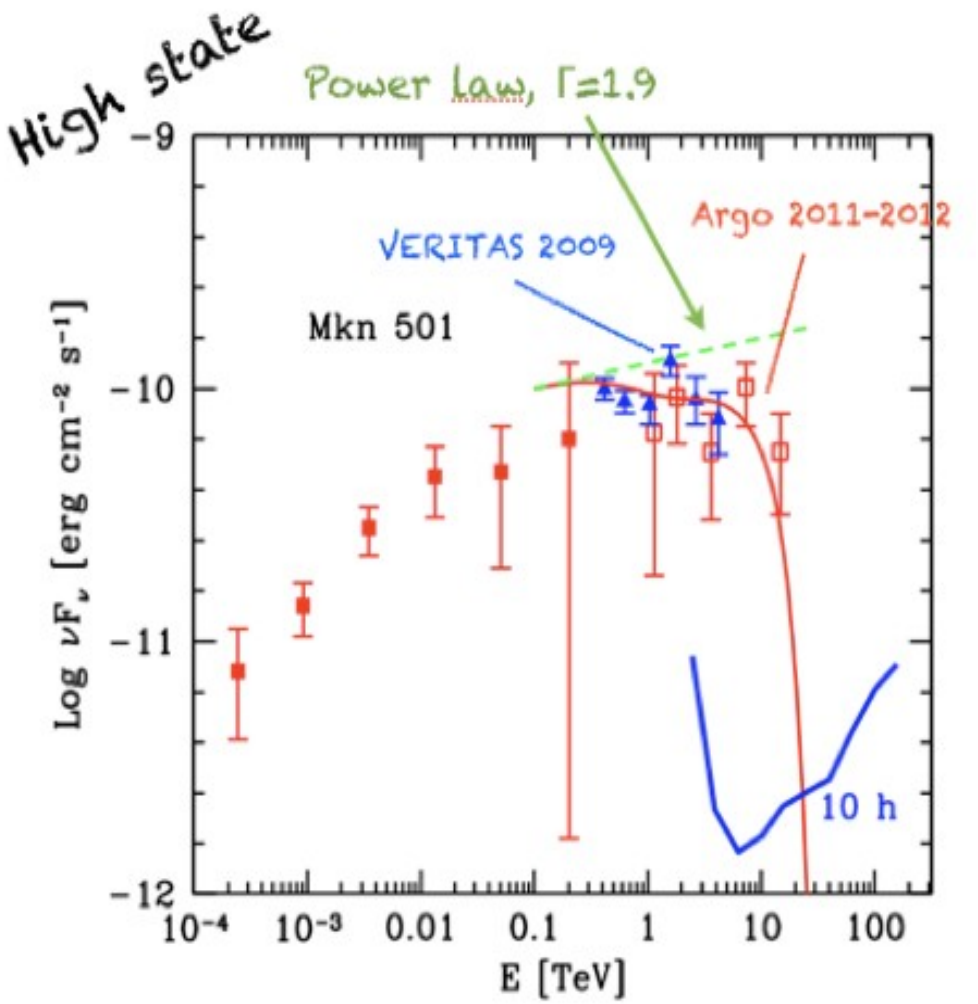


Observer

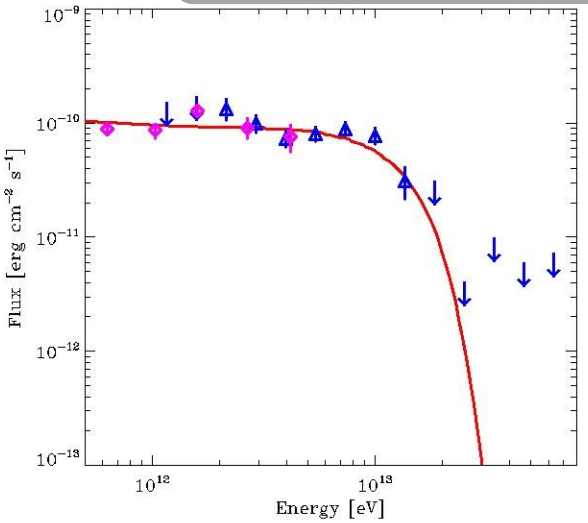




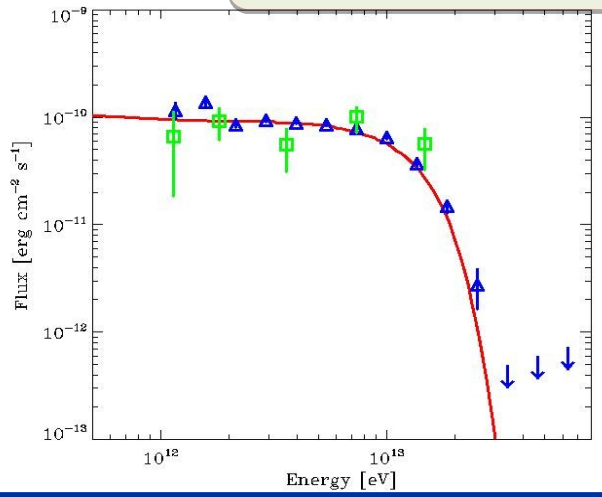
ASTRI mini-array: a MKN 501 Giant Flare



VERITAS 2.5 h
9 ASTRI SST (2 h)

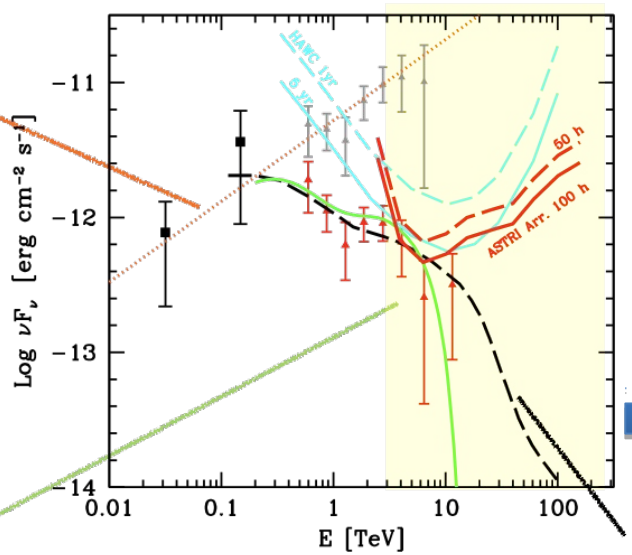


ARGO 2011-2012
9 ASTRI SST (20 h)

