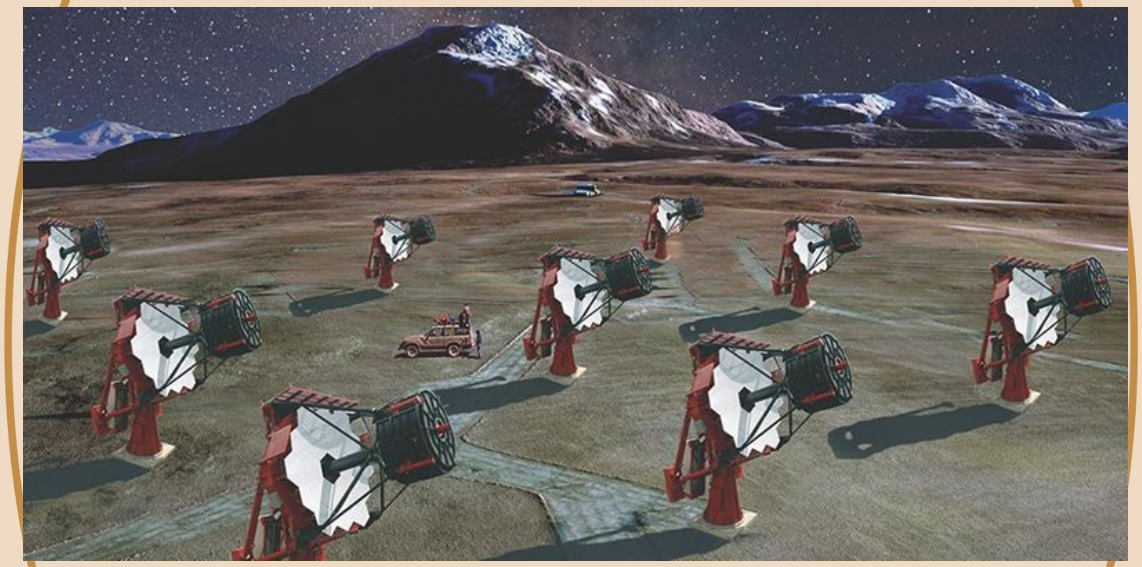
Microquasars with the ASTRI Mini-Array

Antonino D'Aì
(INAF-IASF Palermo)

for the ASTRI project



MQW XI MICRO QUASAR WORKSHOP
«A Microquasar Odyssey: Unveiling the Complexities»

- The **ASTRI Mini Array** is a system of nine 4-meter class Cherenkov telescopes currently under construction at the *Observatorio del Teide* in Tenerife (Spain).
- More than 150 researchers belonging to INAF institutes, Italian Universities, INFN, Fundacion Galileo Galilei, IAC (Spain), University of Sao Paulo (Brazil), North-West University (South Africa), Université & Observatoire de Genève (CH).

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- End to end approach: from design/implementation of all HW/SW components to dissemination of final scientific products.
- Unprecedented performance and wide FoV (10 deg) for observations at multi-TeV energy scale.

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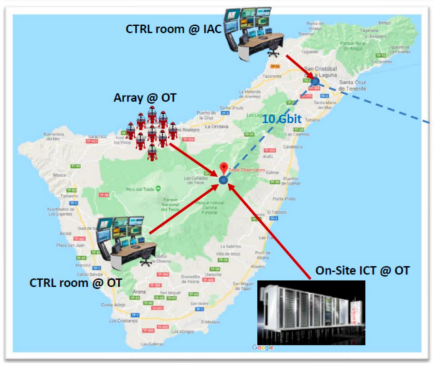
- End to end approach: from design/implementation of all HW/SW components to dissemination of final scientific products.
- Unprecedented performance and wide FoV (10 deg) for observations at multi-TeV energy scale.
- Core Science Program in the first 4 years (Vercellone et al. 2022).
- Important synergies with other Northern ground-based gamma-ray facilities (LHAASO, HAWC, MAGIC, VERITAS, CTAO-N)

Scuderi et al., JHEAP, 2022

The observing site @Teide



[Scuderi et al., JHEAP, 2022]

ASTRI Timeline

- 2022: site foundation

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- 2024: ASTRI-1 construction and calibration

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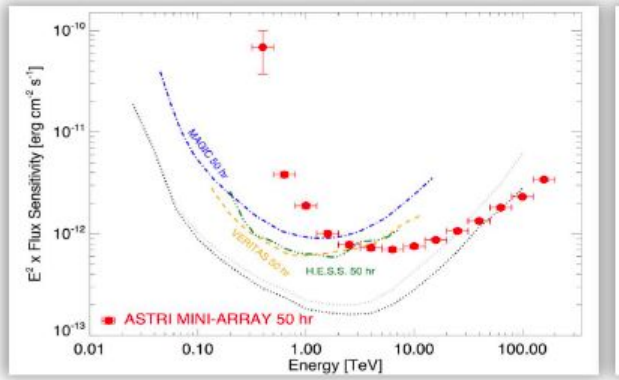
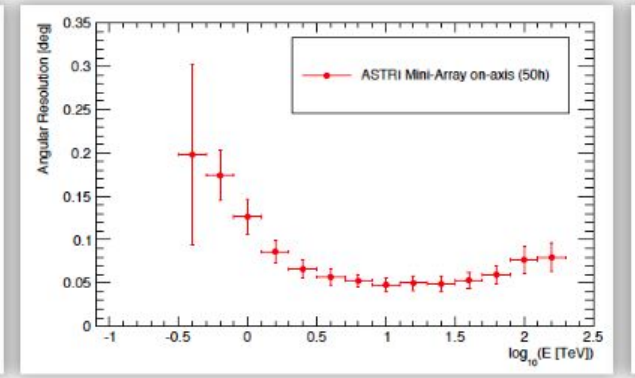
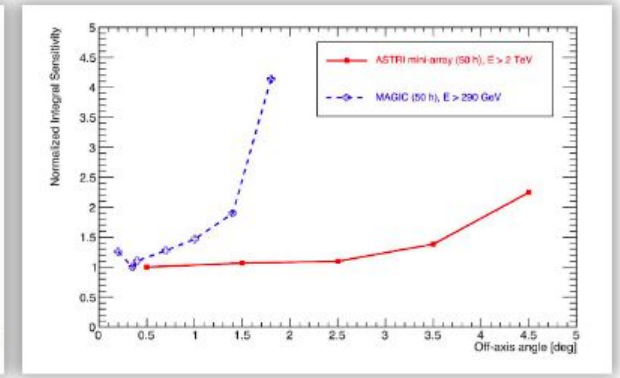
- 2024: ASTRI-1 construction and calibration
- 2025: ASTRI-2, ASTRI-3 and ASTRI-4 construction and calibration
- 2026/2027: full array

