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TELESCOPIO NAZIONALE GALILEO

NORTH-WEST UNIVERSITY YUNIBESITI YA BOKONE-BOPHIRIMA NOORDWES-UNIVERSITEIT

Observatory Galactic Science with the ASTRI-Mini Array during the Observatory phase of the project

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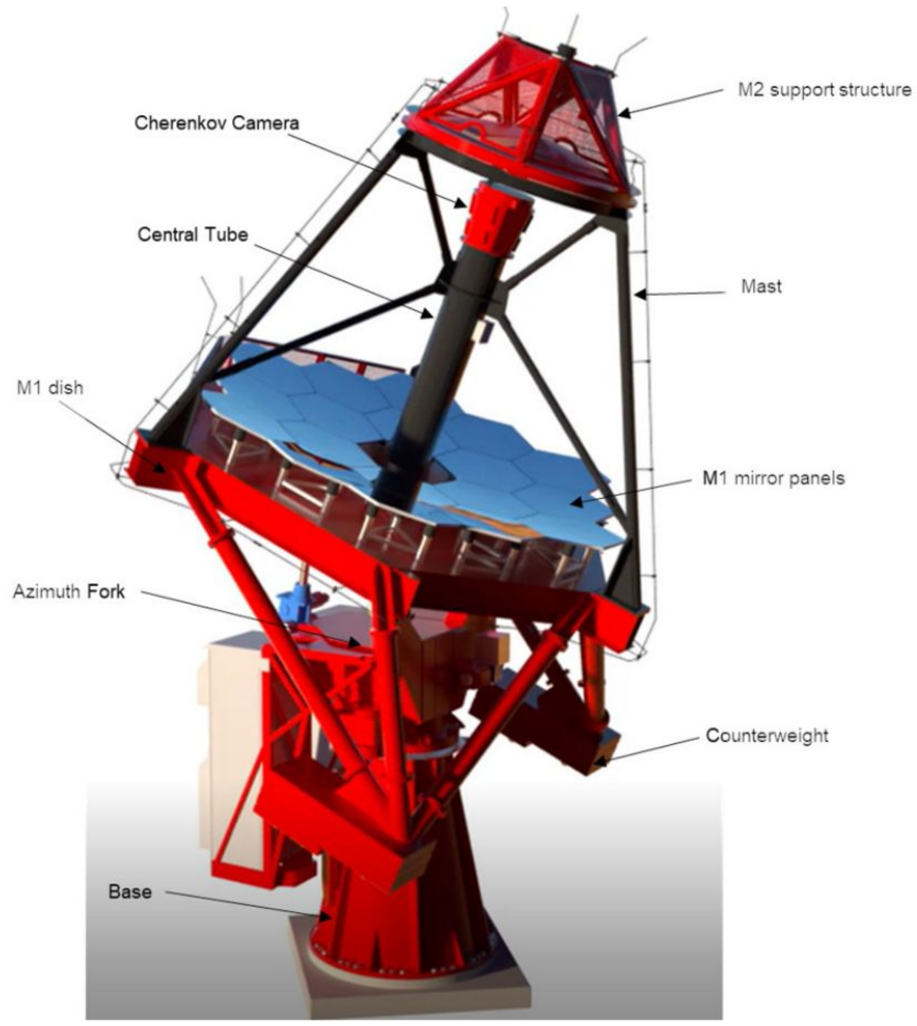
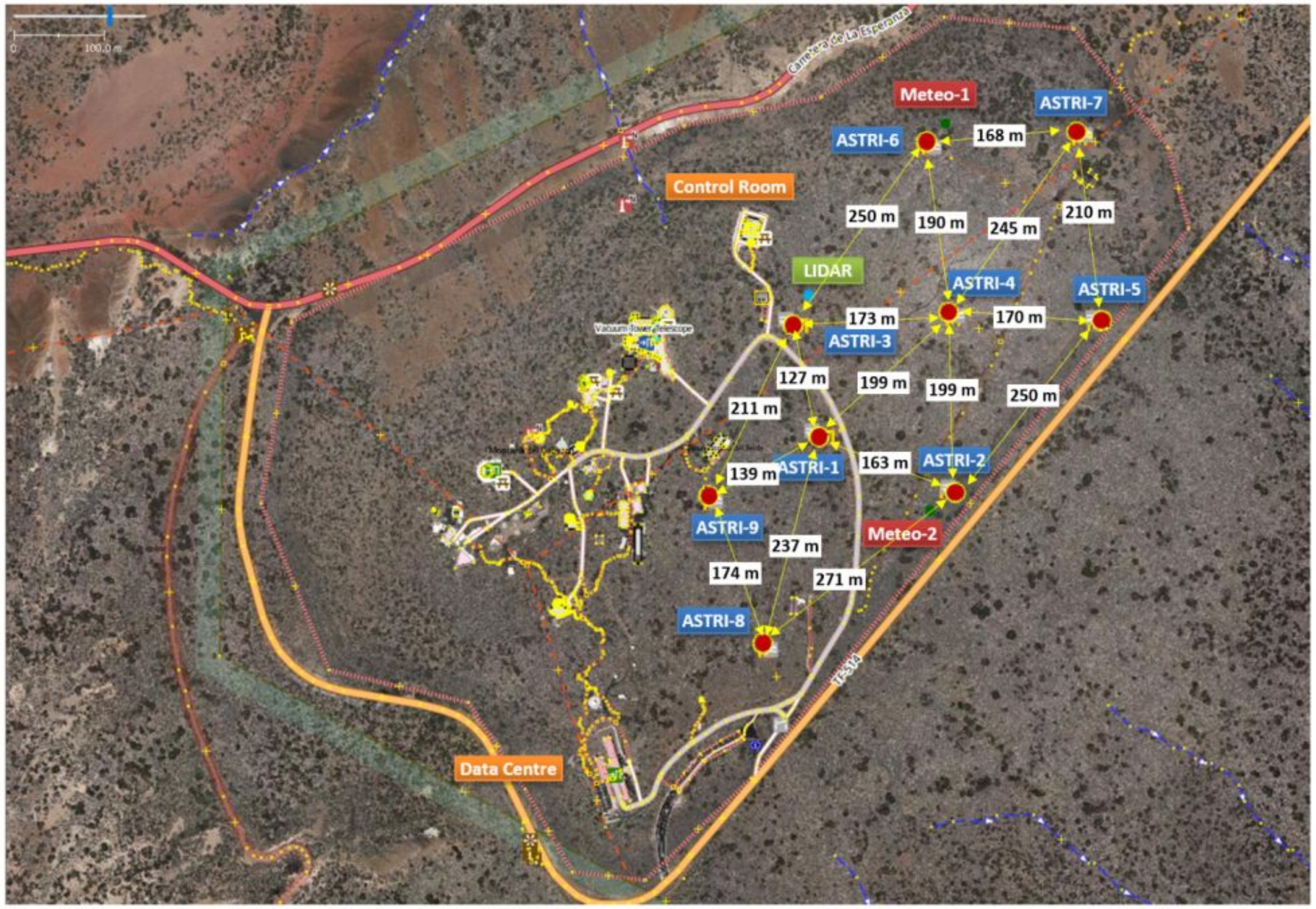
for the ASTRI Project

ICRC 2021, 16 July 2021

ASTRI-MA deployment at Teide



See [Antonelli's talk](#) !



