Sharpening the TeV sky with the ASTRI Mini-Array

A. Stamerra (INAF-OAR) for the ASTRI Project

Credits (more on the slides)

- Saverio Lombardi, Stefano Vercellone, Andrea Giuliani, Giovanni Pareschi, Andrea Bulgarelli, Alessandro Carosi
- The ASTRI-WG coordinators and the science WG collaborators, The ASTRI data-analysis team

HEACOSS, 16 June 2026

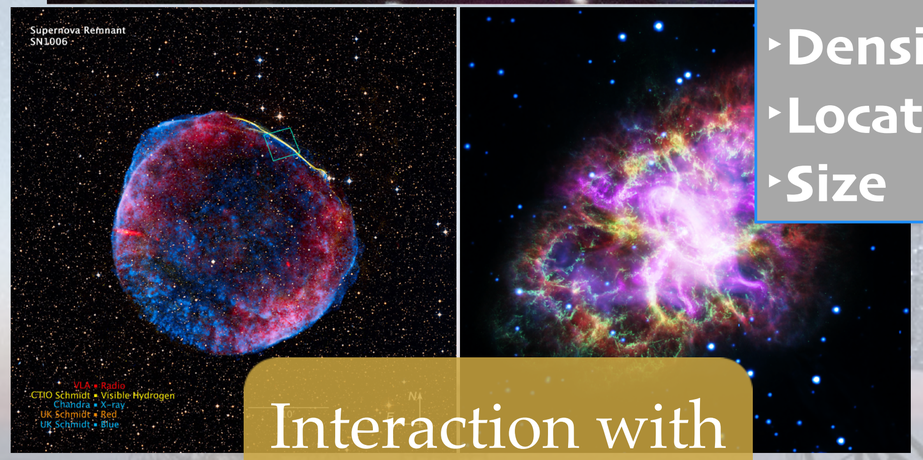
The (astro-)physical processes of the TeV Sky

What can we learn with TeV observations

Particle acceleration

Particle energy distribution
Particle identification
CR-connection

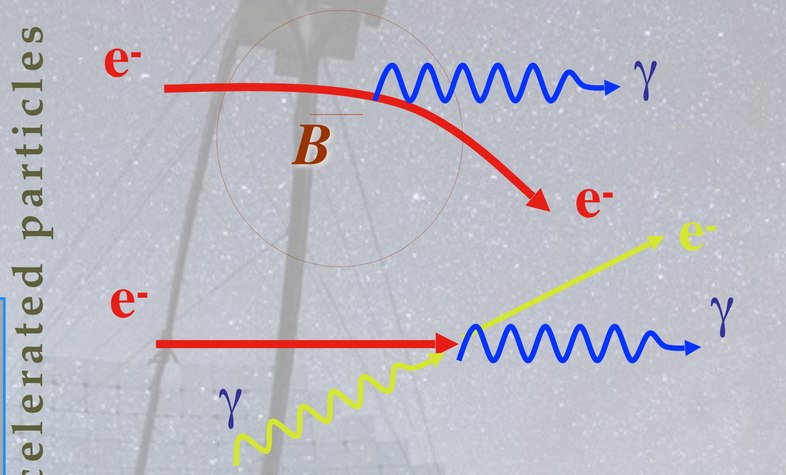
Gamma-ray emission

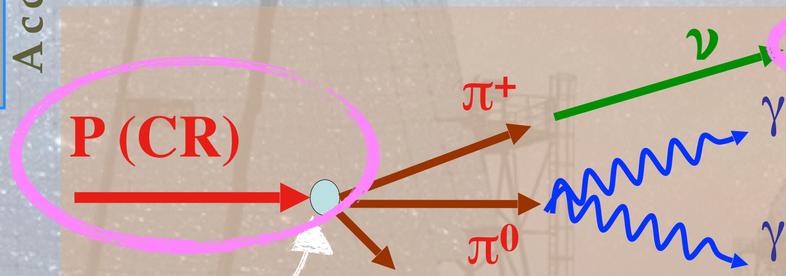


- B-field
- Density
- Location
- Size

Interaction with the ambient

Accelerated particles





Matter (CO clouds, winds, ISM,…)
Radiation field (high density)

Multifrequency and multi messenger

Synchrotron radiation

Radio to gamma-rays

Inverse Compton

gamma-rays GeV-TeV

Neutrinos TeV-PeV

Particle collisions-cascades

gamma-rays GeV-TeV-PeV

APOD 24 Jul 2009

The (astro-)physical processes of the TeV Sky

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Particle identification
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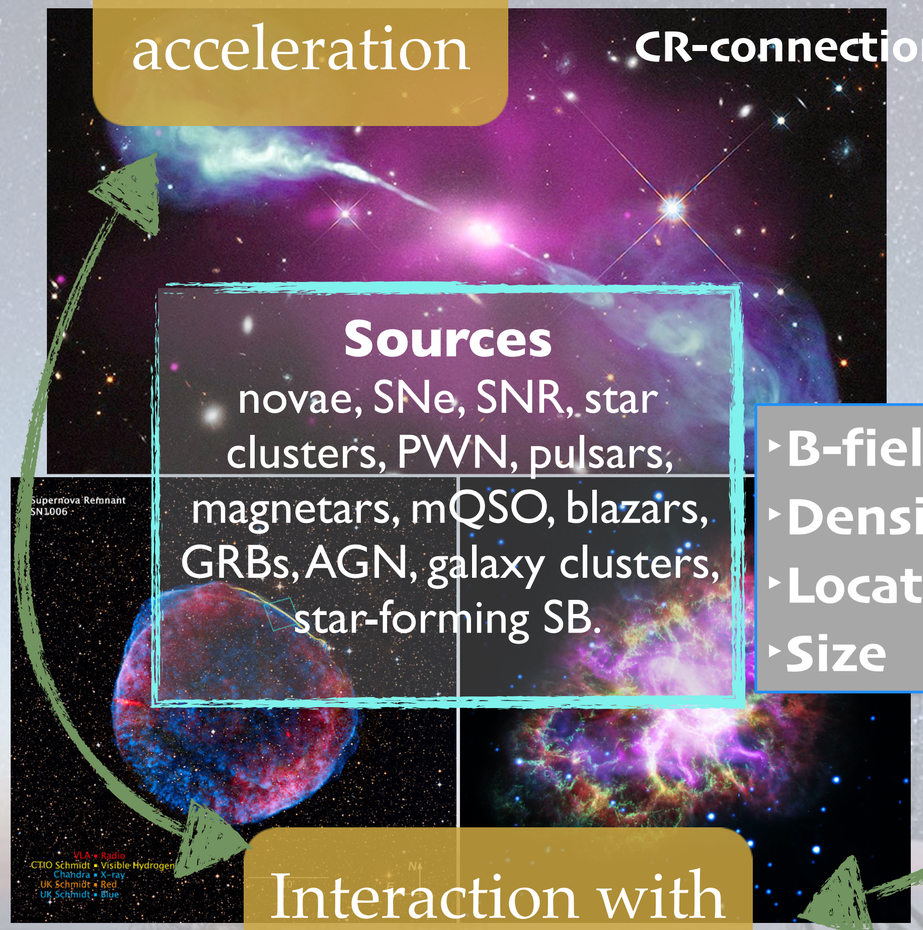
Gamma-ray emission

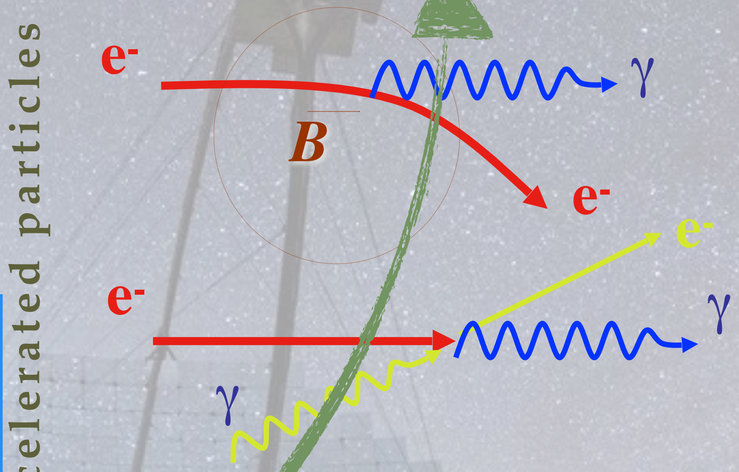
Diagnostics
multi-band observations and correlations, SEDs, variability, light curves, morphology

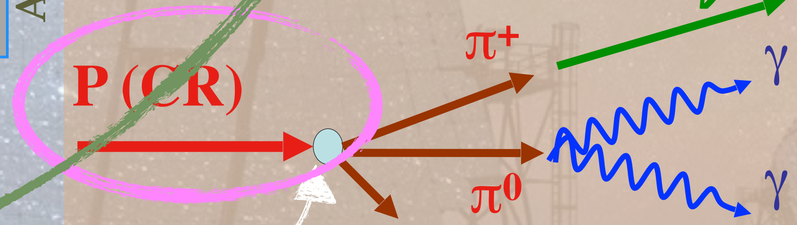


Sources
novae, SNe, SNR, star clusters, PWN, pulsars, magnetars, mQSO, blazars, GRBs, AGN, galaxy clusters, star-forming SB.

- **B-field**
- **Density**
- **Location**
- **Size**

Accelerated particles





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APOD 24 Jul 2009

https://www.astri.inaf.it/

The ASTRI Mini-Array

- An international experiment - IAC site, *Tenerife (Spain)*

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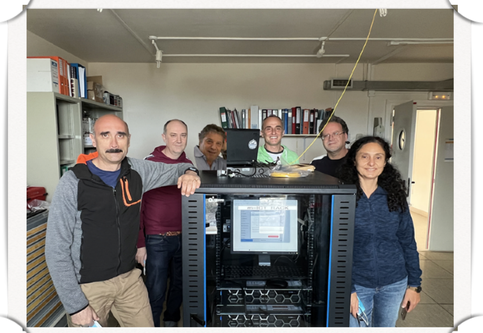
  - 200 researchers from INAF, Italian Universities, INFN, FGG, IAC (Spain), University of São Paulo (Brazil), North-West University (South Africa), Université & Observatoire de Genève (CH)



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The ASTRI Mini-Array

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  - 200 researchers from INAF, Italian Universities, INFN, FGG, IAC (Spain), University of São Paulo (Brazil), North-West University (South Africa), Université & Observatoire de Genève (CH)
  - Collaboration and joint programs with LHAASO, MAGIC, synergies with HAWC, VERITAS, CTAO-North/LST.