Largest IACT for > few TeV until CTAO is completed





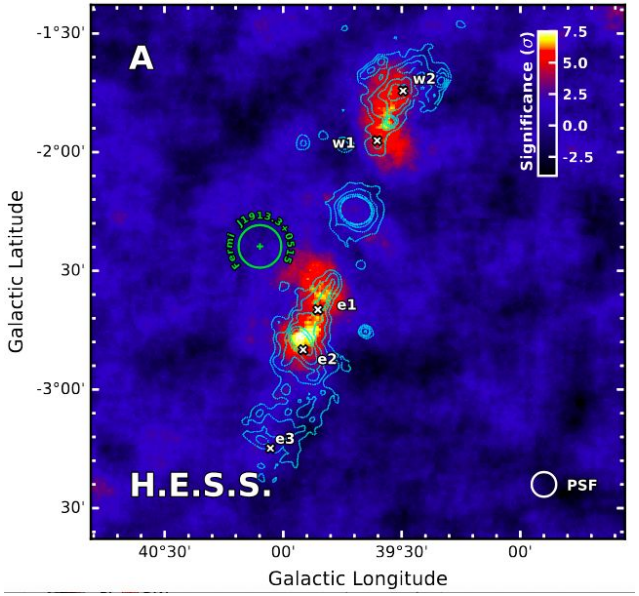


Sensitivity: better than current IACTs (E ≳ 3 TeV):
Extended spectrum and cut-off constraints

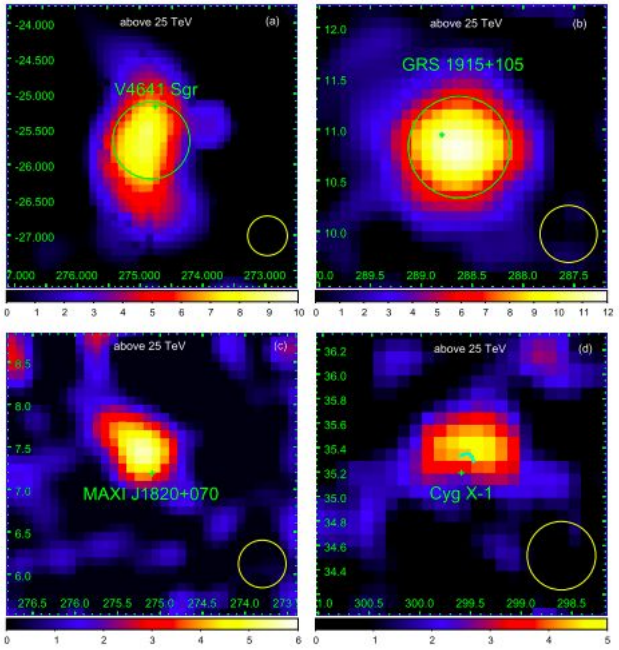
Energy/Angular resolution: ~ 10% / ~ 0.05° (E > a few TeV)
Characterize extended sources morphology

Wide FoV (≥ 10°), with almost homogeneous off-axis acceptance
Multi-target fields and extended sources
Enhanced chance for serendipity discoveries