ASTRI-MA performance & key science programme

Mini-Array

The first 4 years of operations will be devoted to a key-science programme built upon the pillars concepts (See S. Vercellone's talk) -> key targets
BUT observing plan still to defined

Pillar-1 Origin of CRs

Name	RA (deg)	Dec (deg)	Type
Tycho	6.36	64.13	SNR
Galactic Center	266.40	-28.94	Diffuse
VER J1907+062	286.91	6.32	SNR+PWN
SNR G106.3+2.7	337.00	60.88	SNR
γ-Cygni	305.02	40.76	SNR
W28/HESS J1800-240B	270.11	-24.04	SNR/MC
Crab	83.63	22.01	PWN
Geminga	98.48	17.77	PWN
M82	148.97	69.68	Starburst

Pillar-2 Fundamental Physics and Cosmology

IC 310	Radio gal.	03 16 43.0	+41 19 29
M87	Radio gal.	12 30 47.2	+12 23 51
Mkn 501	Blazar	16 53 52	+39 45 38

The Galactic Obs. Science Programme

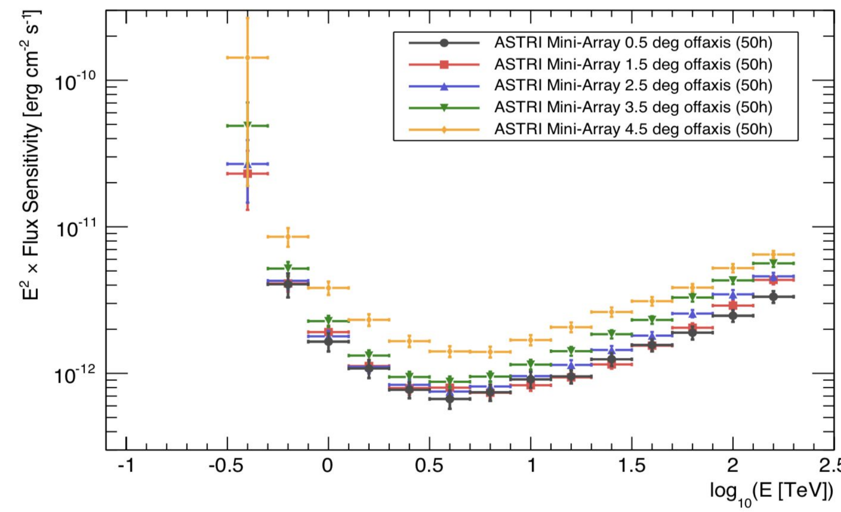
Mini-Array

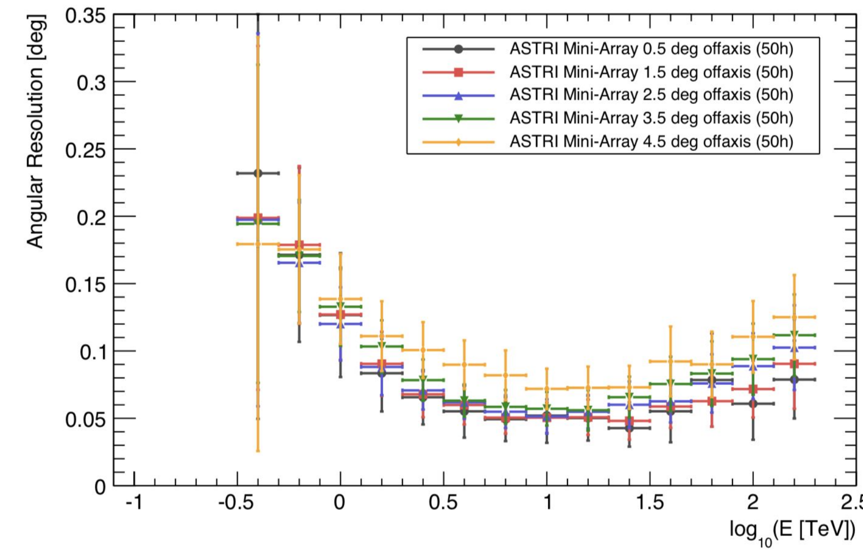
Thanks to the large FOV, observations of *pillar targets* will naturally lead to a large complementary Observatory Science Program that will encompass the study of a large fraction of Northern Galactic sources.

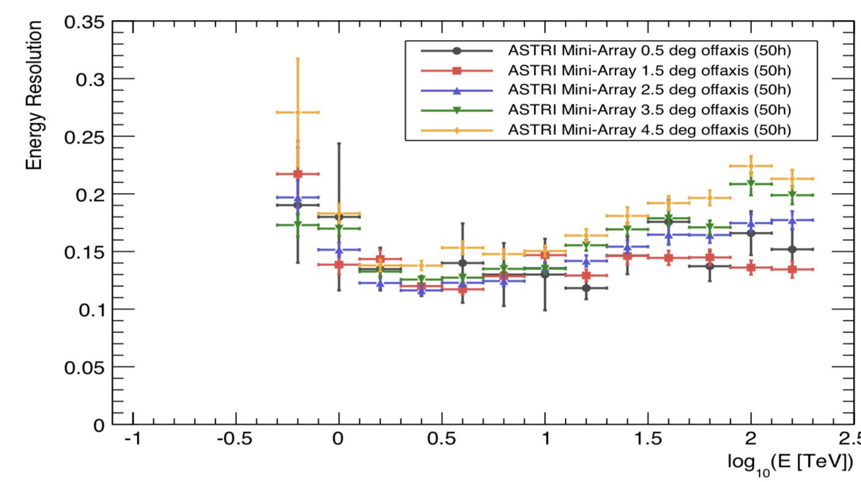
Galactic Observatory Science will constitute an essential part of the long-term planning of the ASTRI-MA observations.

In most cases, the foreseen increase in sensitivity and resolution (spectral/spatial) above 10 TeV with operational IACTs (Veritas, Magic) or water Cherenkov arrays (HAWC, LHAASO), is about 1 order of magnitude.
Possible great synergy with CTAO-N.

Essential targets will be careful investigate and they will be benchmarks for extended GO programmes.