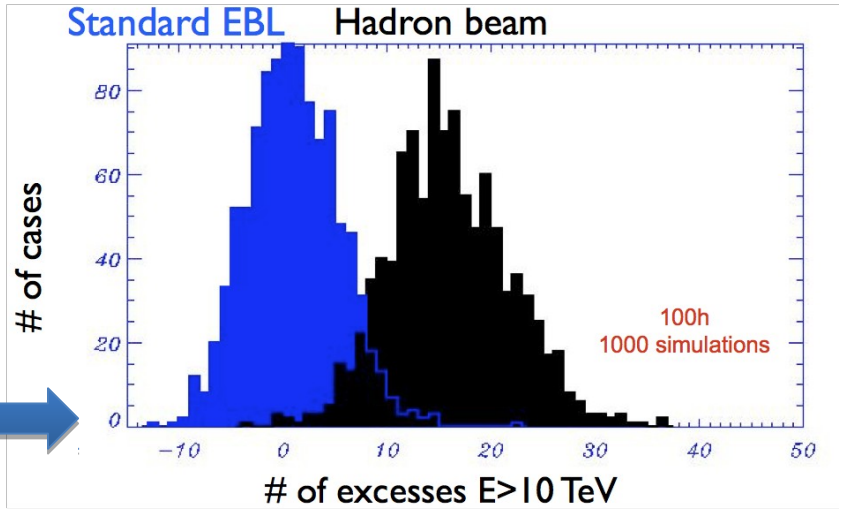


1ES 0229+200: the Rosetta stone of E-HBLs

Standard – deabsorbed



Standard EBL

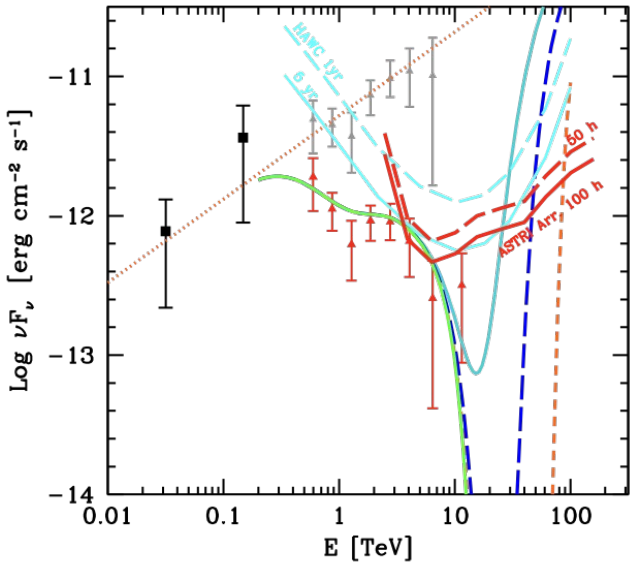


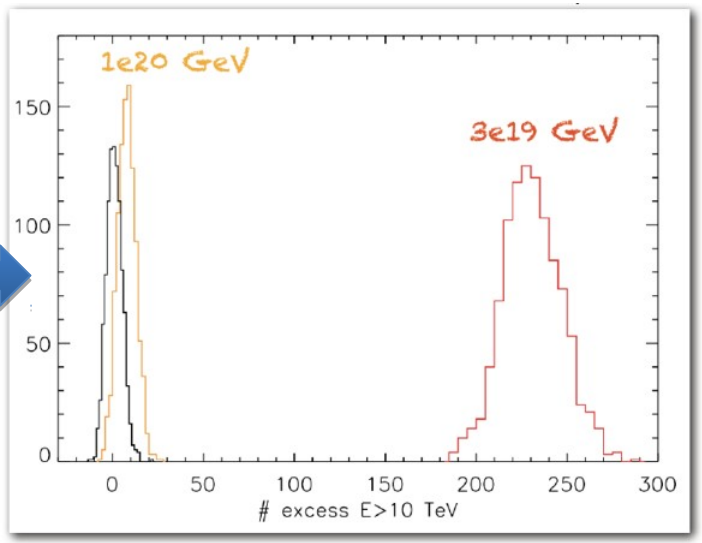
Hadron beam

$M_{LVI} = 10^{19}\,\mathrm{GeV}$

$M_{LVI} = 3 \times 10^{19}\,\mathrm{GeV}$

$M_{LVI} = 10^{20}\,\mathrm{GeV}$





The ASTRI SST-2M E2E prototype

We expect to detect
1 Crab flux level sources at 5-sigma in a few hours at E > 1 TeV

More information:
Vercellone et al., 2015, arXiv:1508.00799 (and references therein)

ASTRI SST-2M **innovative solutions**:

Dual-mirror optical layout
first time for VHE IACTs;
reduces the plate-scale;
optimal PSF across the entire FoV.

SiPMs photo-detectors
small pixel-size;
can work during moonlight;
fast front-end and control electronics;

Wide field-of view (9.6°)
excellent for:
extended sources, surveys;
allows to extend the energy range above 100 TeV.

Science with ASTRI SST-2M Prototype

Study of flares in TeV blazars with *Swift* and the ASTRI Cherenkov Telescope

S. Vercellone, P. Romano, F. Tavecchio, G. Pareschi (INAF/OAB)
M. Capalbi (INAF/IASFPA), G. Bonnoli (Univ. of Siena)

1. Abstract

We propose to perform almost simultaneous observations of a small sample of blazars during flaring episodes with *Swift* and the ASTRI Cherenkov telescope prototype. The selected targets are the TeV blazars BL Lac, Mrk 421, Mrk 501, and 1ES 1959+650. The scientific goal is to investigate possible near simultaneous correlations in the synchrotron (optical–UV–X-ray) and inverse-Compton (GeV–TeV) energy bands, deriving an accurate description of the X-ray spectrum and its temporal evolution, which would allow us to extract the shape of the underlying electron population, a key ingredient to derive the intrinsic inverse Compton spectrum. We expect to start our intense monitoring by *Swift* according to both X-rays (*Swift*) or VHE (ASTRI) trigger conditions. If either trigger condition is satisfied by one of these sources, we request 1 observation each day, for 5 days on the triggered source, in order to follow the full flaring events and investigate in great detail its spectral evolution. We shall request a total of 5 triggers, depending on which source satisfies our trigger conditions, for a maximum total exposure of 75 ks.

Submitted to the Call for the *Swift* 2-Msec Italian time on Sept. 29th

This proposal is part of the core programme of the INAF Bando SKA-CTA (years 2017-2018) "*Probing particle acceleration and γ-ray propagation with CTA and its precursors*" (PI. Tavecchio; Co-Is. Bonnoli, Pareschi, Romano, Vercellone).

Summary

- **The ASTRI mini-array** will constitute one of the *pre-production* set of telescopes for the whole CTA array, allowing us to investigate innovative technological solutions.

- **CTA early science** performed by means of ASTRI mini-array observations of a few selected sky regions will allow us to obtain several solid detections during the first year.

- **Excellent synergies** with other pre-production CTA telescopes (SSTs, MSTs, LSTs) and with several observing facilities from 2017 and beyond.