Microquasars as TeV sources

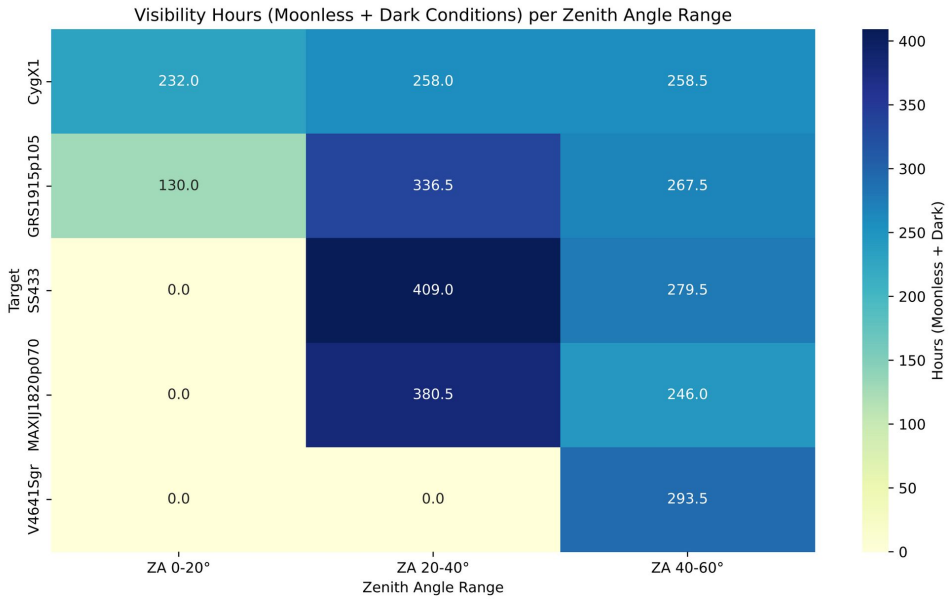


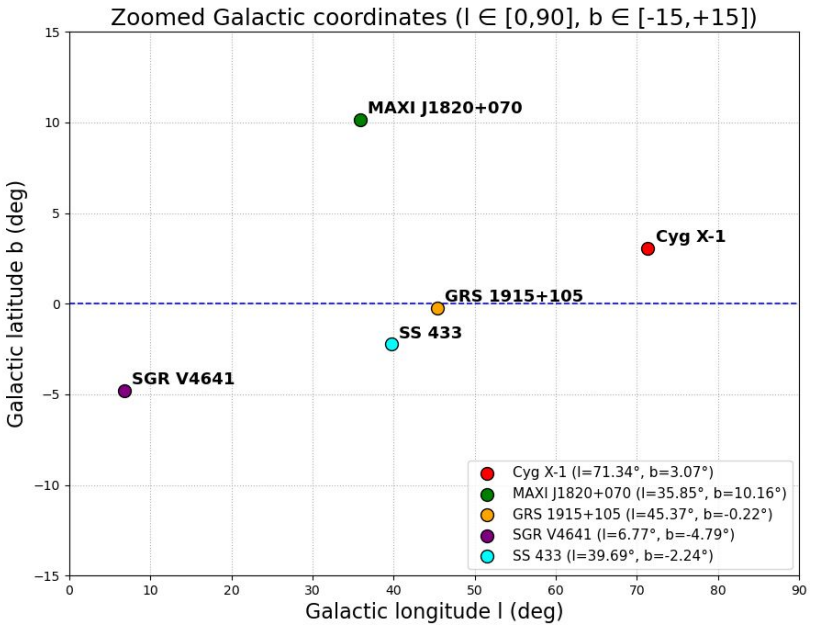
HESS Coll., Science, 2024



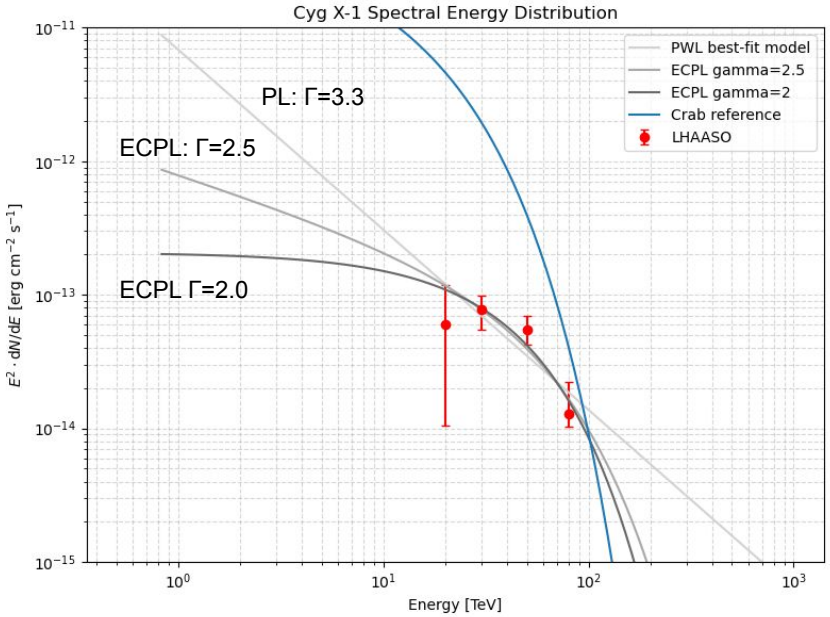
LHAASO Coll, Arxiv, 2025

Visibility of LHAASO TeV detected sources from Teide

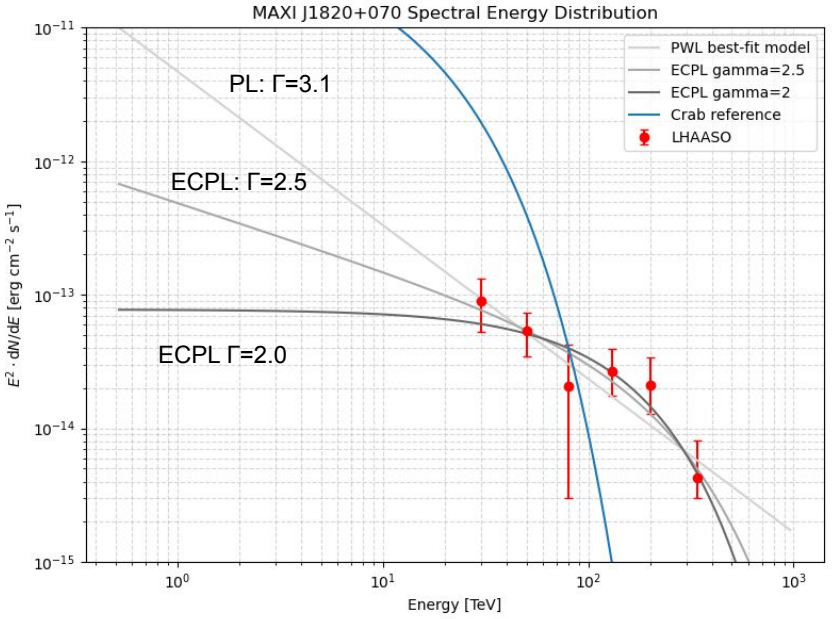




Unresolved Sources: Cyg X-1 and MAXI J1820

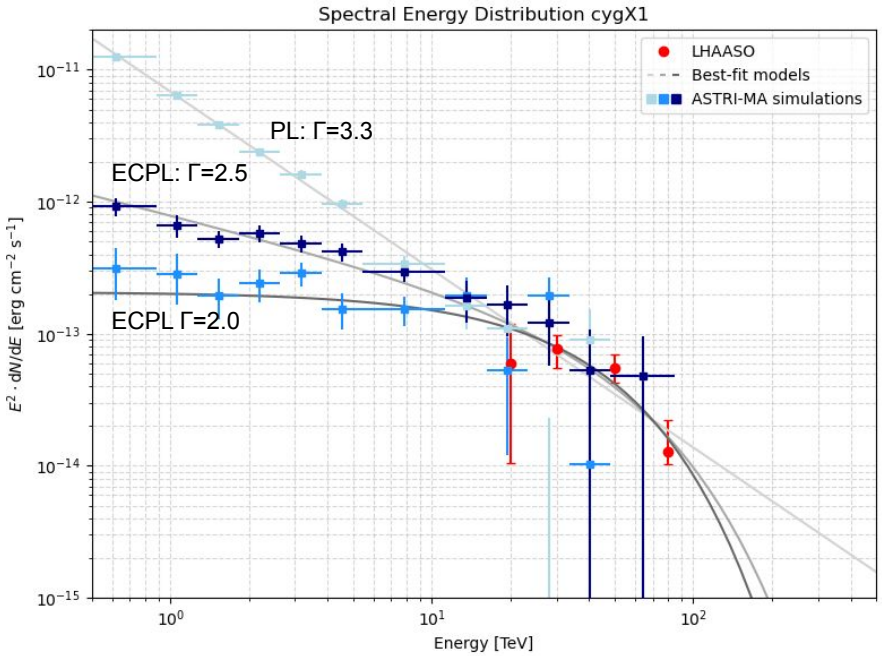


LHAASO Coll, Arxiv, 2025



LHAASO Coll, Arxiv, 2025

ASTRI-MA 300hr simulated observations.
ASTRI 50hr optimized IRF (available at Zenodo)