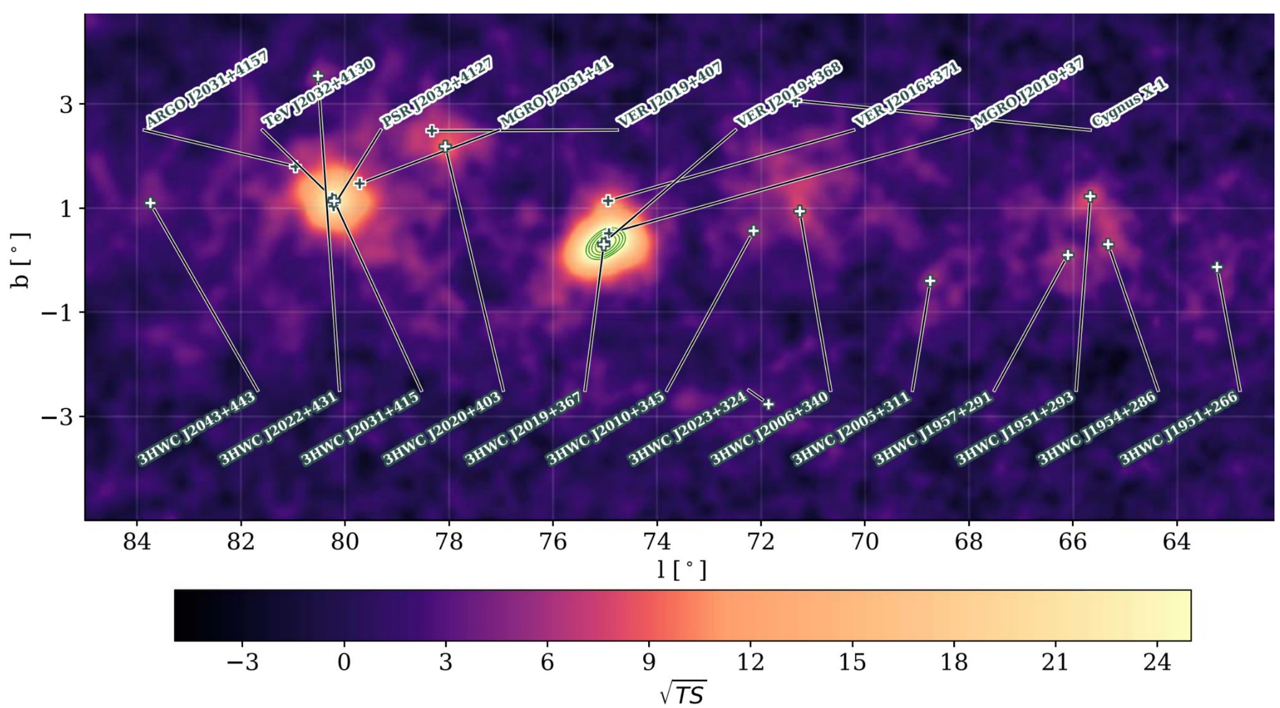




The Survey Census in the Cygnus region

Mini-Array

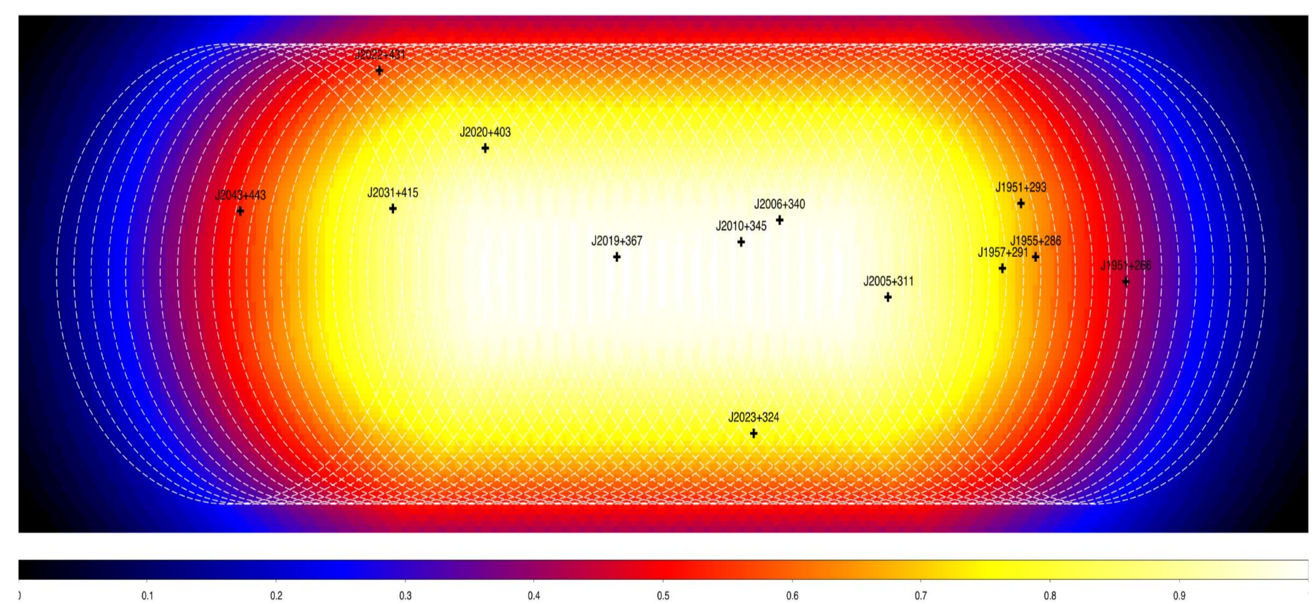
A region of particular interest for VHE observation along the Galactic Plane is the Cygnus region.
It extends from 64° to 84° in Galactic longitude and from -3°to 3° in Galactic latitude. The region comprises the nearest and most massive star-forming regions of the Galaxy, with a wealth of possible cosmic accelerators, among the many SNRs and PWNe. HAWC has recently released a census of the TeV population in this region.



[3rd HAWC catalogue]