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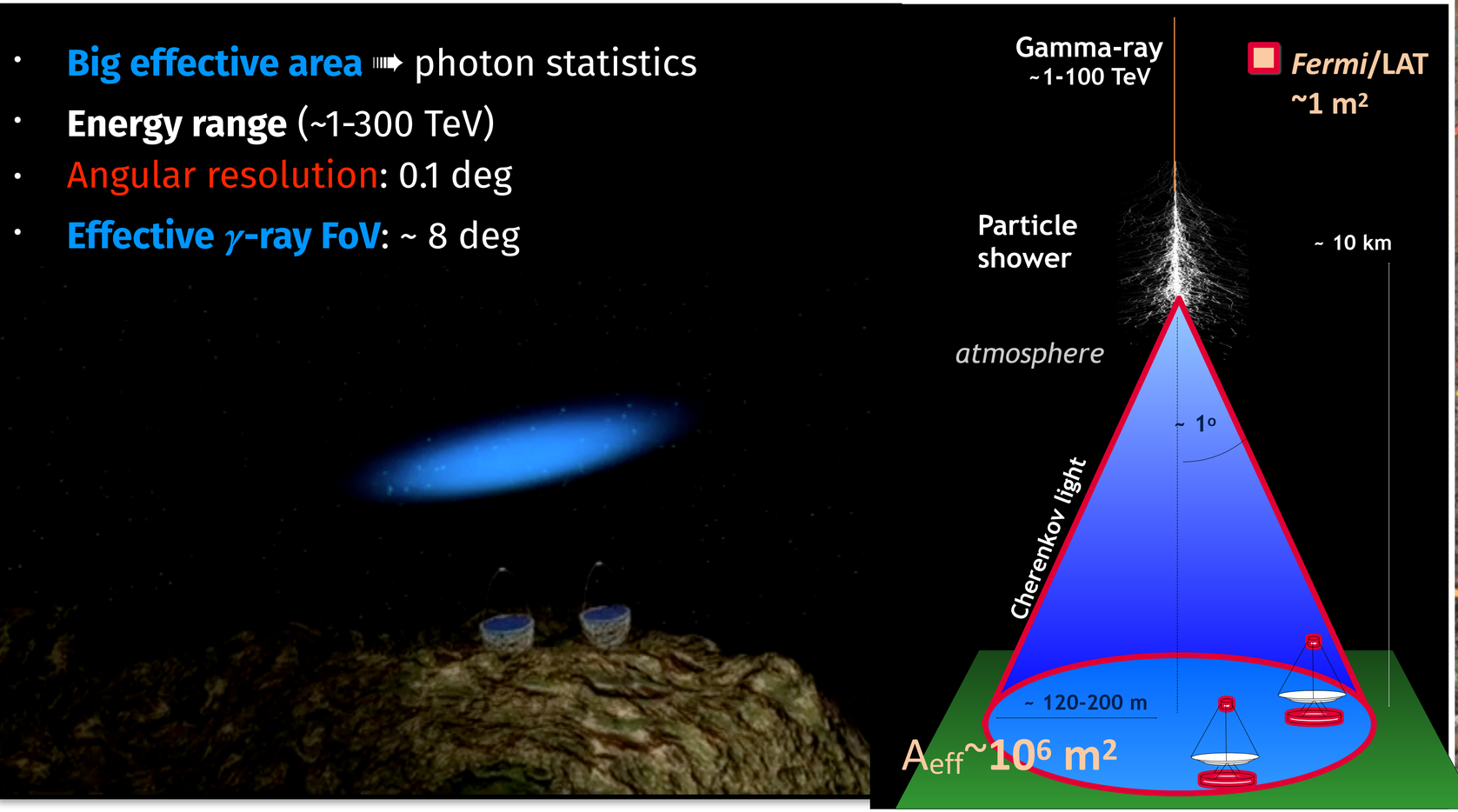
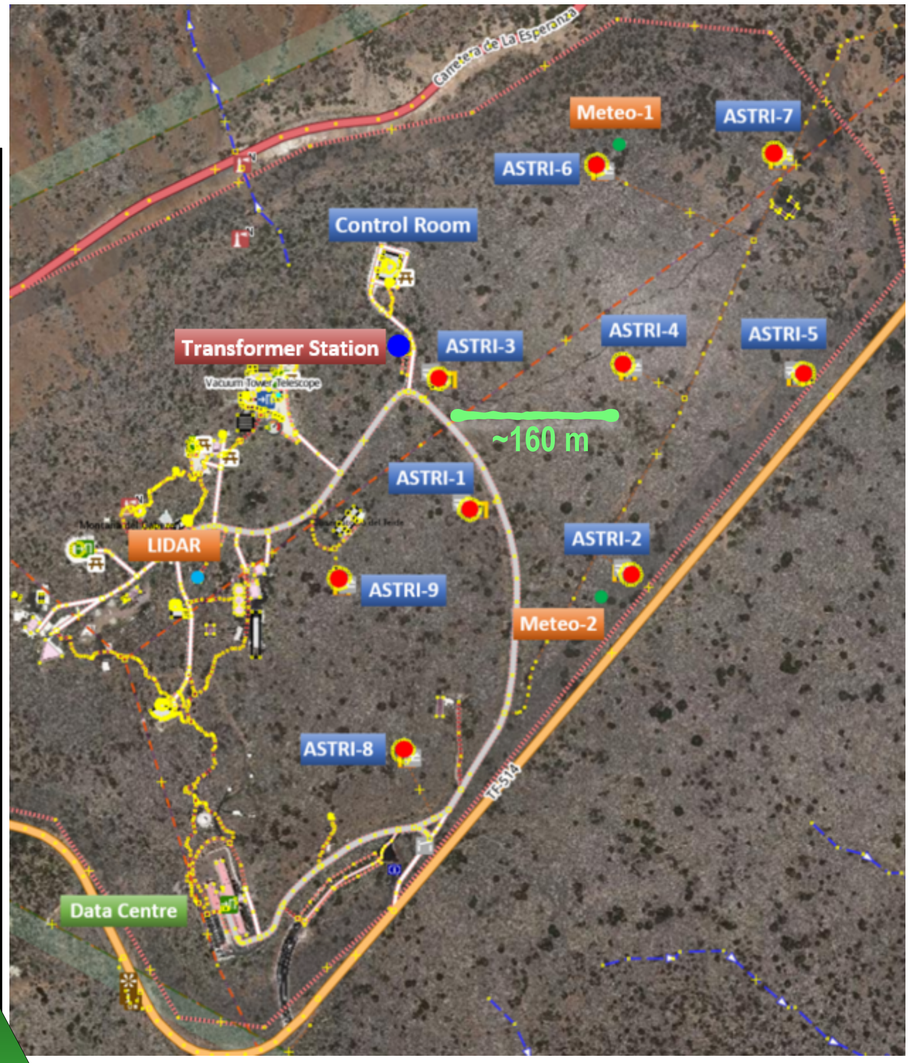
The ASTRI Mini-Array

- Array with 9 Cherenkov telescopes



- **Big effective area** ➠ photon statistics
- **Energy range** (~1-300 TeV)
- Angular resolution: 0.1 deg
- **Effective γ-ray FoV**: ~ 8 deg



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The ASTRI Mini-Array

- Array with 9 Cherenkov telescopes
  - 7 telescopes on site fully assembled; 2 shipped

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Angular resolution: 0.1 deg

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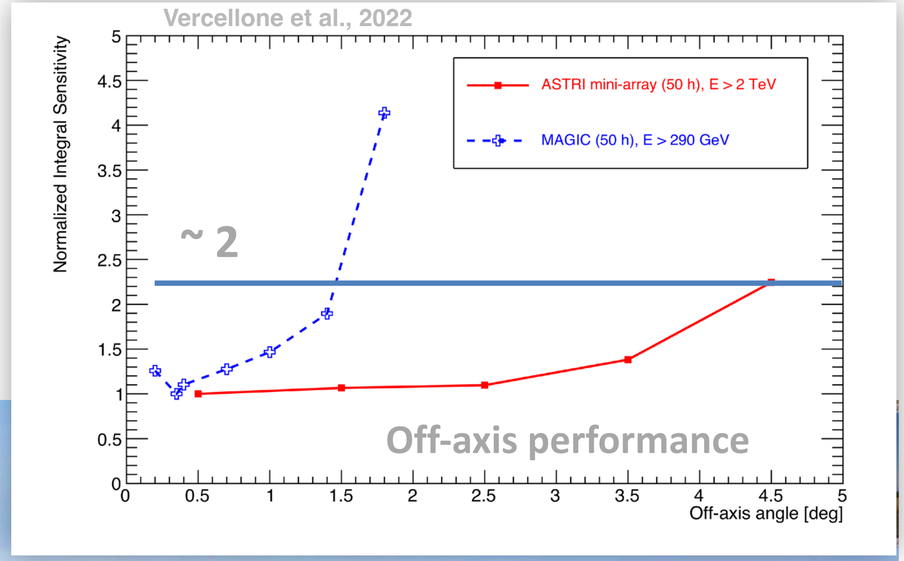