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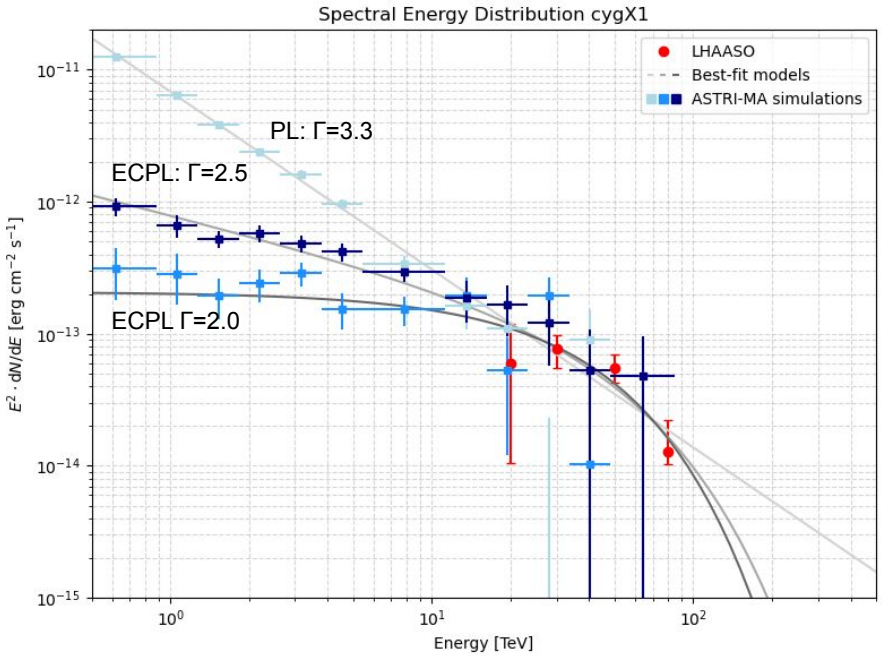
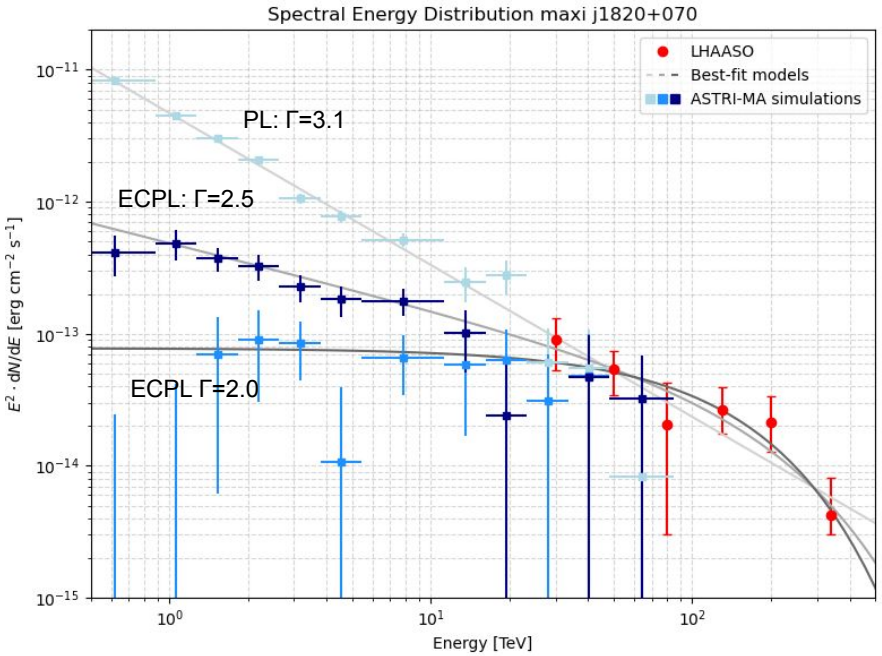
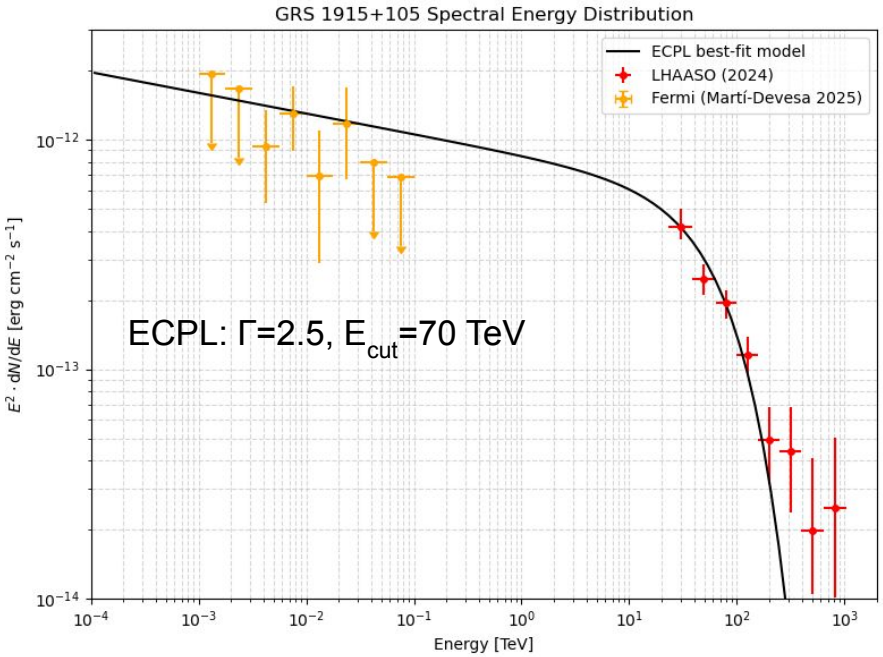




GRS 1915+105: filling the spectral TeV gap



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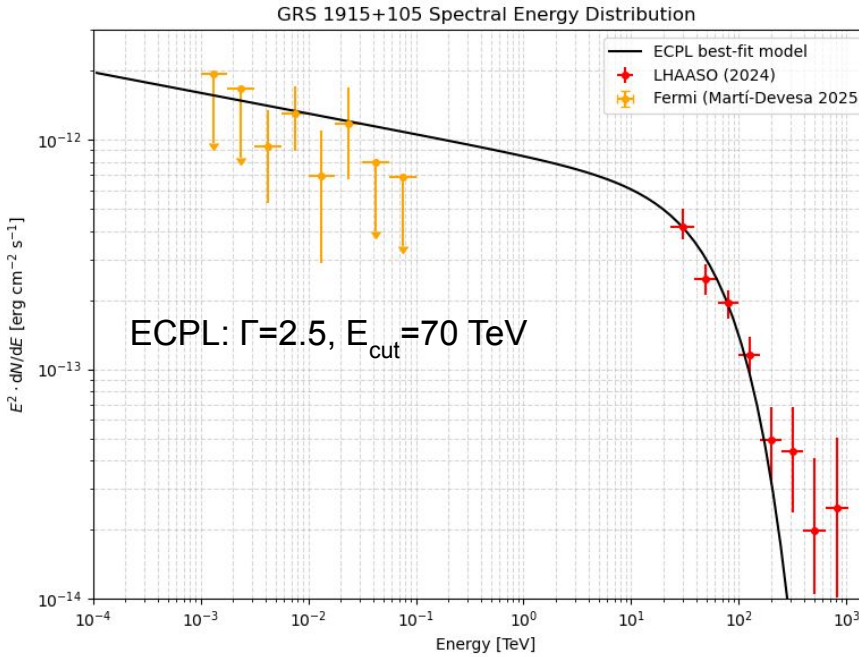
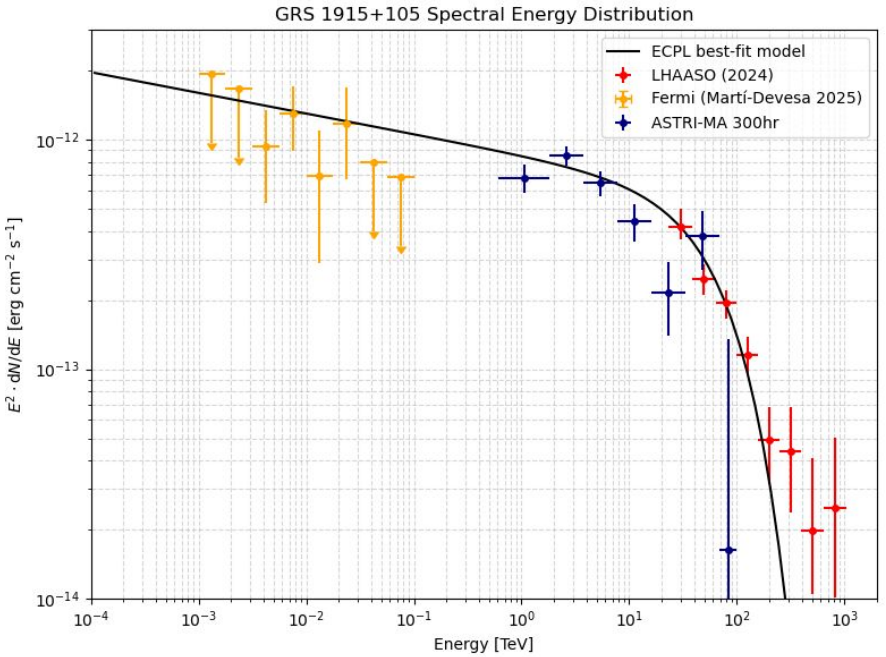