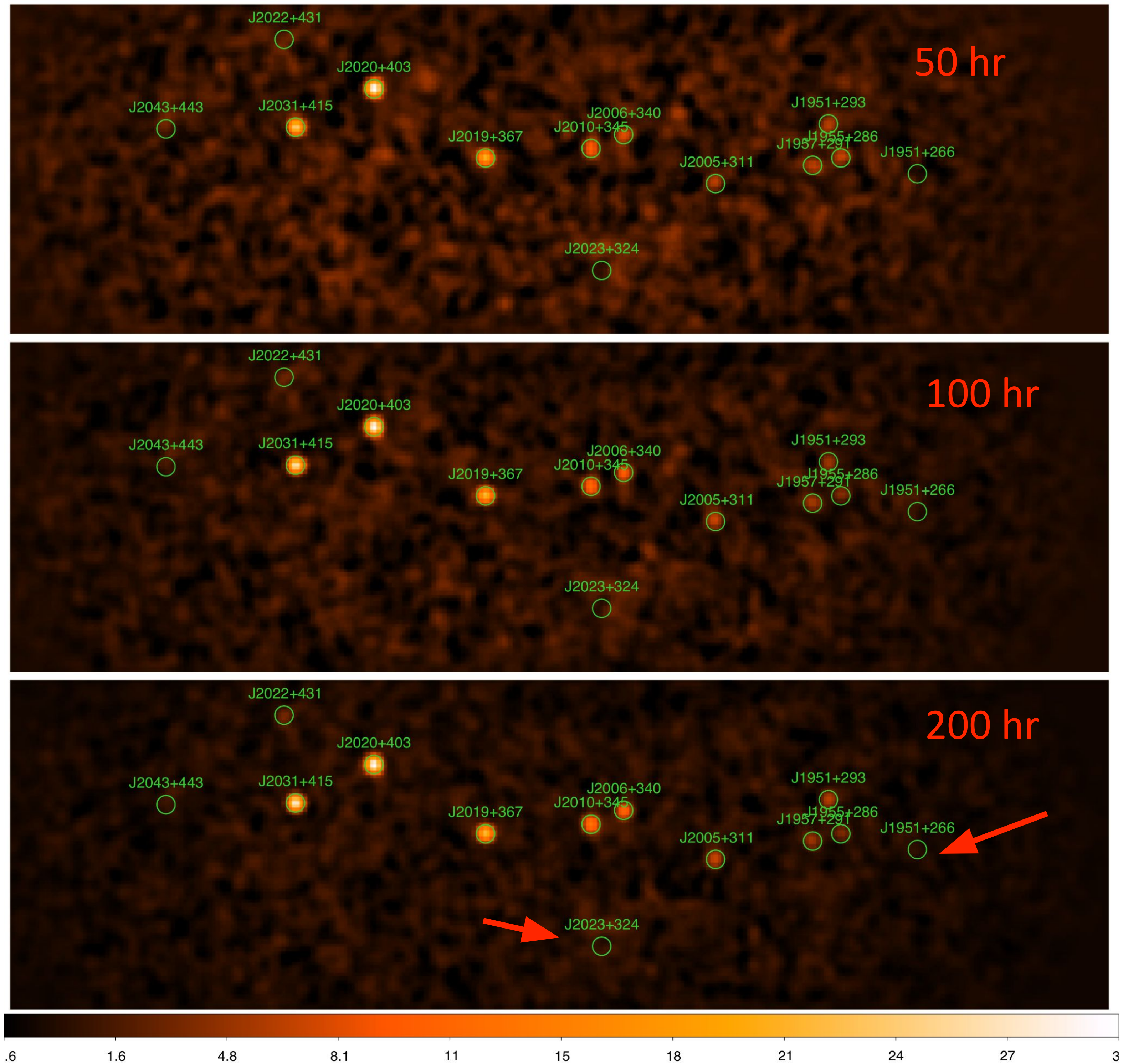
Adopting best-fit values for spectral / morphology of the [HAWC sample,] we studied as a function of the observing time and survey strategy the likelihood detection capabilities of the ASTRI-MA.

In this example the zero-order survey strategy is a linear scan with 50 different observations. Each pointing is shifted 0.4° with respect to the preceding.



The resulting normalised exposure map with the position of the simulated HAWC sources

The Cygnus survey



We examined results from a survey of a total exposure time of 50, 100 and 200 hr.
13 HAWC source simulated in the field.
TS value and parameters calculated for the stacked field.

In 50hr a 5 sigma detection (TS > 25)
9 out of of 13

In 100hr a 5 sigma detection (TS > 25)
10 out of 13

In 200hr a 5 sigma detection (TS > 25)
11 out of 13

2 sources are marginally detected because they are at the edge of the stacked FOV.

SNRs: IC 443

Mixed-type SNR remnant with a shell-like morphology visible in the radio band and a centrally filled thermal X-ray emission.

Gamma -ray emission is associated with the interaction of the SNR with the nearby molecular cloud at both HE and VHE range

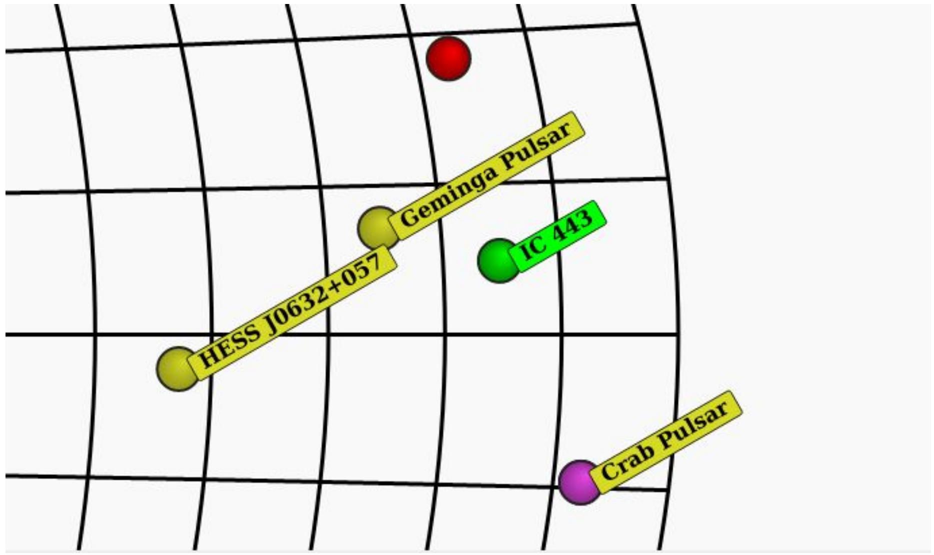
Spectral features strictly related with the characteristic pion-bump (Ackermann et al. 2013) strongly suggests that IC 443 is a CR protons accelerator.

We simulated 200h or ASTRI-MA observations at 3° offset.

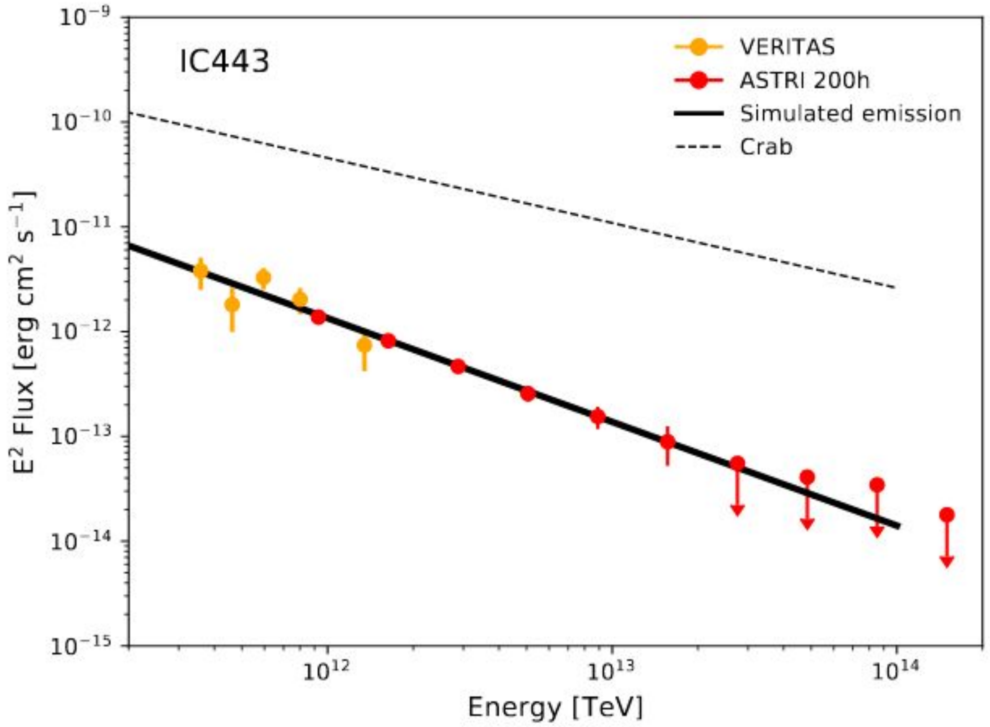
Extended morphology (*RadialGaussian* 10') and power-law spectrum with photon index = 3.0.