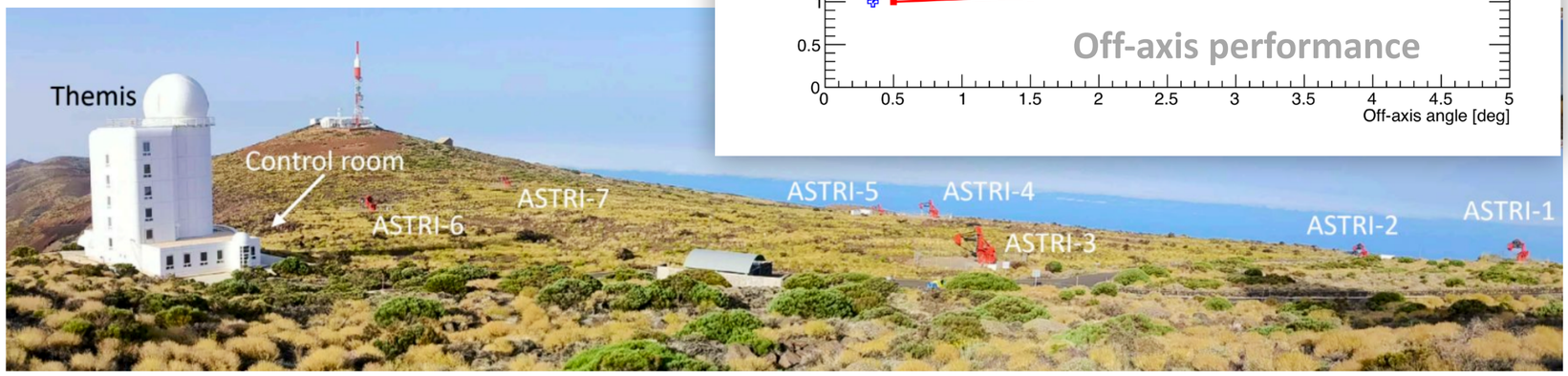

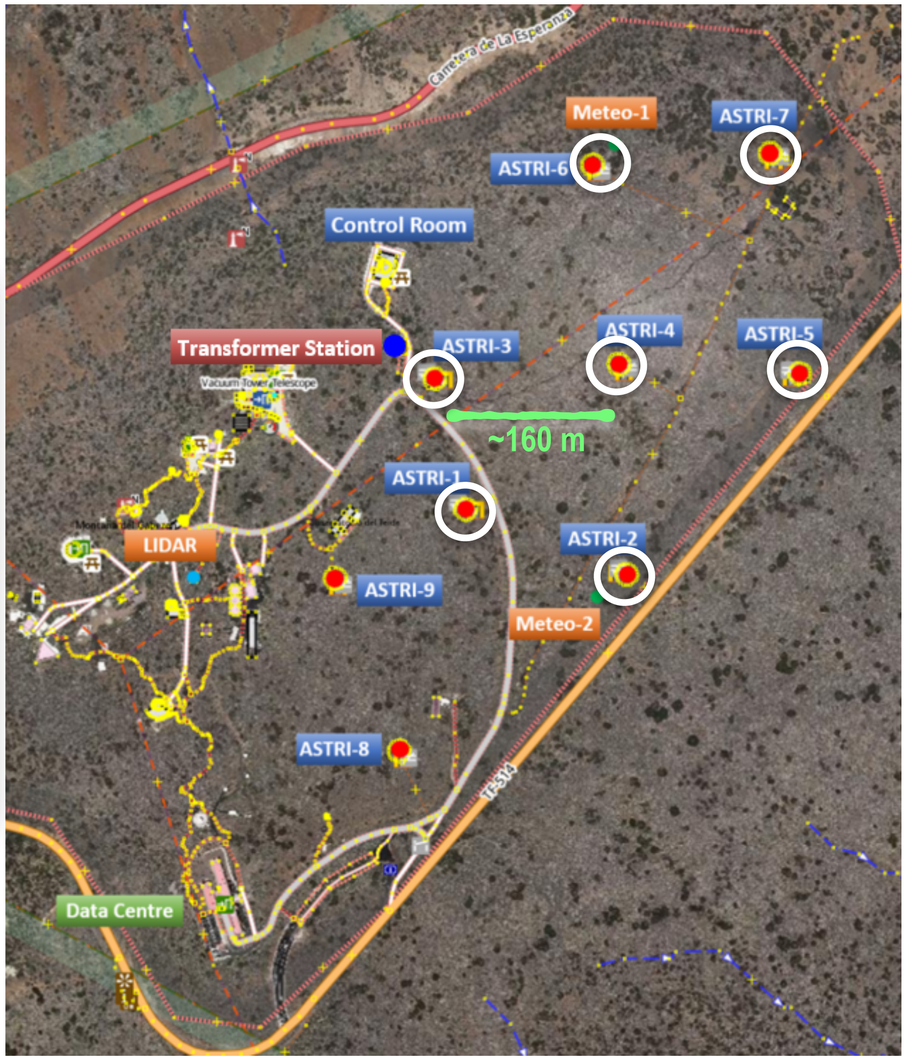

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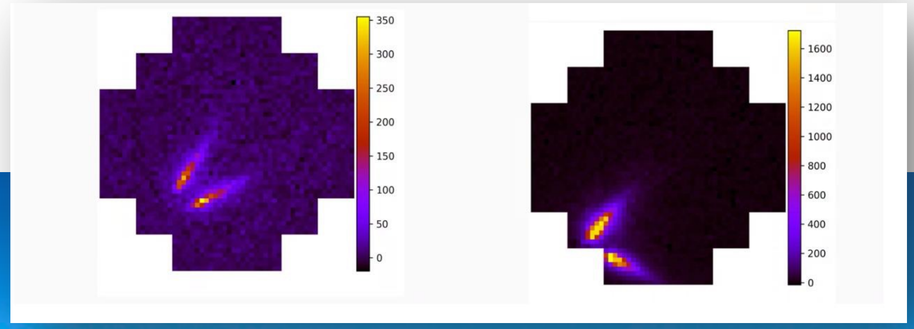
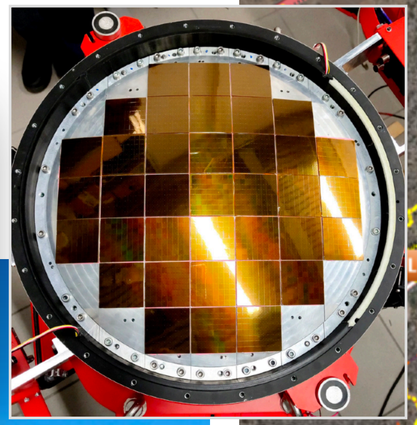
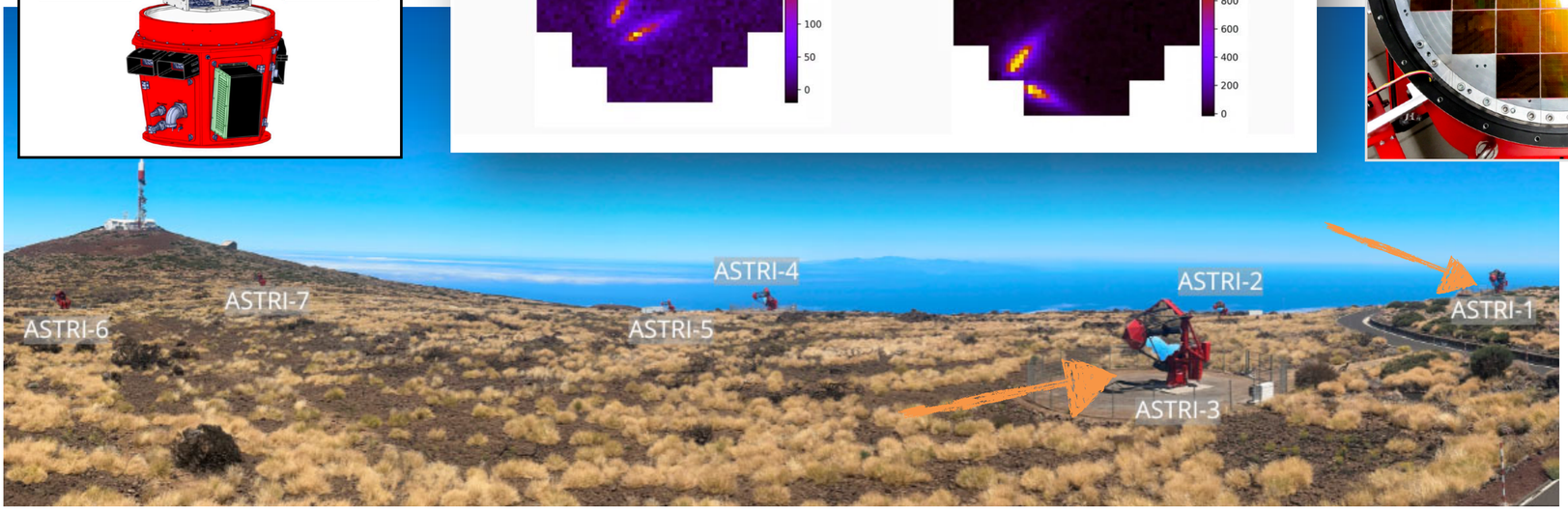
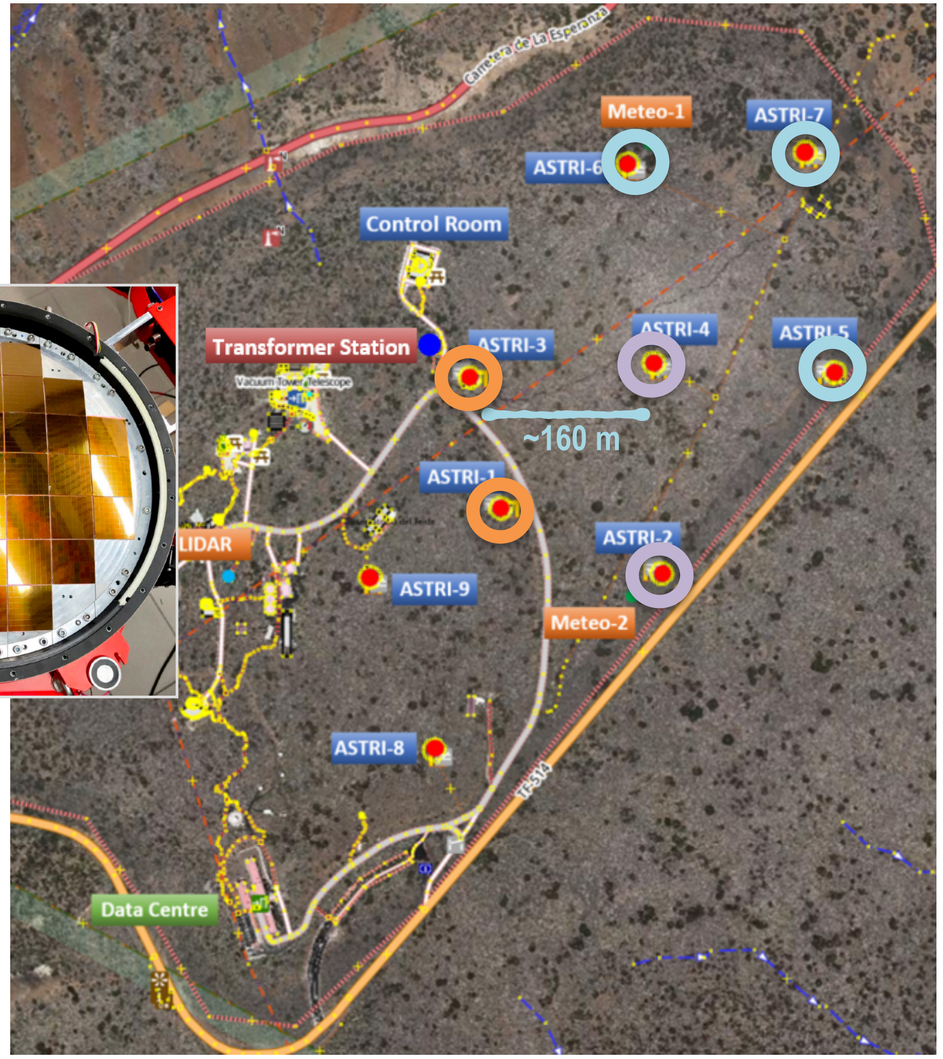
- Array with 9 Cherenkov telescopes
  - 7 telescopes on site fully assembled; 2 shipped
  - 2 telescopes operating in stereo (2 more on the blocks)









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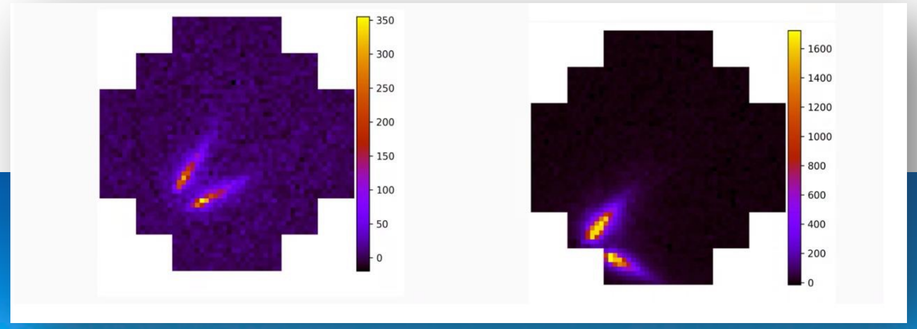
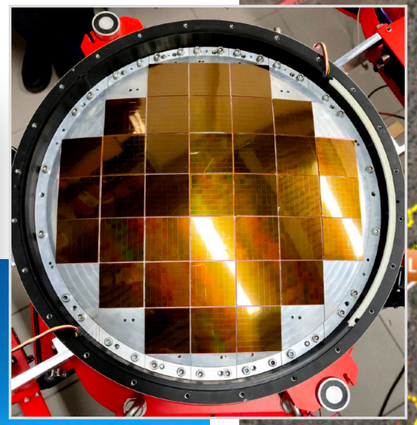
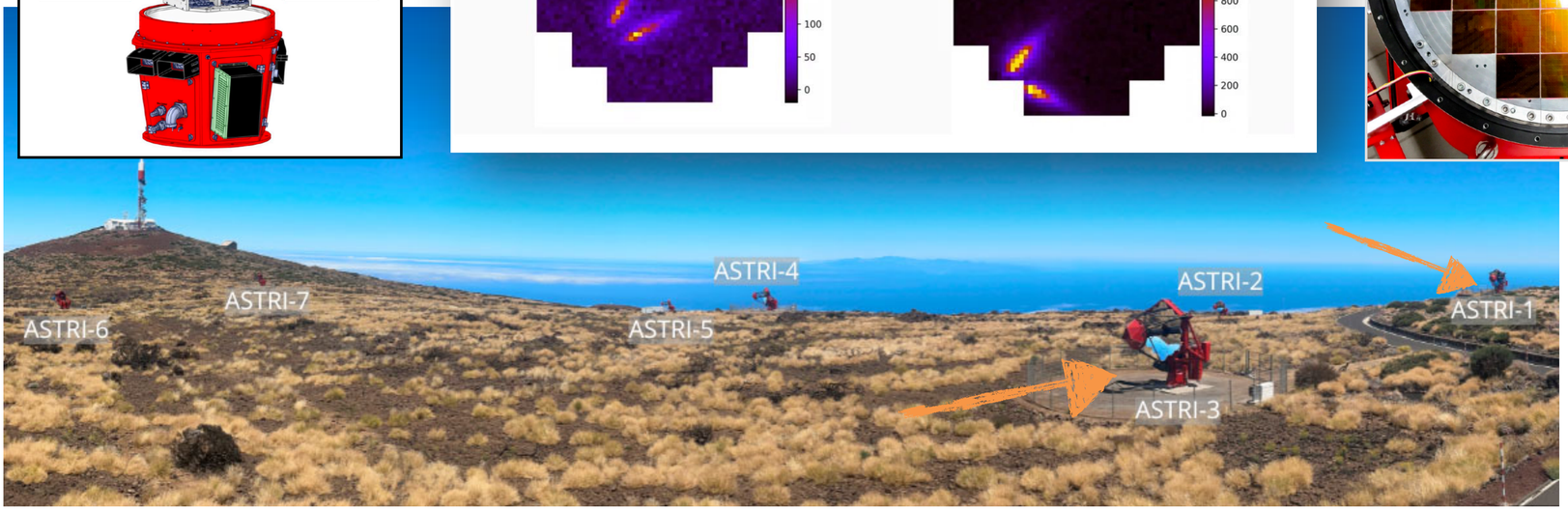
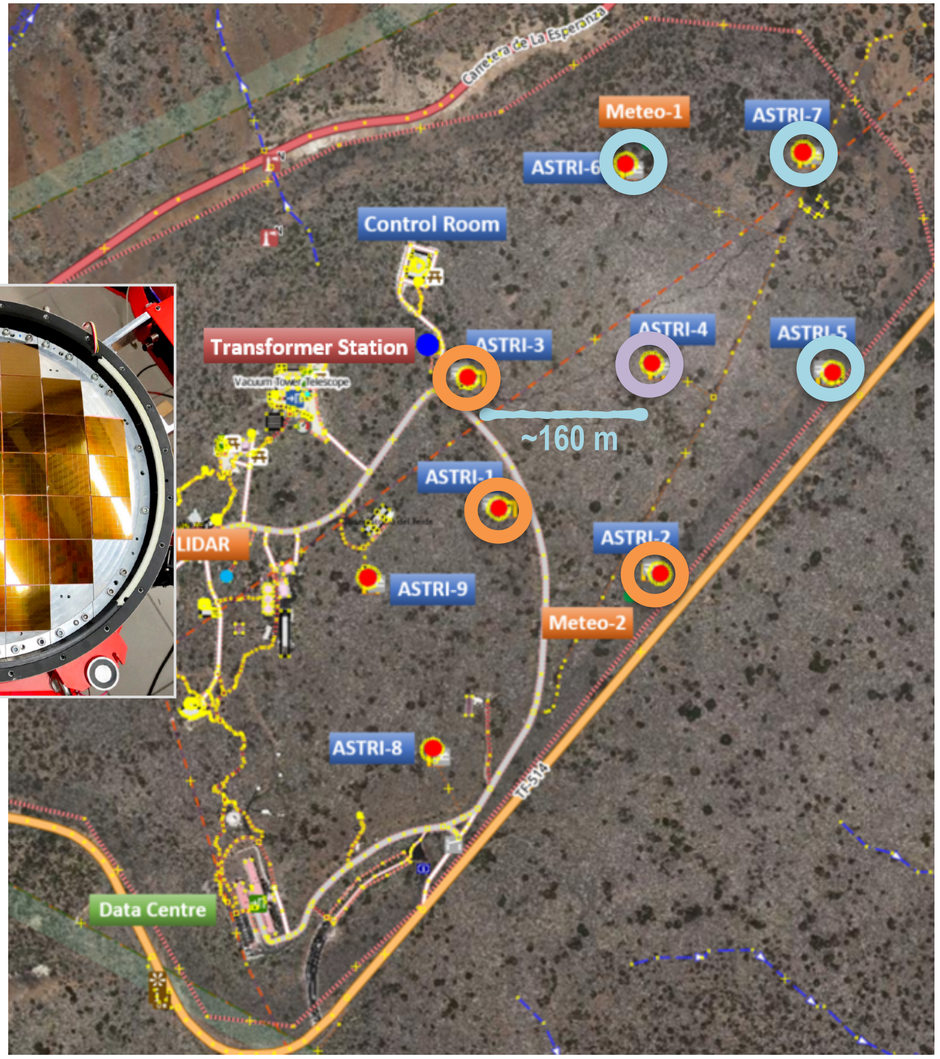
  - 3 since last week!
  - 2 telescopes operating in stereo (2 more on the blocks)