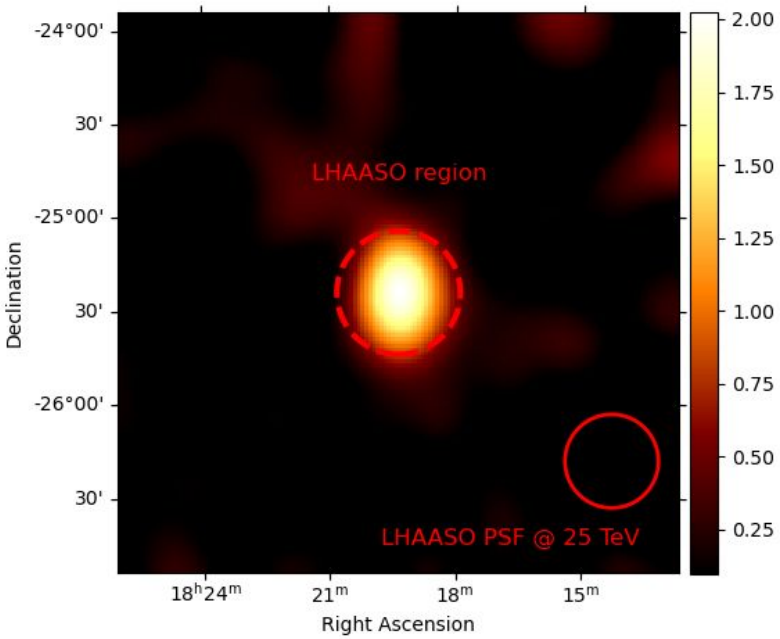


LHAASO Coll, Arxiv, 2025

GRS 1915+105: how to reveal complex morphologies

ASTRI MA: 300 hr simulations

Gaussian Disk



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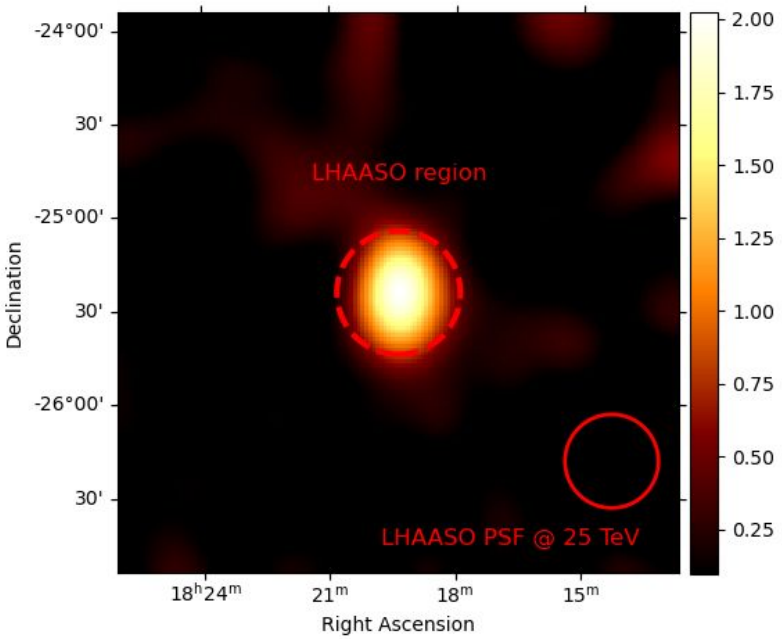
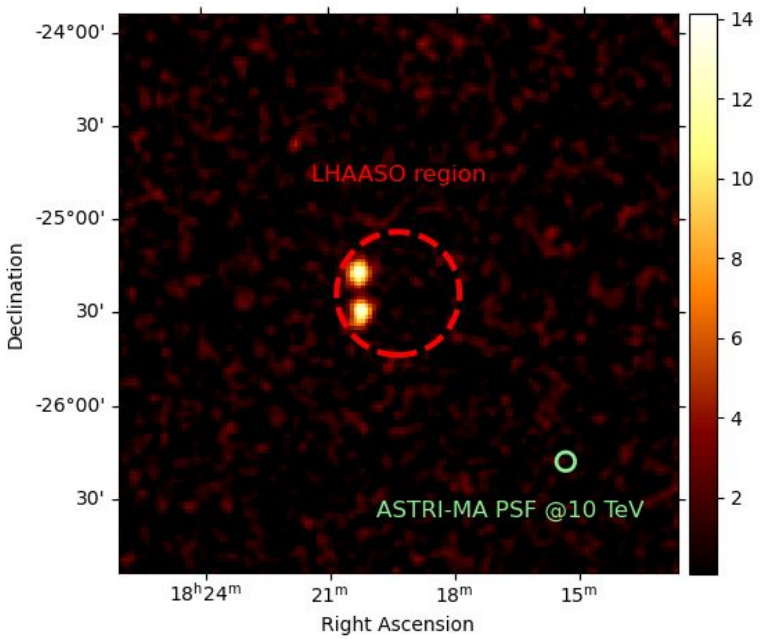
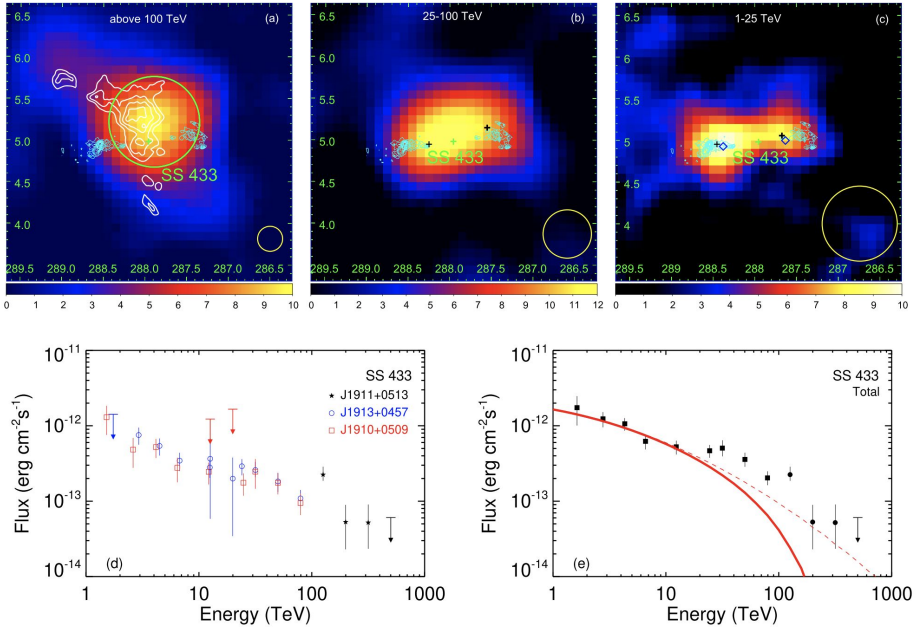