Comparison with VERITAS literature data.

Work in progress on possibile spectral-spatial dependence.



from http://tevcat2.uchicago.edu/

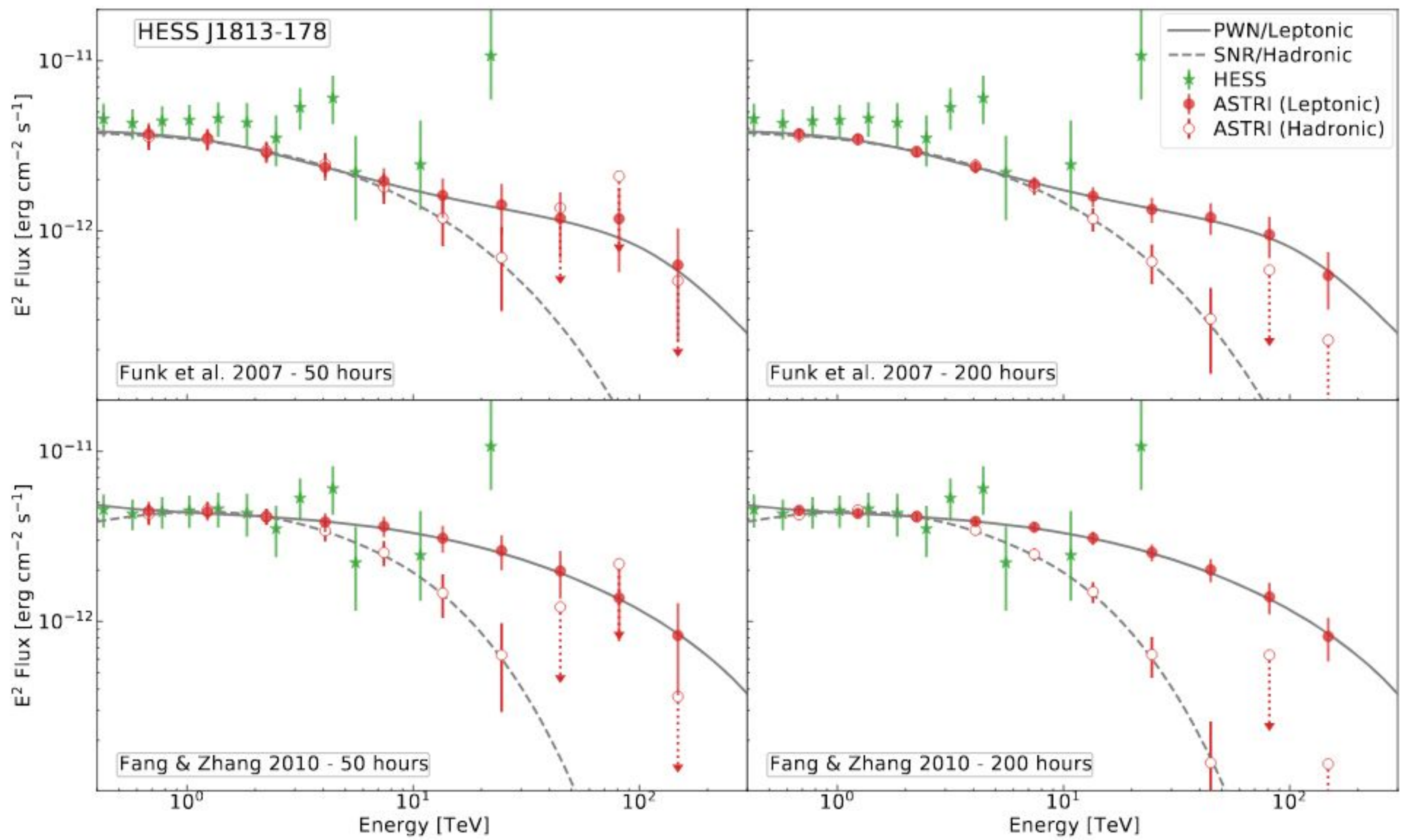


HESS J1813-178

Moderately bright PWN (0.06 Crab) with hard spectrum (Gamma = 2). 6° from W28
Very energetic pulsar at the centre, PSR J1813-1749 (spin-down luminosity 7E37 erg/s, only Crab shows a greater value!). Possibly not so old (age 3.3-7.5 kyr). Very recent estimates on the PSR distance (12 kpc) would make it one of the brightest TeV source in the Galaxy.
Two possible scenario for TeV emission have been examined: Funk (2007) and Fang (2010)

The Funk et al. 2007 model (time-dependent one-zone leptonic) describes the input electron spectrum as a power-law -> requires PeVatron electrons !

The Fang & Zhang 2010 model describes the leptonic spectrum as Maxwellian with a non-thermal tail.



TeV J2032+4130

The only known PWN inside a binary system (orbital period 50 yr, Abeysekara18).
It resides close to massive OB associations (Cygnus cocoon) where >100 TeV emission has very recently been detected with HAWC and LHAASO.

It is still uncertain whether, and to which degree, the emission is connected to TeV J2032 or it is entirely due to young stellar population winds.

We simulated the PWN spectrum of TeV J2032 according to the baseline model obtained with MAGIC. A power-law of index 2.0.
ASTRI-MA will detect any cut-off below 60 TeV with just 100hr observations.