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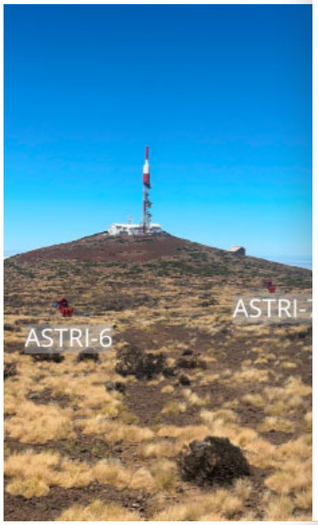
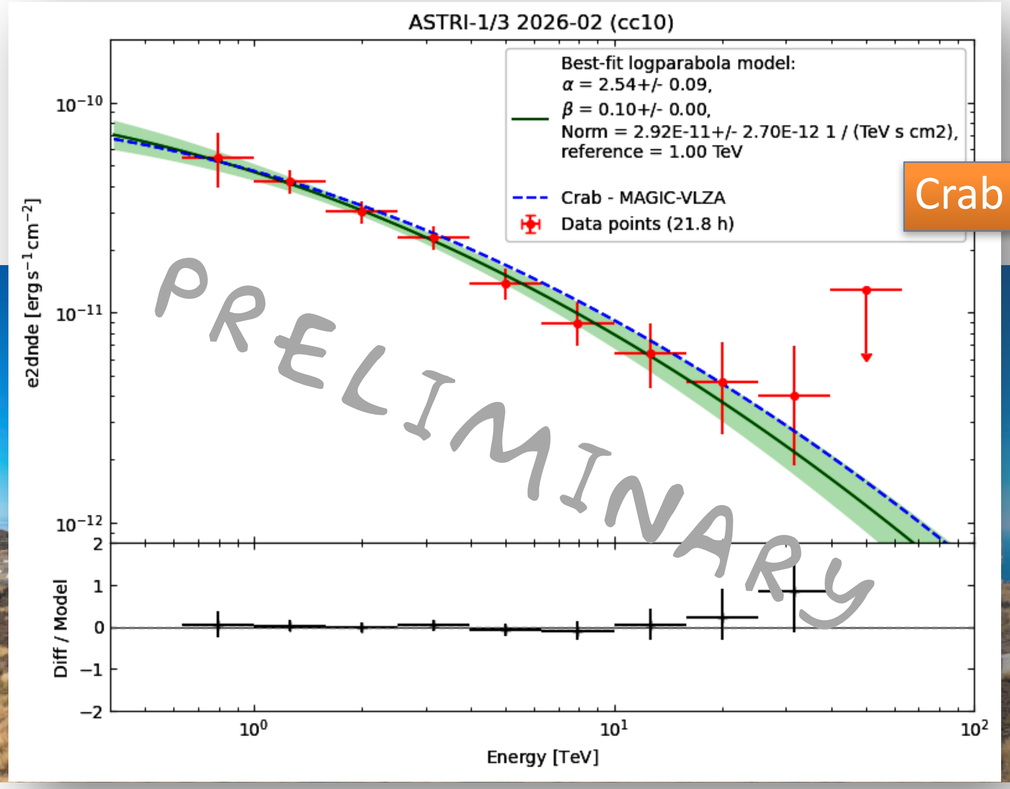
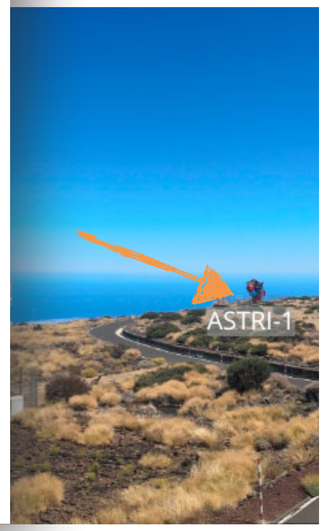
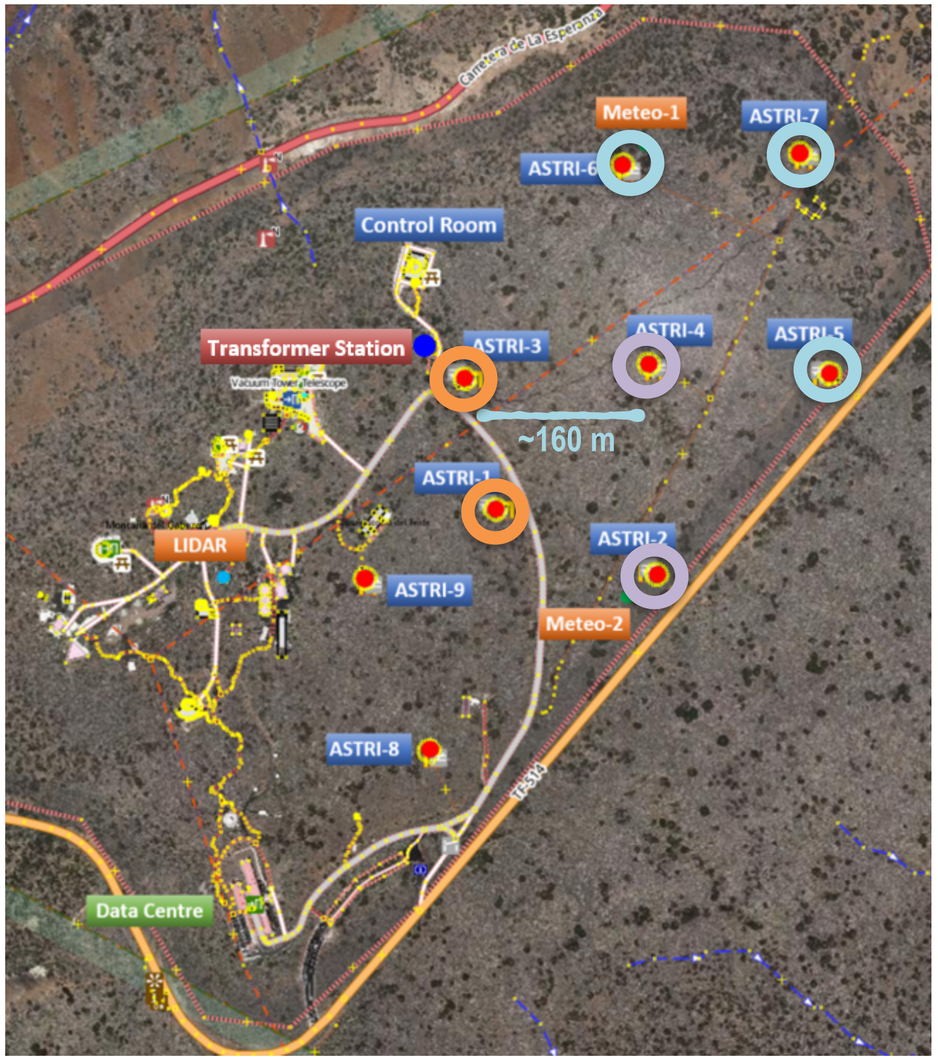




Crab Spectrum





Credit: S. Lombardi and Data Analysis team

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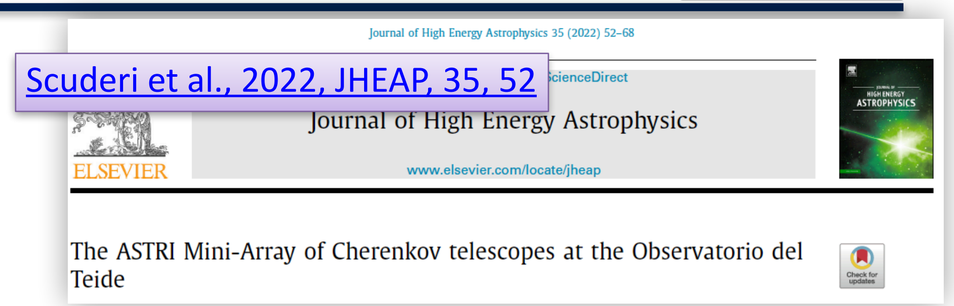
🎬 **Ready for the Early Science!**

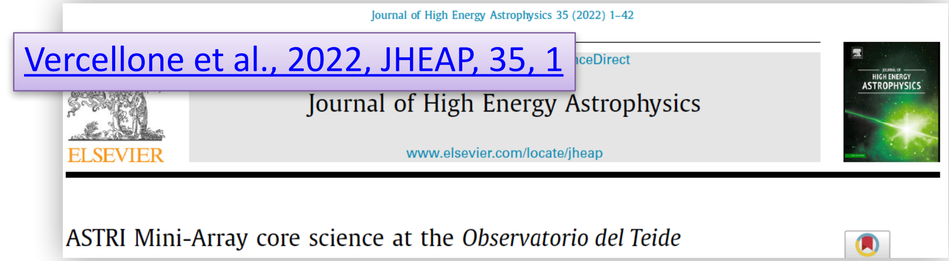
❖The observation program will follow the Core Science targets during the first 4 years

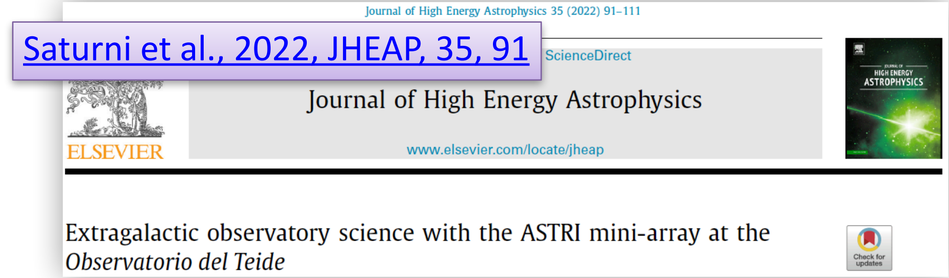
Do it yourself!