Two 0.2 deg separated Point Sources

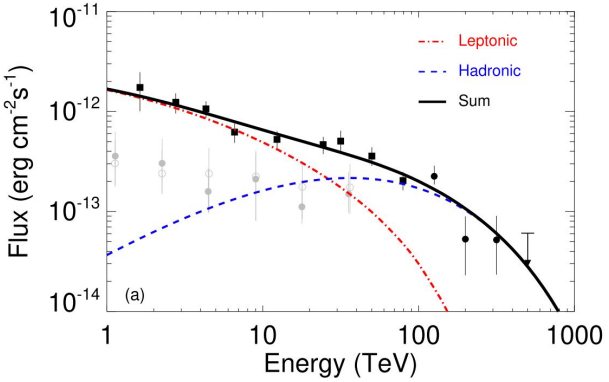


SS 433: an energy-dependent morphology

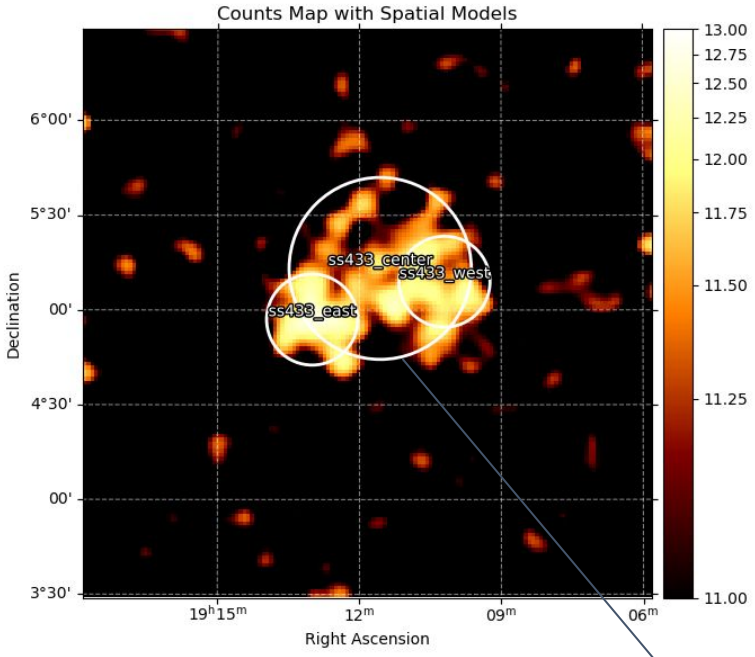


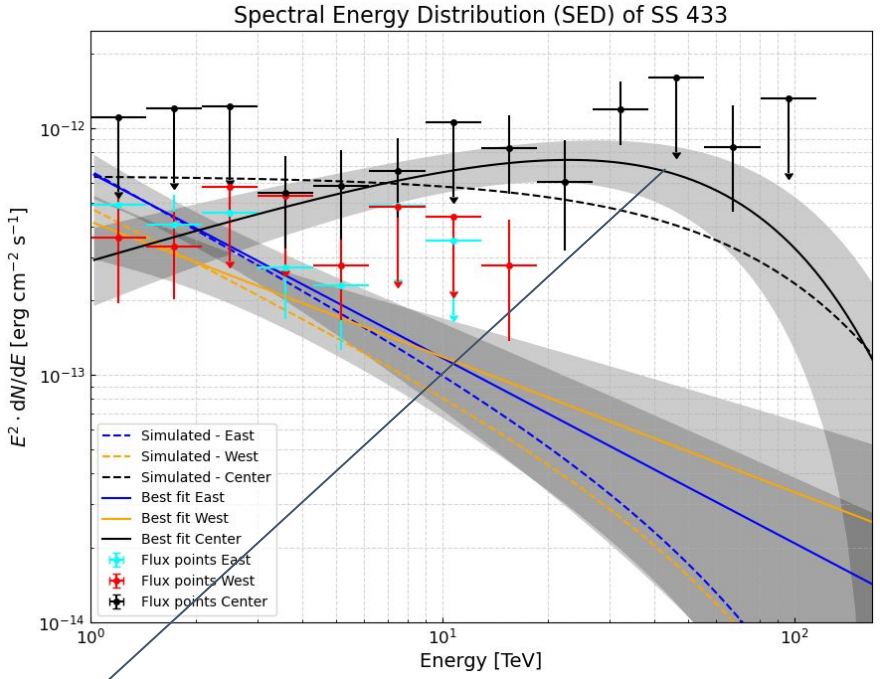
[LHAASO Coll, Arxiv, 2025]

Leptonic emission associated with the two jet lobes. Central excess emission starting to emerge above tens of TeV from a (possible) hadronic contribution?