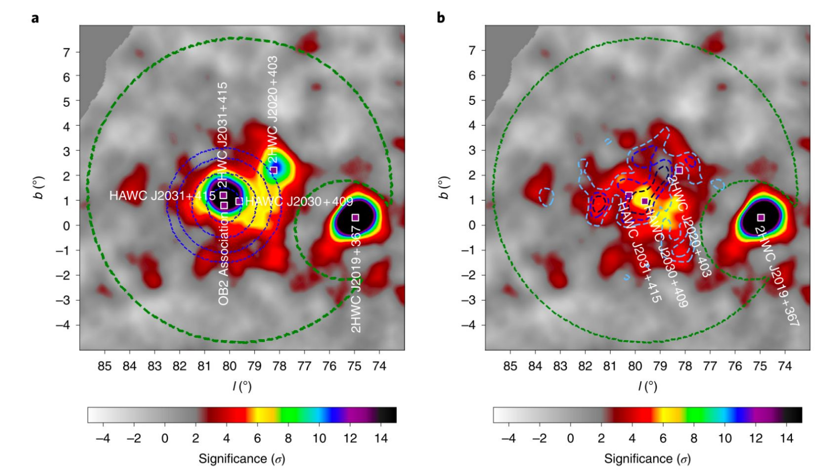
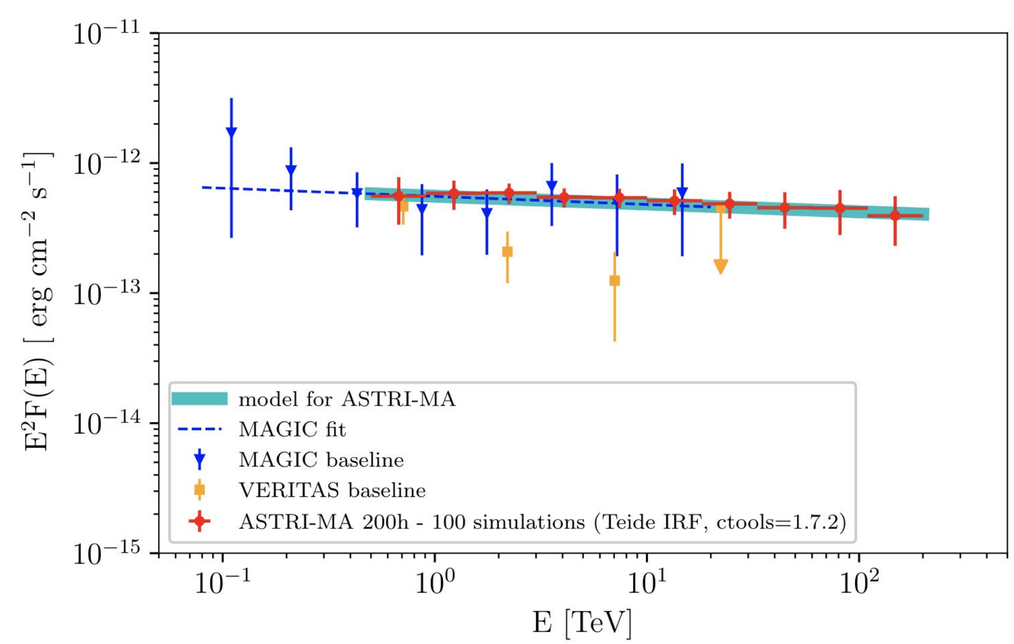


Fig. 1 | Significance map of the Cocoon region before and after subtraction of the known sources at the region. a, Significance map of the Cocoon region. The map is in Galactic coordinates, where *b* and *l* refer to latitude and longitude, respectively. It is produced as described in ref. [11]. The blue contours are four annuli centred at the OB2 association as listed in Supplementary Table 1. The green contour is the ROI used for the study, which masks the bright source 2HWC J2019+367. **b**, Significance map of the Cocoon region after subtracting HAWC J2031+415 (PWN) and 2HWC J2020+403 (γ Cygni). The light-blue, medium-blue and dark-blue dashed lines are contours for 0.16, 0.24 and 0.32 photons per 0.1°×0.1° spatial bin, respectively, from Fermi-LAT Cocoon[10]. Both maps are made assuming a 0.5° extended disk source and a spectral index of −2.6 with 1,343 days of HAWC data.