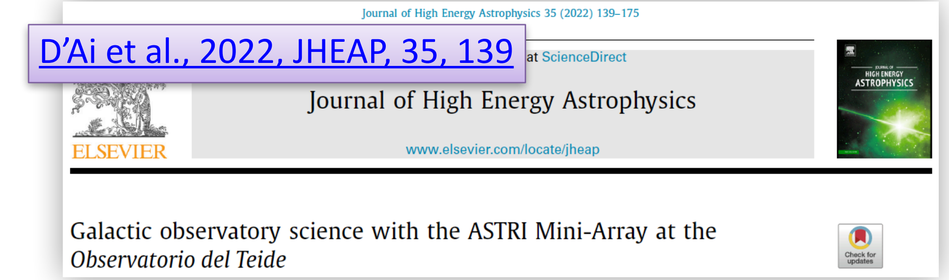
IRF files (Prod2, V1.0) can be retrieved from Zenodo:
https://zenodo.org/record/6827882#.Y_N34-zMJ60

Gammapy [https://gammapy.org/]
can be used to simulate & analyse sources









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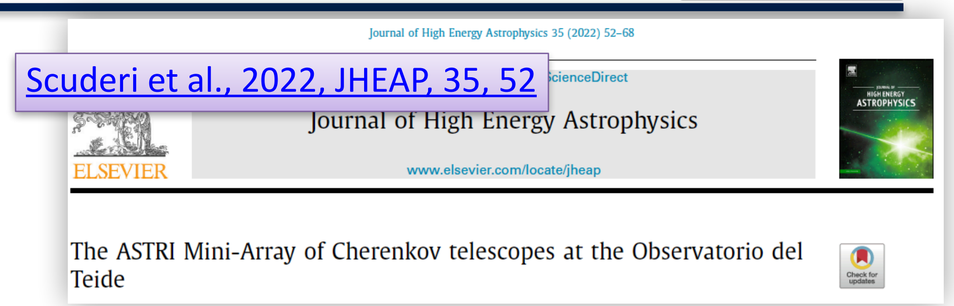

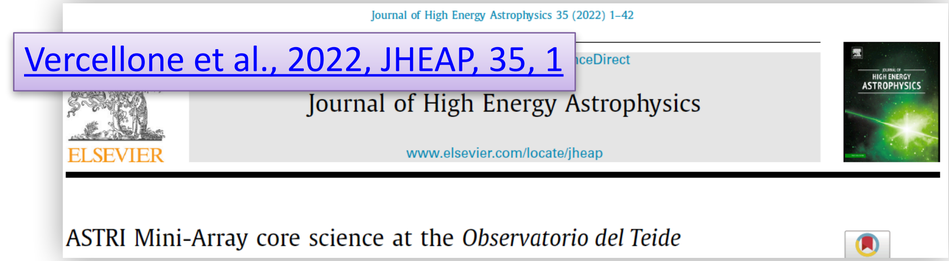

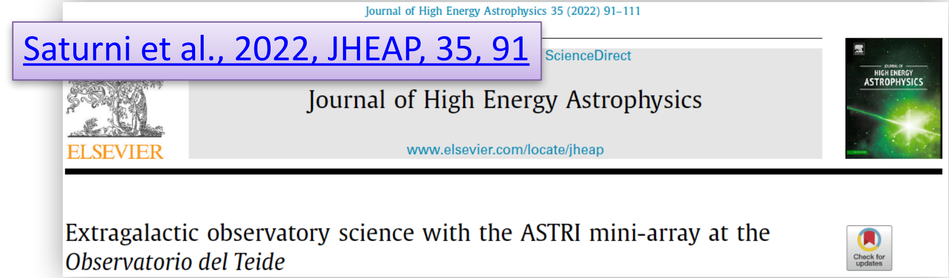

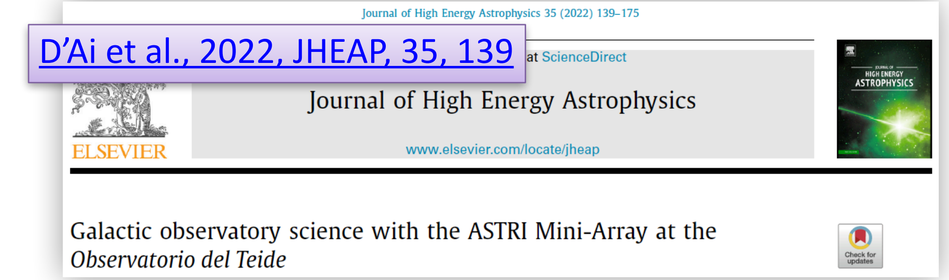

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The ASTRI Mini-Array: early science

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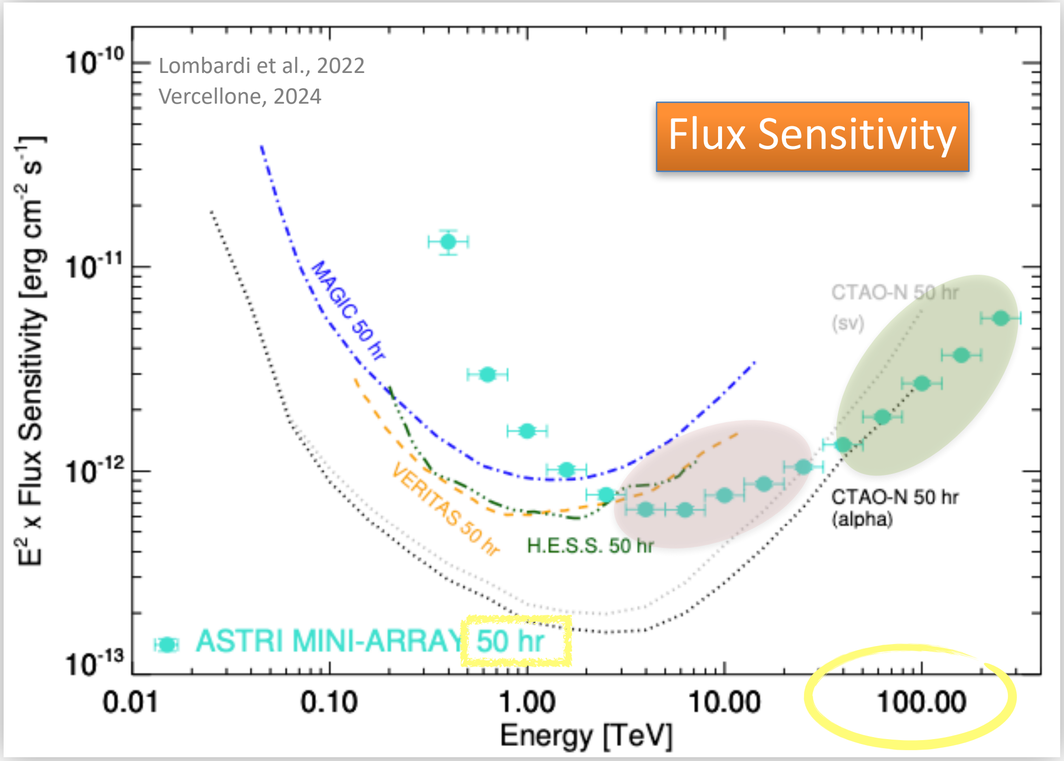
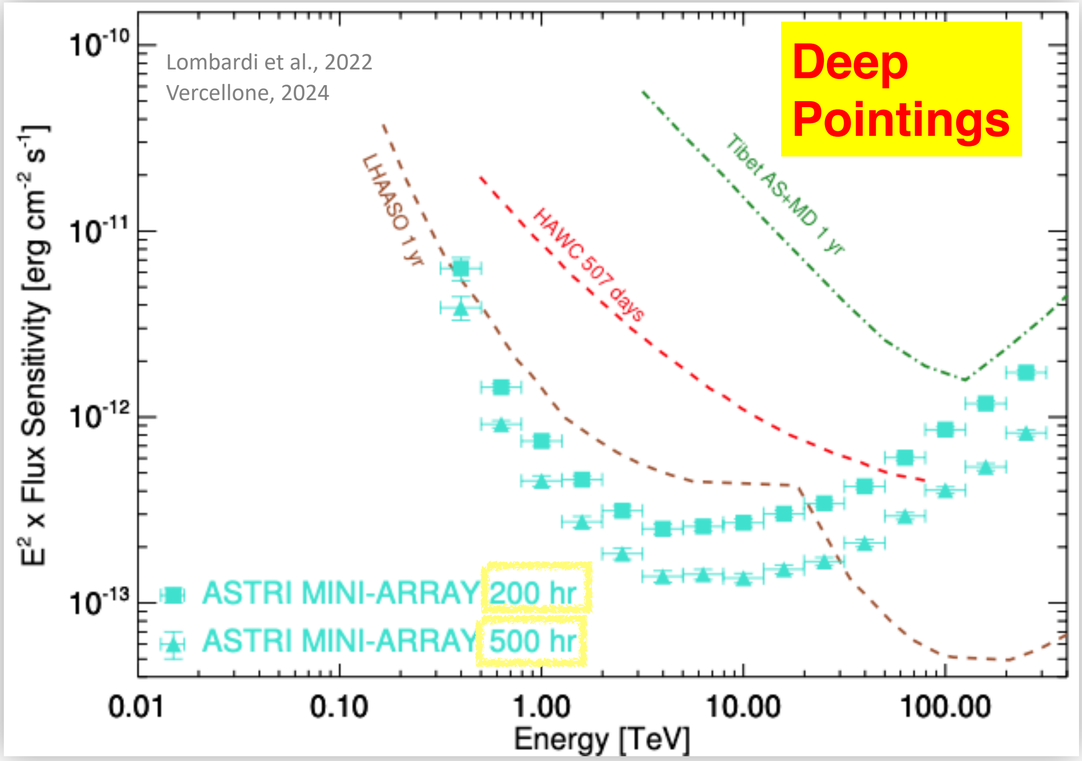
- ASTRI Mini-Array sensitivity in the 1 to >100 TeV range





Credit: S. Vercellone

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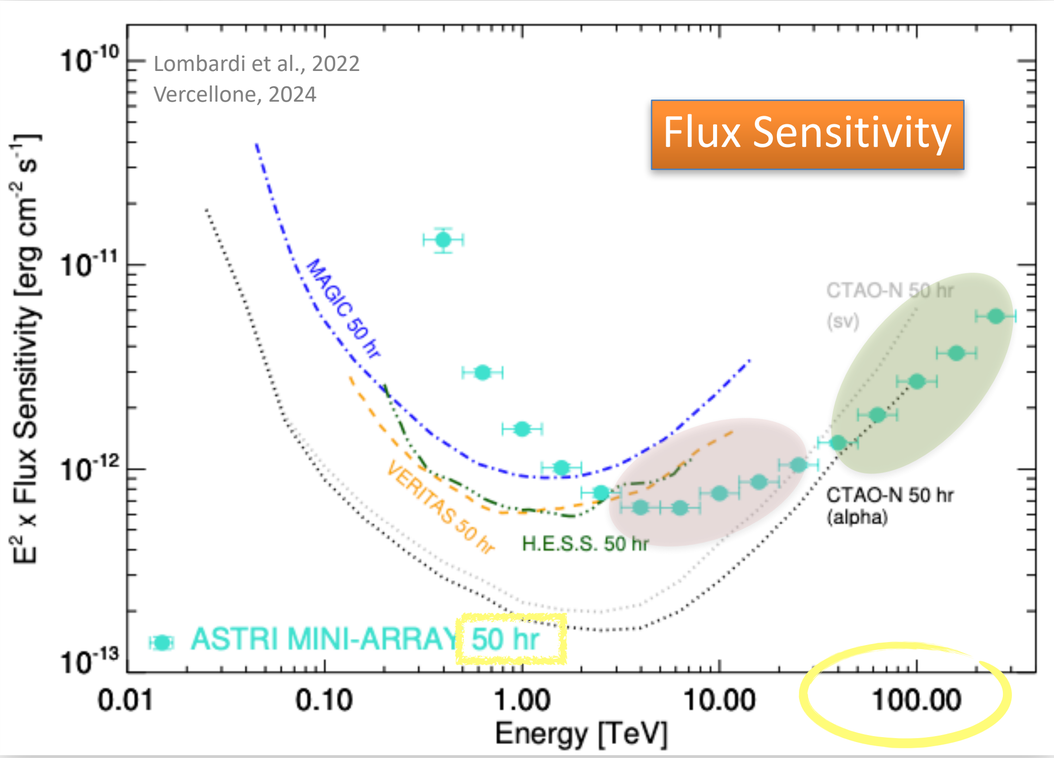
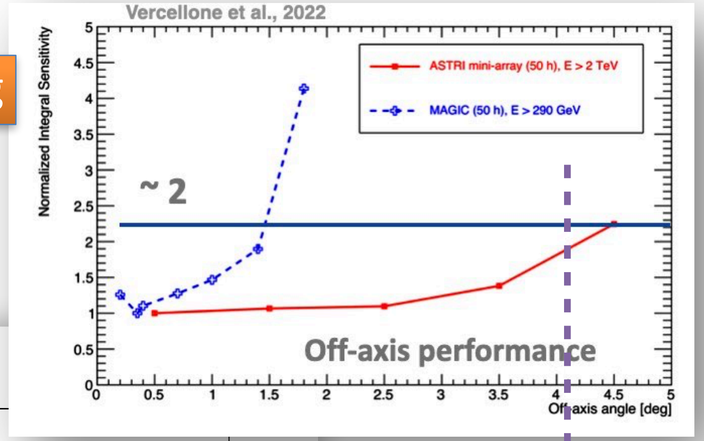
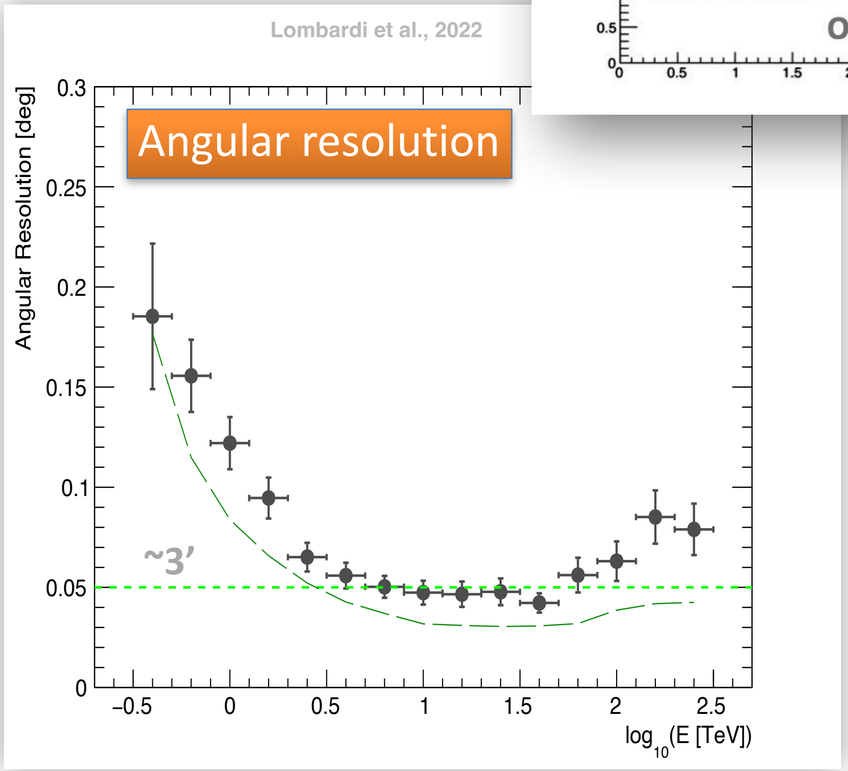
- ASTRI Mini-Array sensitivity in the 1 to >100 TeV range
- Angular resolution and wide Field of View