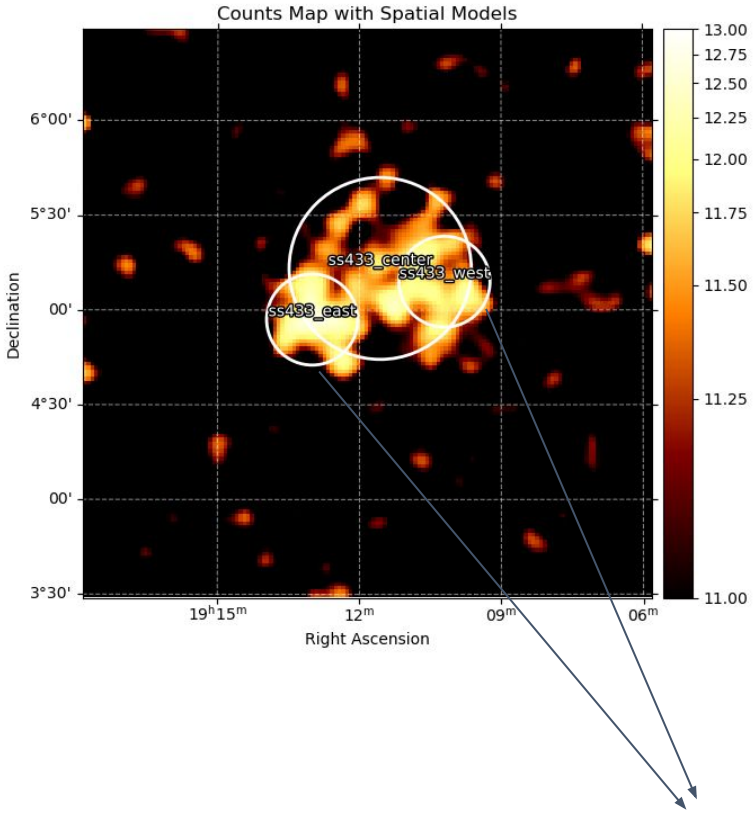
SS433 : ASTRI MA 300 hr simulations

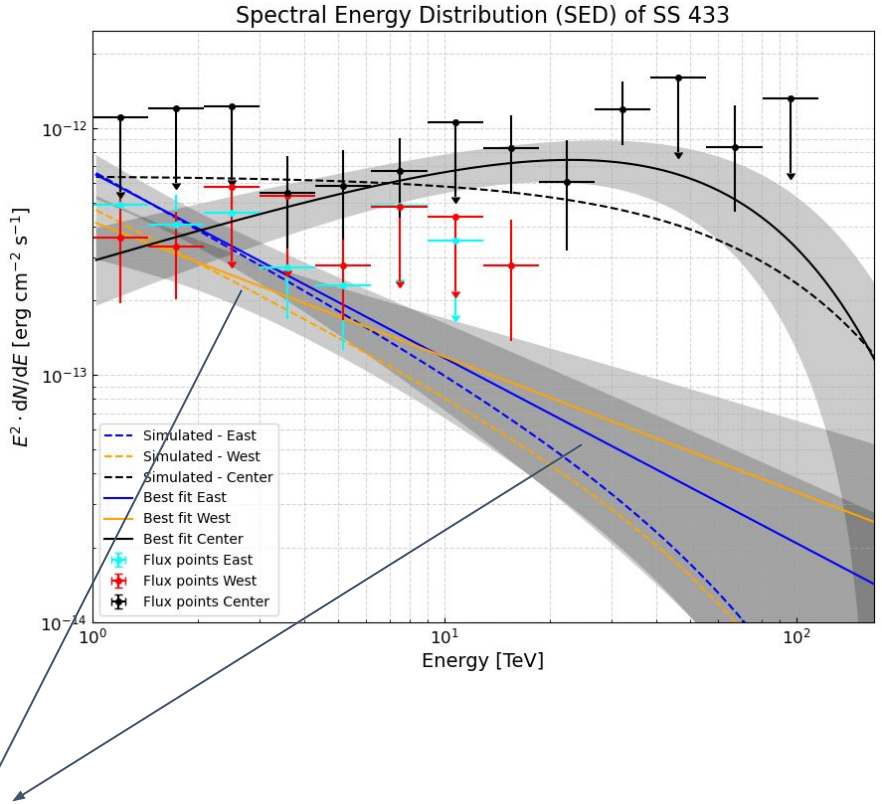




A 0.32°σ Gaussian spatial model + ECPL (Γ=2, E_{cut} = 100 TeV)

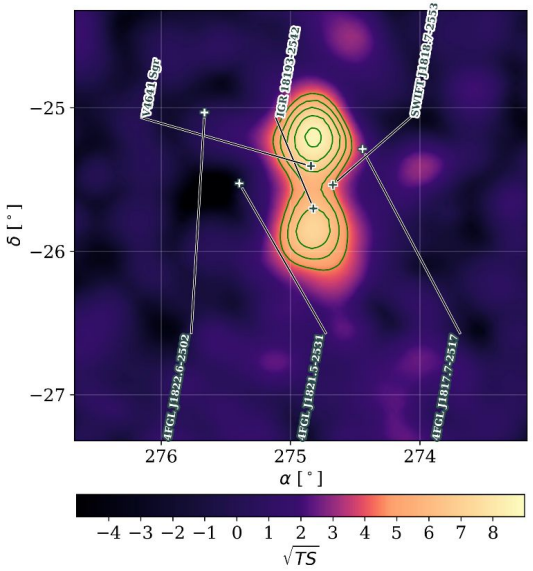
SS433 ASTRI MA: 300 hr simulations

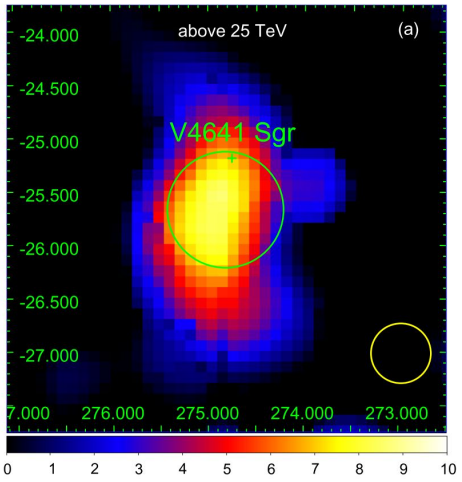


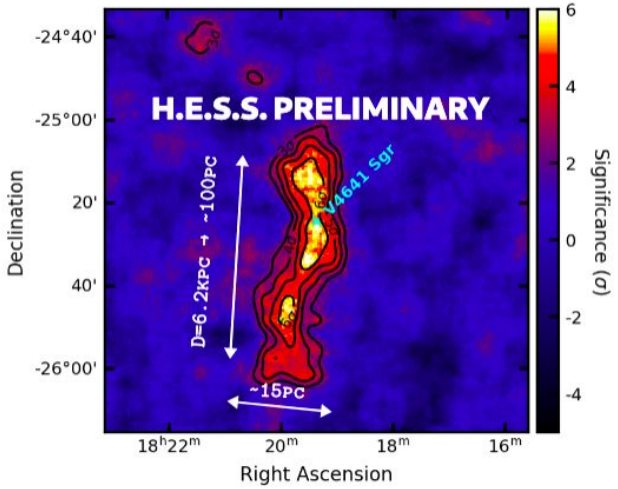


Extended East/West lobes (both 0.16°σ Gaussian spatial model) with soft ECPL spectral shapes (Γ=2.8, E_{cut} = 80 TeV).