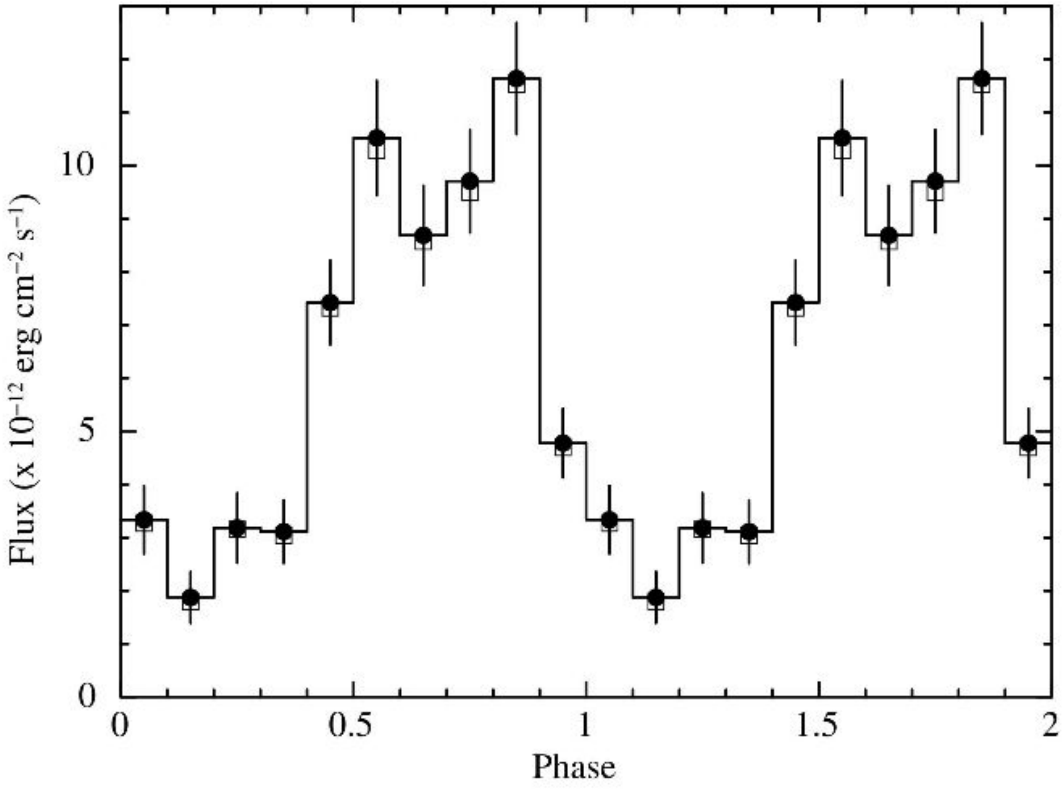


The gamma-ray binary LS 5039

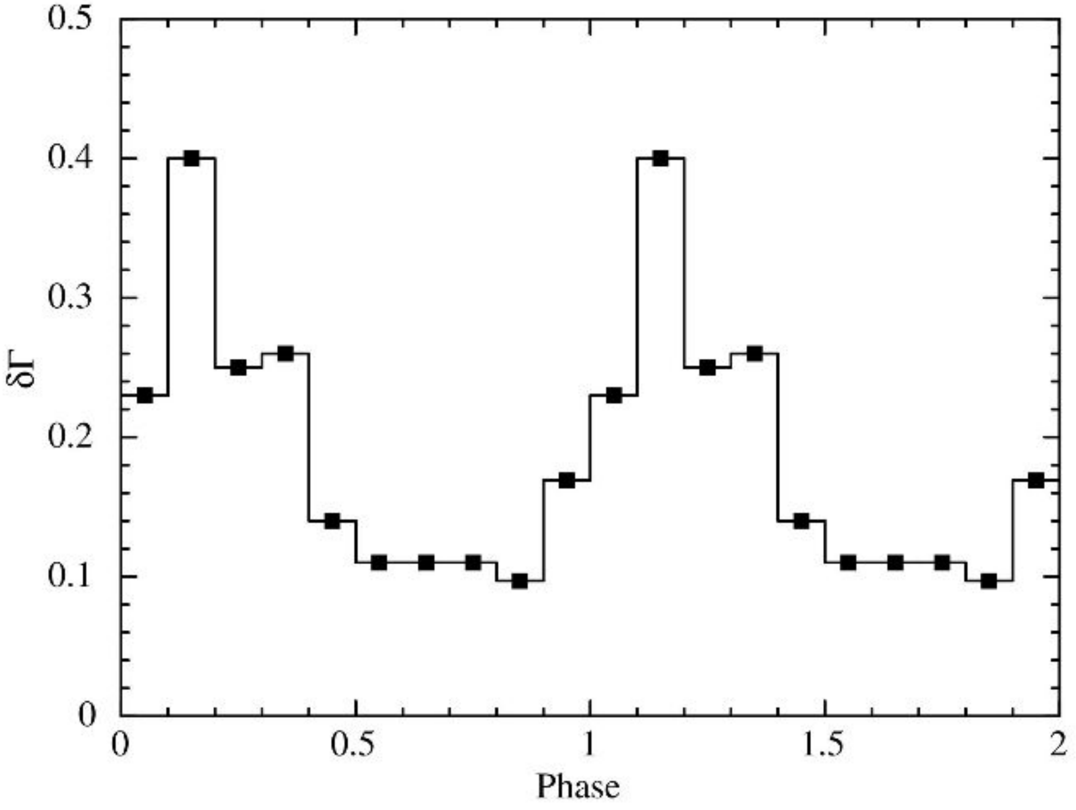
It has the shortest orbital period (3.9 days) among the gamma-ray binaries.
A spin period of few seconds has been recently claimed.
Its TeV flux is highly modulated and the TeV spectral shape also changes according to the orbital phase: a high luminosity (phase 0.45-0.9, gamma 1.85, cut-off 9 TeV) to low luminosity state (gamma 2.35, cut-off 13 TeV).

We tested the capabilities of the ASTRI-MA to detect flux and spectral variations, adopting a fixed exposure of 10 hr per phase bin (10 bins in total), and an orbitally averaged spectrum.