FoV ~8-9 deg



4 deg radius



Credit: S. Vercellone

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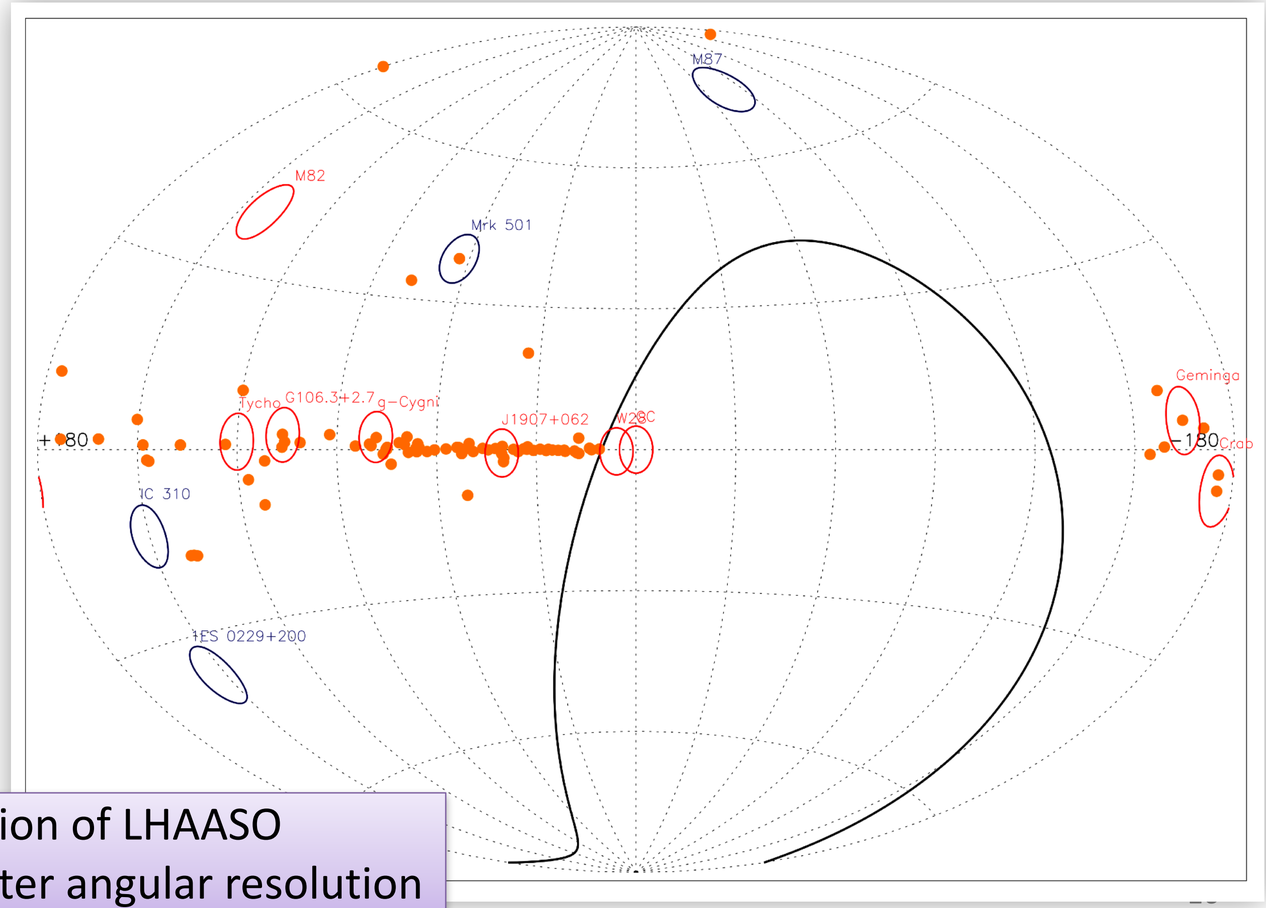
- Angular resolution and wide Field of View

ASTRI Mini-Array:

- ✓ precise identification
- ✓ morphology and spectra
- ➡ Crowded and extended regions
  - ✳ e.g. LHAASO sources
  - ✳ Cygnus region
- ◉ Caveat: complex analysis!



Localisation and possible Identification of LHAASO sources (several extended) with better angular resolution

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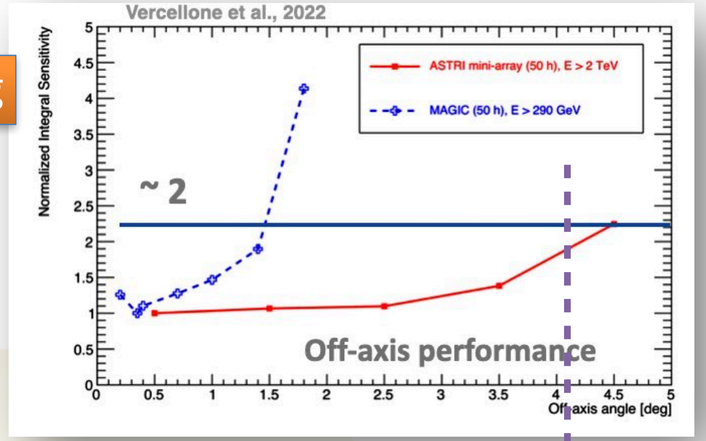

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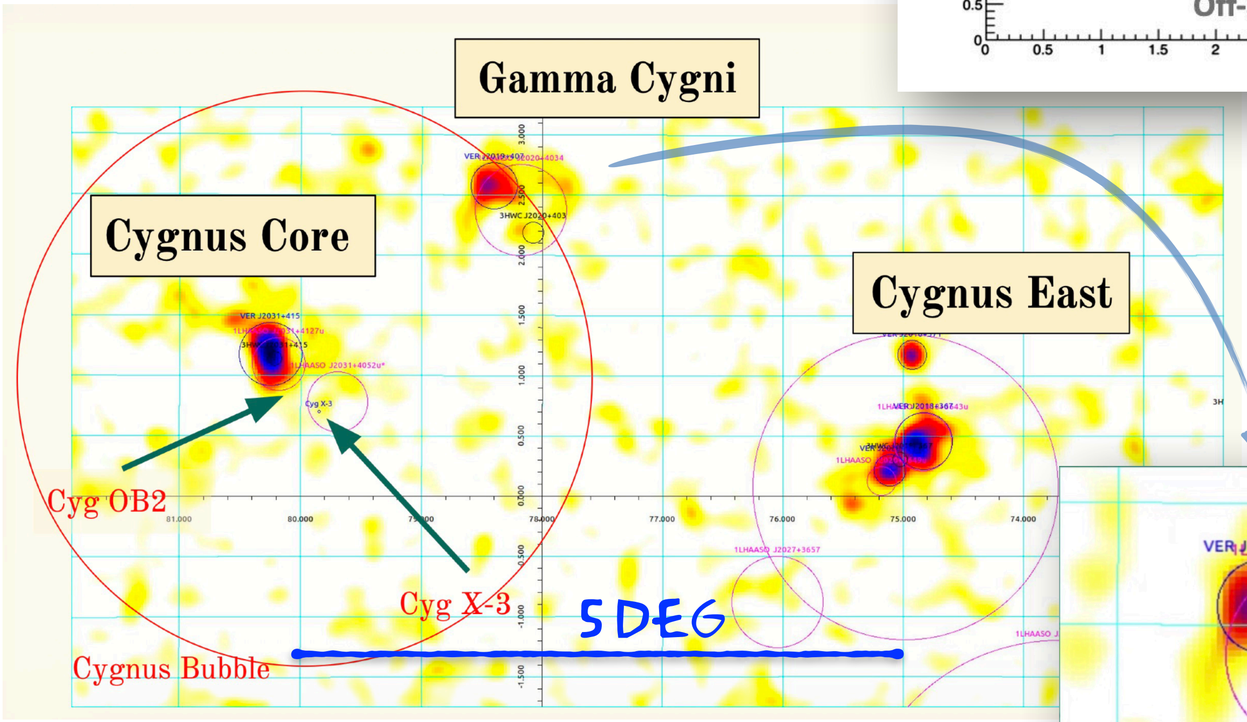

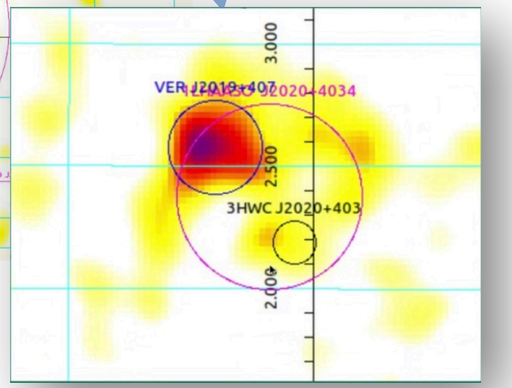

Credit: A. Giuliani

Simulations with ASTRI 3-telescopes IRF ongoing

https://www.astri.inaf.it/

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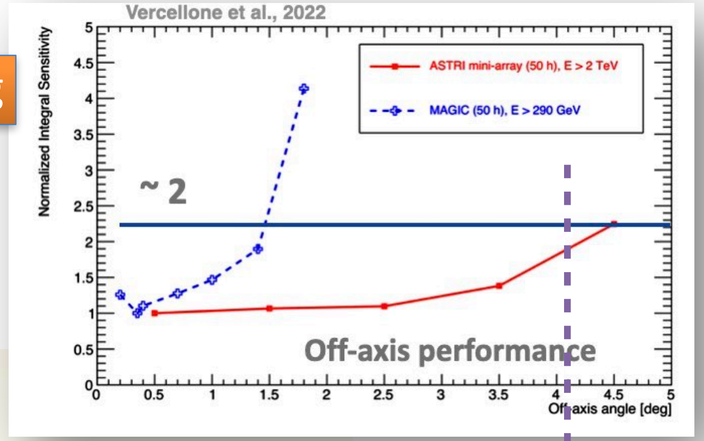
FoV ~8-9 deg