V4641 Sgr: the SuperPeVatron







[HAWC Coll., 2024]

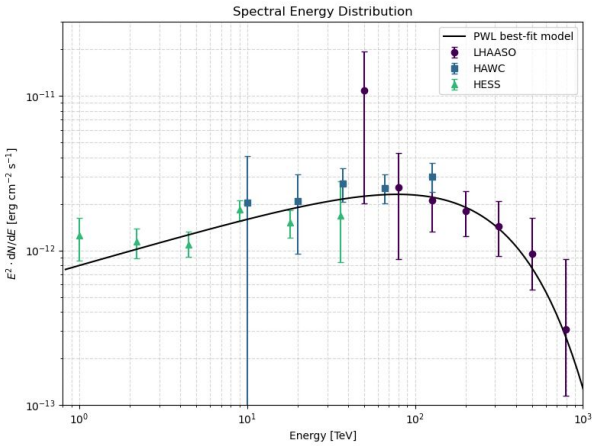
[Lhaaso Coll. 2024]

[HESS Coll. 2024 (preliminary)]

V4641 Sgr: ASTRI MA: 300 hr simulations

Morphology: a uniform disk spatial model component (major axis =0.45°, e=0.95)

Spectral model: ecpl from the best-fitting model of LHAASO+HAWC+HESS data



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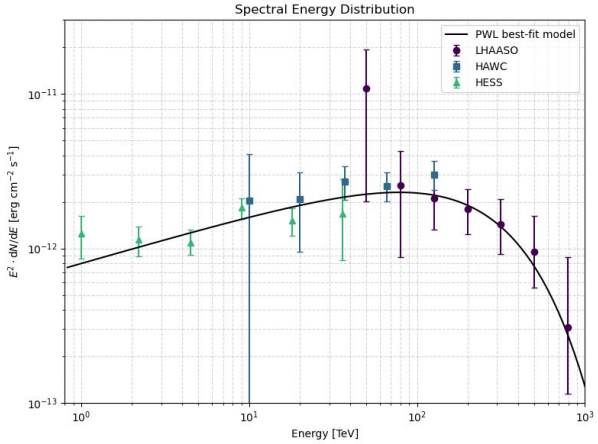
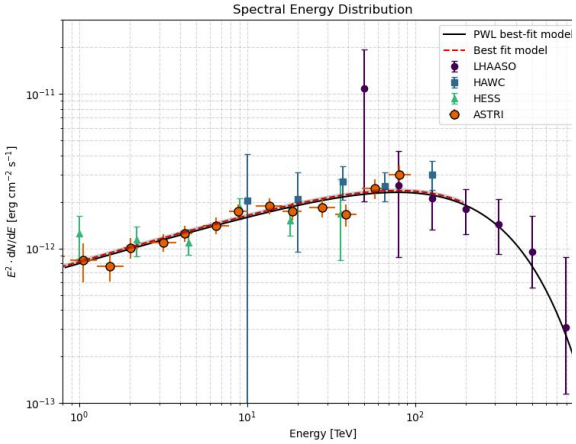
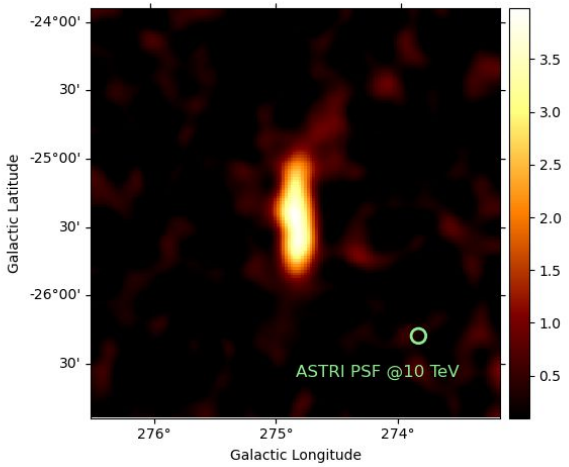


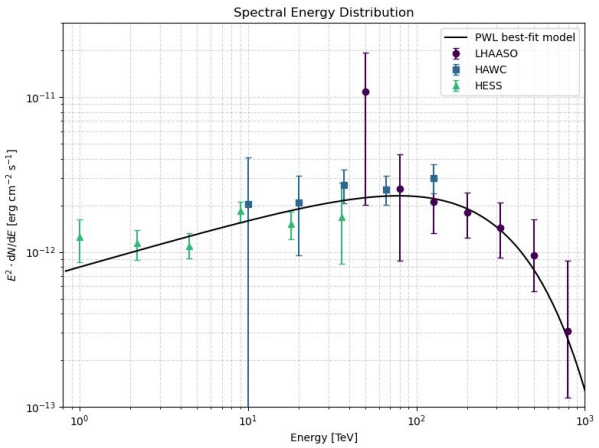


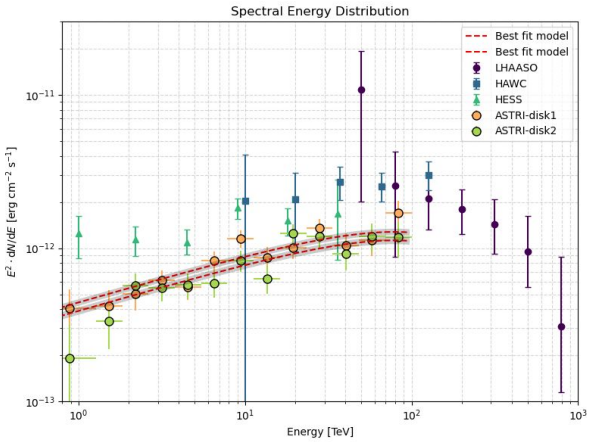


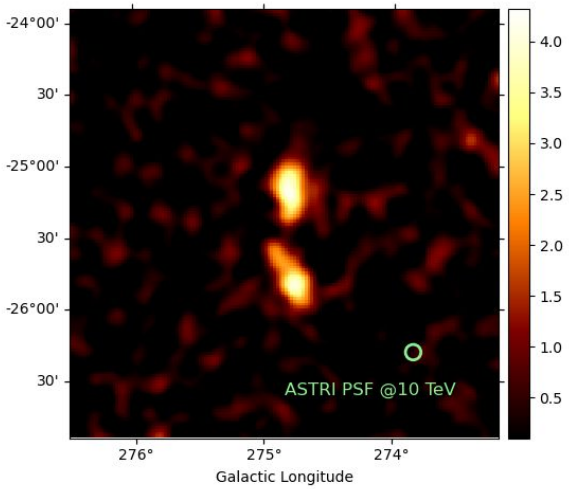
V4641 Sgr: ASTRI MA: 300 hr simulations

Morphology: two spatially-resolved extended lobes (major axis =0.25°, e=0.95)

Spectral model: ecpl from the best-fitting model of LHAASO+HAWC+HESS data.
Each lobe contributing half of the total flux (as HAWC data suggest)







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- Our preliminary simulations indicate that ASTRI Mini-Array will provide key coverage (especially in the 10-100 TeV band) to spectrally constrain the VHE emission of micro-quasars.
- ASTRI Mini-Array data will be able to disentangle the morphological shapes and provide spectral properties for selected spatial regions.
- Coordinated observations with other facilities (e.g. LST, CTAO-N, and LHAASO) will offer a comprehensive view of the spectrum, thus distinguishing contributions from the core and outer regions.

Acknowledgements

This work was made possible thanks to the contribution of many ASTRIans:

- *Elena Amato (INAF/Arcetri)*
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- *Enrico Peretti (INAF/Arcetri)*
- *Fabio Pintore (INAF/IASFPA)*
- *Alan Sunny (INAF/IAPS, Rome)*
- *Antonio Tutone (INAF/IASFPA)*