FLUX ORBITAL MODULATION

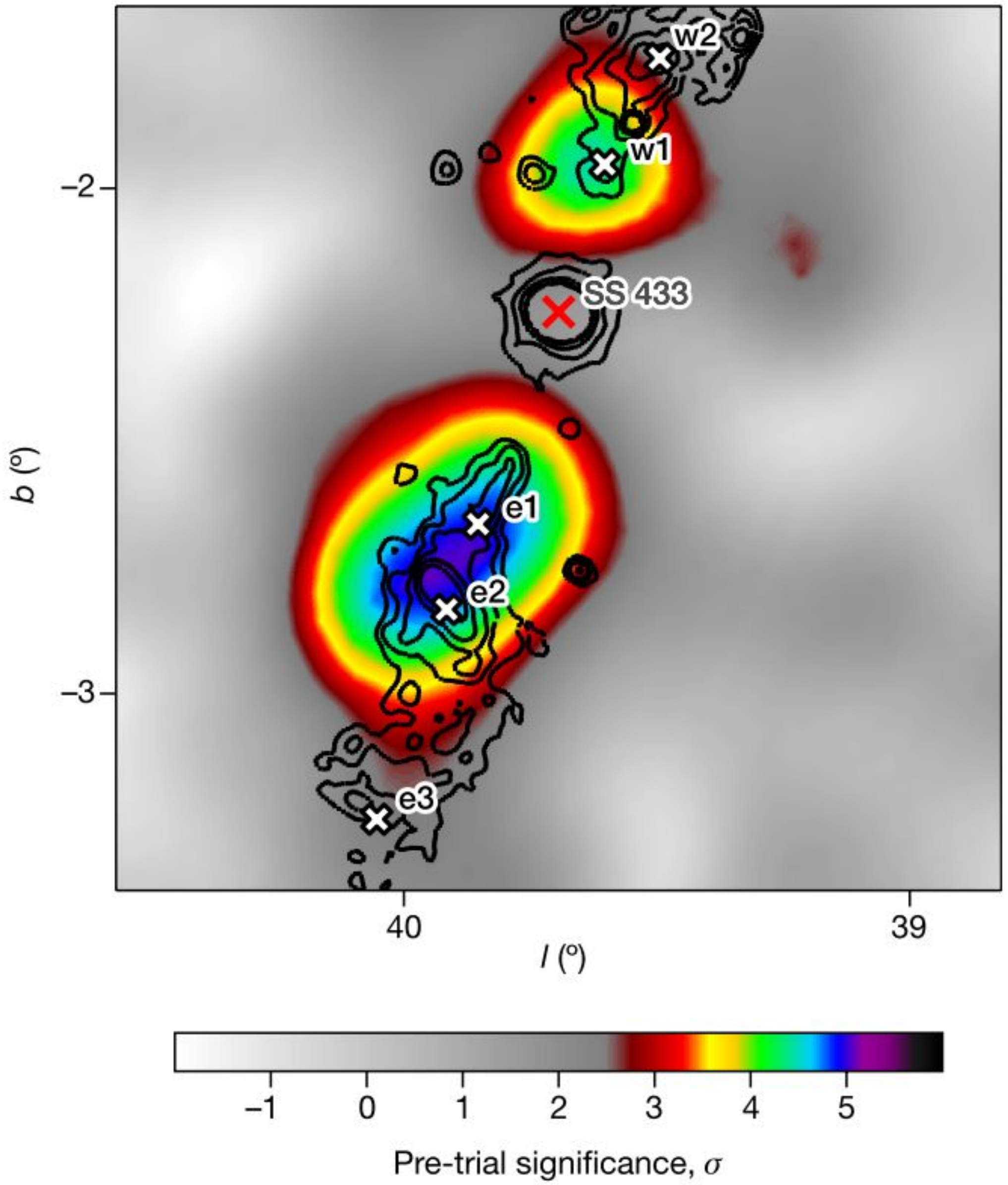


PHOTON INDEX ERROR



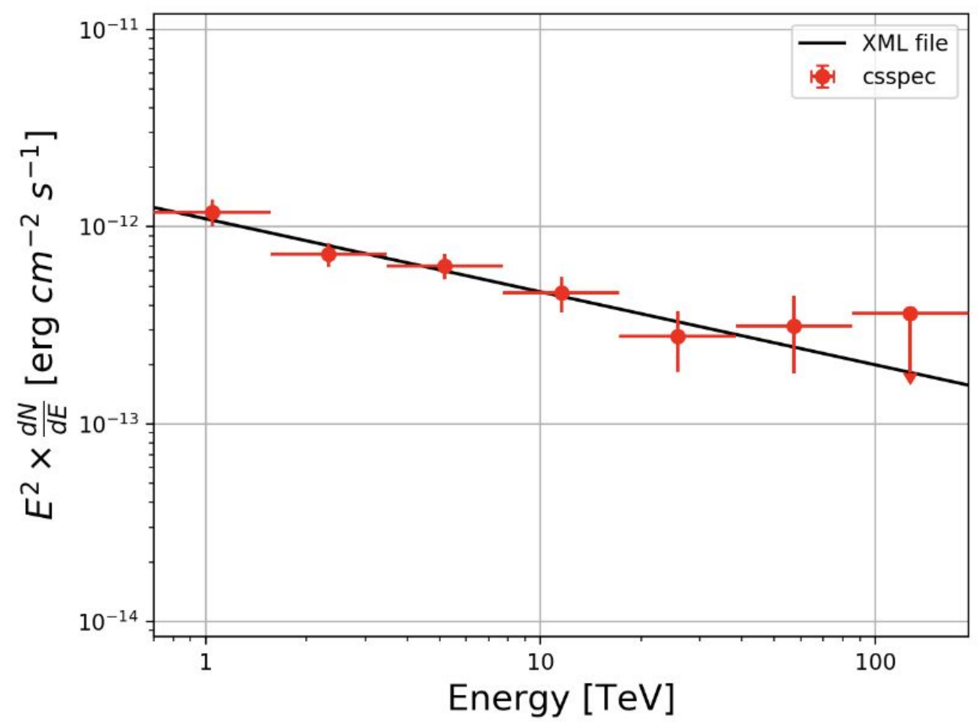
Micro-quasars

A small group of X-ray binaries (Cyg X-1, Cyg X-3 and SS 433) show HE emission up to GeV.
SS 433 (likely a super-Eddington accreting source) with broad MWL emission is a key target to understand particle acceleration in XRB jets. The jet produces two bright TeV spots (e1 and w1).



HAWC Coll. 2018

SS 433 is 1.5° from pillar source eHWC J1907+063. Using HAWC recent results we investigated the constraints that ASTRI-MA will be able to set on this source. In case of a point-like e1 source, ASTRI-MA spectrum in 100hr would detect the emission up to 100 TeV!



Globular Clusters in the GC

Mini-Array

GCs harbour the richest NS population per unit volume in the Galaxy.

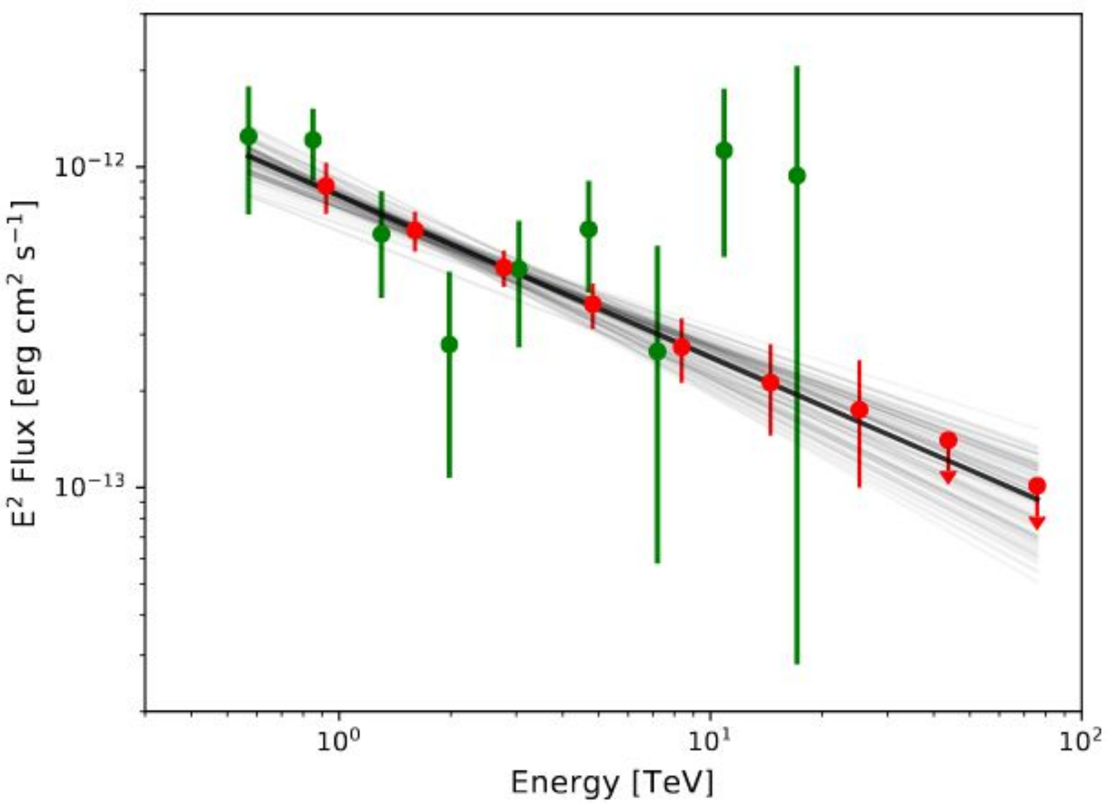
Many GC revealed emission in the HE (with typical cut-offs around few GeV, Tam2016). Search for TeV emission has given only upper limits.

The only exception is the GC Terzan 5 (HESS J1747-248), which has been detected by HESS in 2011 (Abramowski11), though the TeV best-fit position lied at few armin from the GC center.

The HESS spectrum was fitted with a power-law of index 2.5, 1.5% Crab lum. Extended morphology.

Different scenarios to produce the observed TeV flux

- EMISSION FROM MSPs (Bednarek 2014)
- RELIC EMISSION FROM A NS-NS MERGING EVENT (Abramowski11, Domainko11)



We simulated 200hr observations with ASTRI-MA at 3° offset. Using the same HESS best-fit model, we verified that the ASTRI-MA can indeed prolong the HESS spectrum up to 30 TeV, and a cut-off could be detected if less than 12 TeV.

Positional uncertainty on the TeV emission better constrained with ASTRI-MA by a factor of 2.

The long-term perspective

After the commissioning phase, ASTRI-MA will perform a scientific programme based on a limited number of sources (*Pillars targets*).

At the same time, large sky areas will be also deeply observed, thus collecting a similar equal total exposure on a considerable number of field targets, still observable at high spatial-spectral resolution. We have shown for the expected deep exposures (50-200 hours) foreseen in the Core-Science programme targets, significant improvements *at the same time* are obtained for field sources at moderate offset angles.

Scientific cases, simulations and analysis performed by the **ASTRI-MA Science WG**

In particular:

Young SNR: A. Tutone, A. D'Aì, A. Compagnino
PWN & Pulsars: E. Amato, M. Fiori, A. Burtovoi
Galactic Binaries & Microquasars: A. Paizis, N. La Palomara, G. Piano, A. Giuliani
GC & DM search: D'Aì, A. Compagnino, FG Saturni

Thank you for your attention