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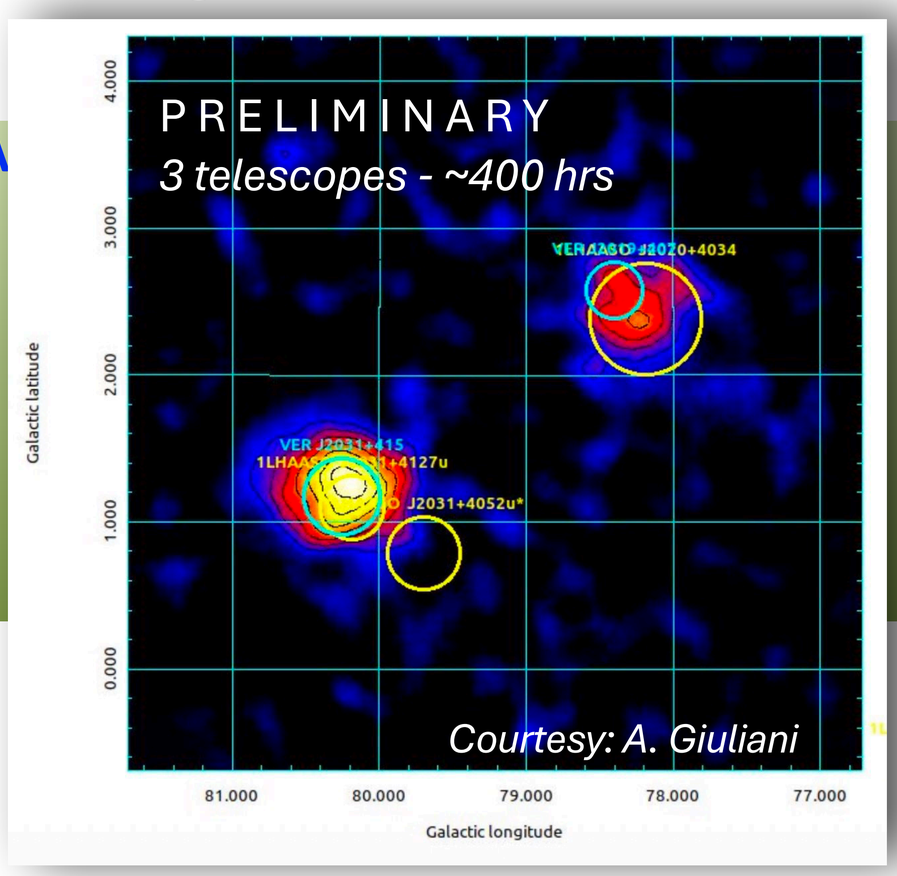

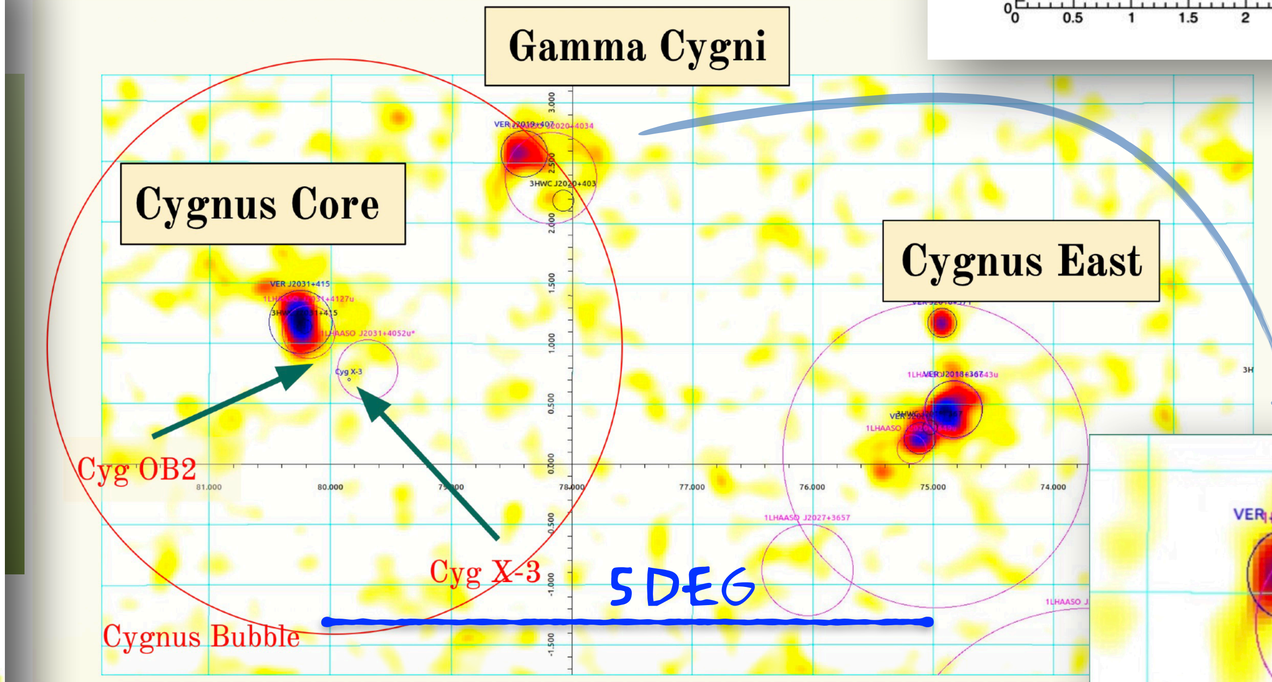

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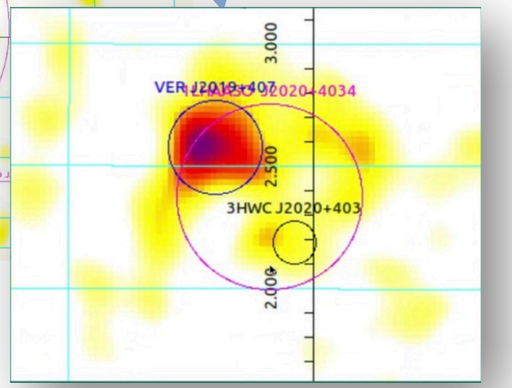

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- Angular resolution and wide Field of View
- First ATel on a flare by Mrk421

ASTRI-1 detection of enhanced very high-energy gamma-ray emission from Mrk 421 at TeV energies

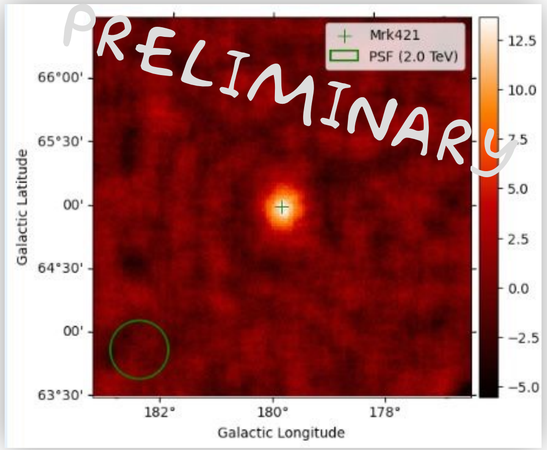
ATel #17602; *S. Crestan (INAF/IASF Milano), C. Quartiroli (INAF/IASF Milano), A. Sunny (INAF/IAPS Roma), S. Lombardi (INAF/OAR Roma), F. Lucarelli (INAF/OAR Roma), F. Pintore (INAF/IASF Palermo), for the ASTRI Project*
*on **15 Jan 2026; 17:41 UT***
Credential Certification: Fabio Pintore (fabio.pintore@inaf.it)

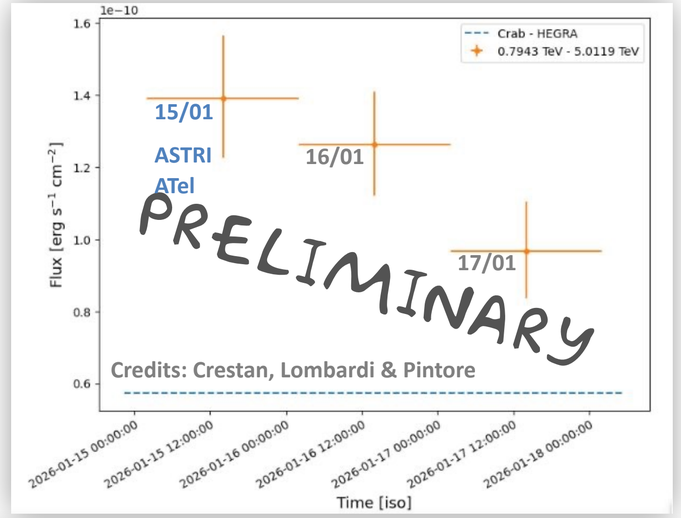
Subjects: Gamma Ray, TeV, VHE, AGN, Blazar

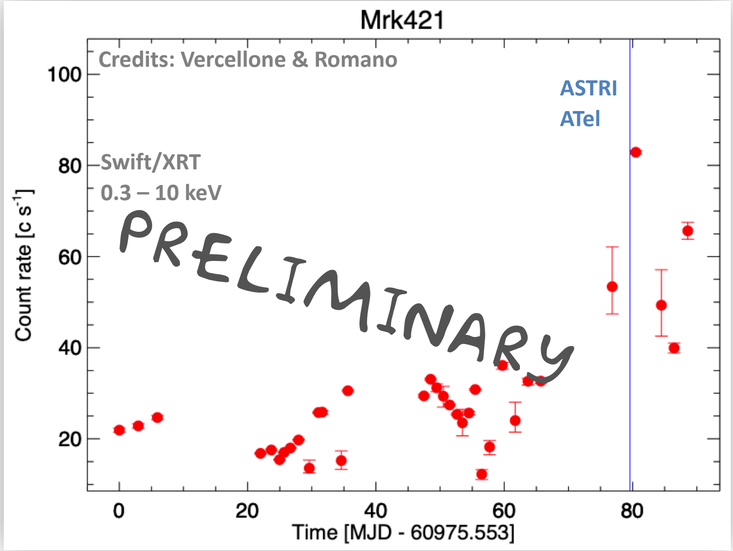
Referred to by ATel #: 17622

Tweet

The ASTRI-1 telescope has observed an increase in the very high-energy gamma-ray flux from the blazar Mrk 421 (z = 0.031). Observations were performed between 2026/01/15 - 2:00 UTC (MJD 61055.08) and 04:40 UTC (MJD 61055.20) for a total effective observation time of approximately 2.5 hr. A preliminary analysis of the collected data reveals a significant detection of 11 sigma. The detected gamma-ray flux between 0.8 and 5 TeV is estimated to be 2.3 +/- 0.3 (stat) Crab Units.







https://www.astri.inaf.it/

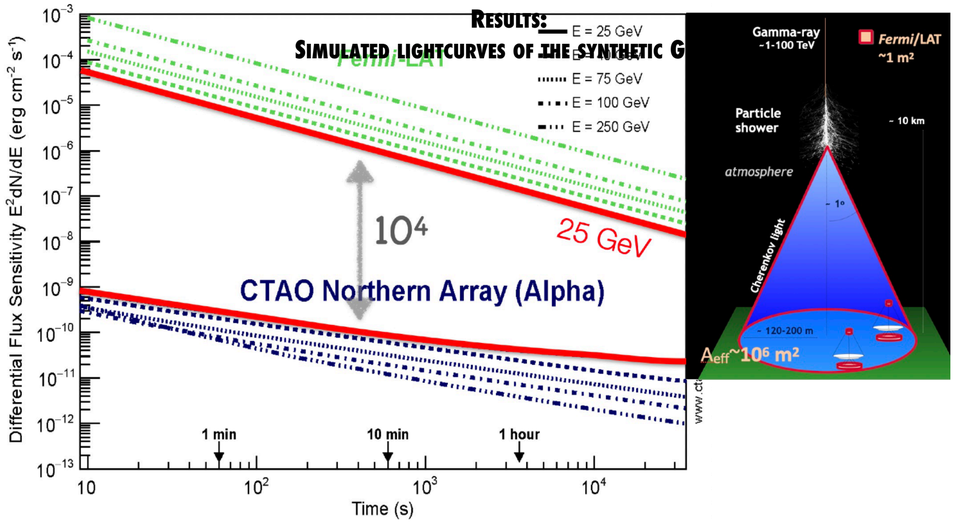
The ASTRI Mini-Array: transients

- Cherenkov telescope are ideal for transients!
- GRBs have been detected up to 13 TeV
- GRBs emit up and beyond 1 TeV

Name	T_{90} [s]	Redshift	E_{iso} [erg]	IACT	α_{obs}	E_{max}
180720B	48.9	0.653	6×10^{53}	H.E.S.S.	3.7 ± 1.0	440 GeV
190114C	362	0.4245	3×10^{53}	MAGIC	5.43 ± 0.22	1 TeV
190829A	58.2	0.0785	2×10^{50}	H.E.S.S.	2.59 ± 0.08	3.3 TeV
201216C	48	1.1	5×10^{53}	MAGIC	-	-
201015A	9.8	0.423	10^{50}	MAGIC	-	-

T0+10h
T<~15 min
up to T0+3days

+2221009A z=0.15 (LHAASO) ~13 TeV



Credit: A. Carosi

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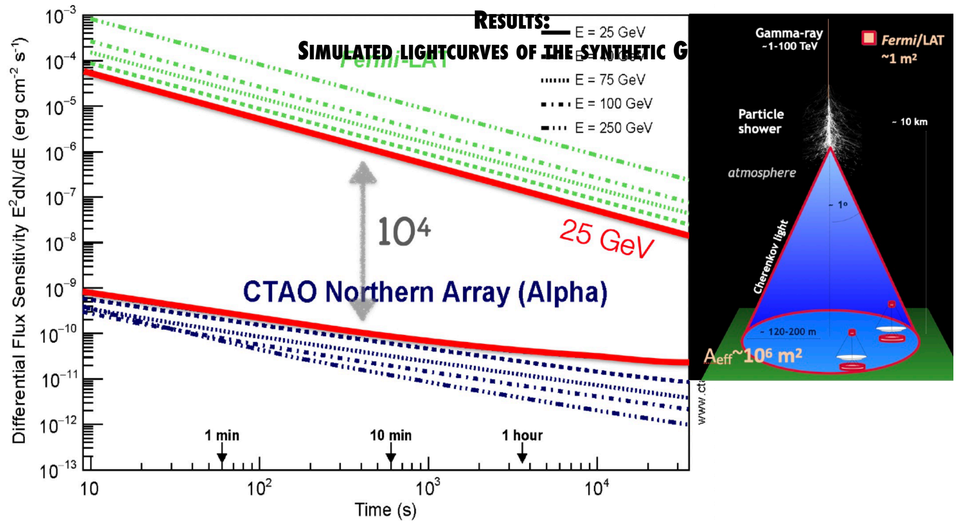

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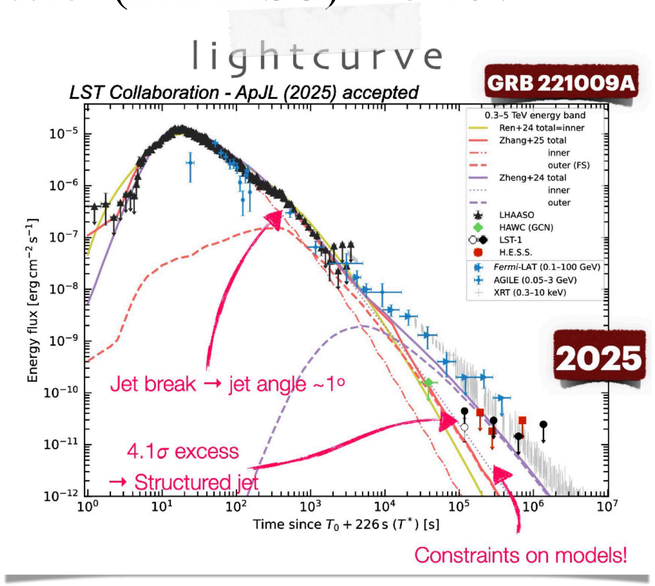
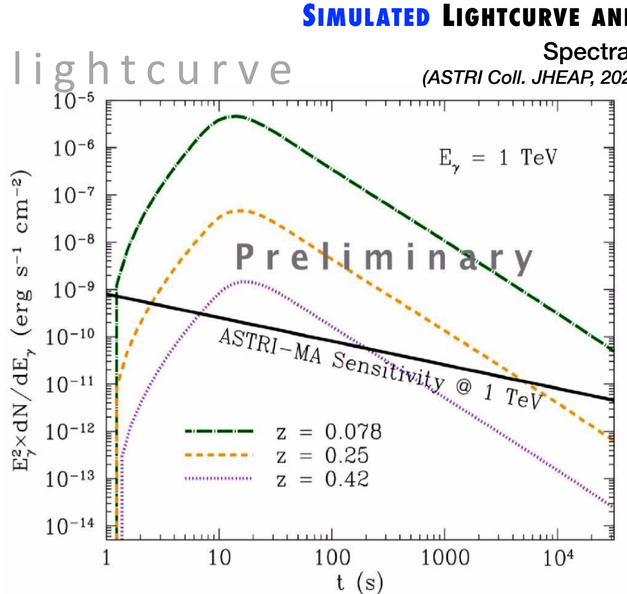


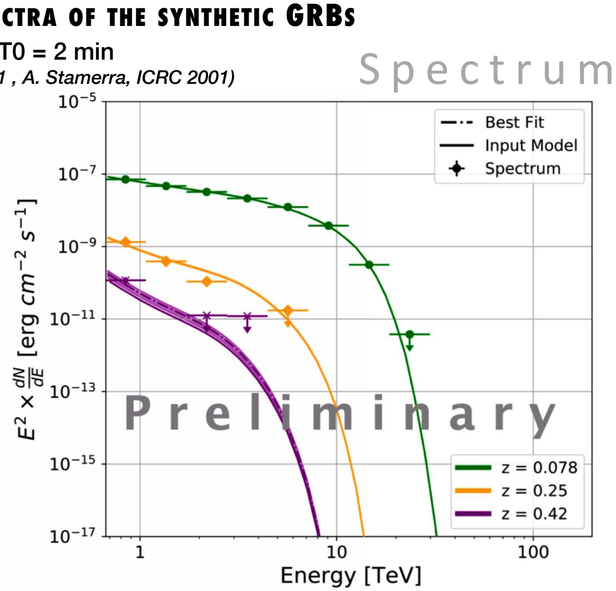
Credit: A. Carosi

SIMULATED LIGHTCURVE AND SPECTRA OF THE SYNTHETIC GRBS

Spectra at T-T0 = 2 min

(ASTRI Coll. JHEAP, 2022, 35, 1 , A. Stamerra, ICRC 2001)





https://www.astri.inaf.it/

The ASTRI Mini-Array: transients

- Cherenkov telescope are ideal for transients!
- GRBs have been detected up to 13 TeV
- GRBs emit up and beyond 1 TeV
- Extended study to a population of synthetic GRBs (*L. Nava, A. Carosi*)

ASTRI wider γ-ray FoV can be effective on poorly localised GRBs, HE-Neutrino counterpart (IceCube, KM3Net) and for GW alerts followups. *Studies in progress!*

ASTRI MA GRB Sim Pipeline

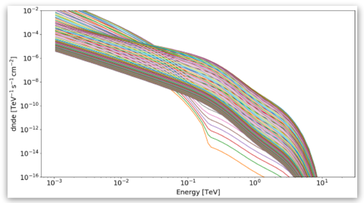
Synthetic GRB Population

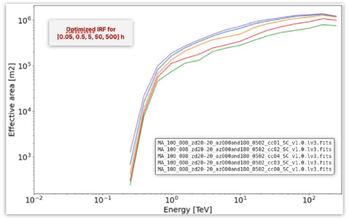
↓

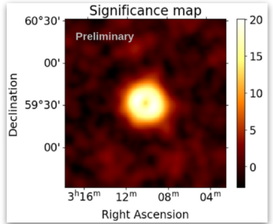
ASTRI MA Follow up strategy

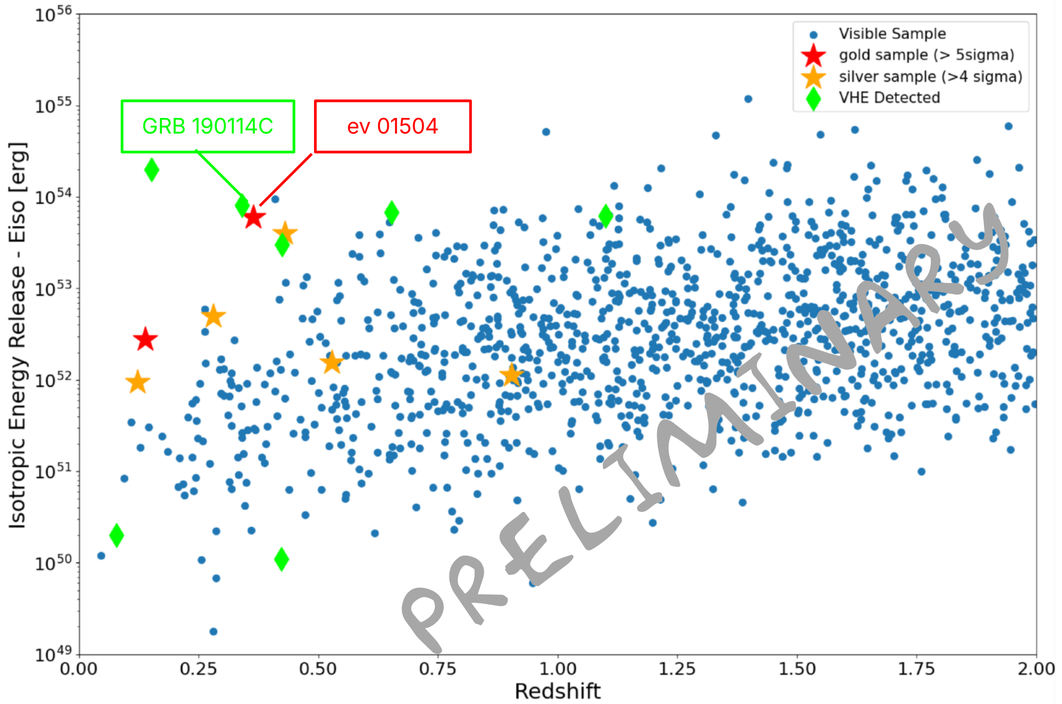
↓

IRFs + Gammapy for simulations









ASTRI-MA can respond to alerts in ~60 s

The total detection rate depends on the specific instrument providing the alert.
Work is ongoing to establish the expected rate based on a framework with possible multiple alert chains (Swift, GBM, SVOM…)

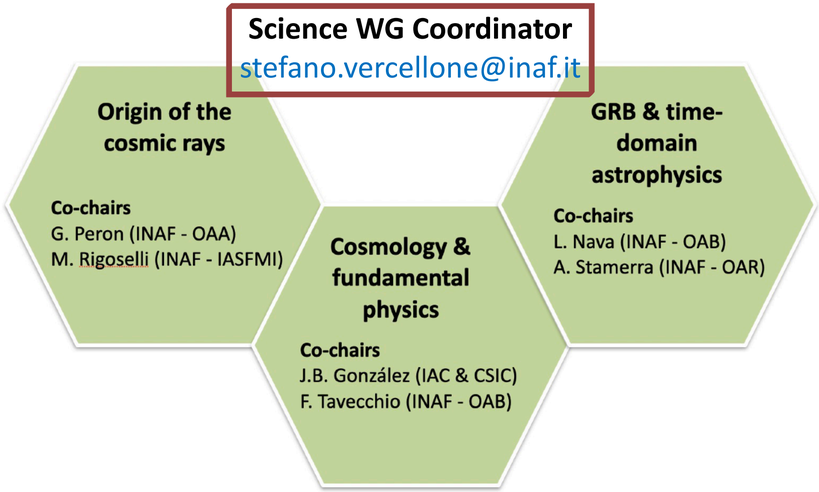
Credit: A. Carosi

https://www.astri.inaf.it/

Take away messages

- ✓ ASTRI Mini-Array, 9 Cherenkov telescopes; a subset already in operation. Full steam in 2027.
- ✓ Early science commenced!
- ✓ First 3 telescopes will be dedicated to deep exposures (3-400 hrs) on the Cygnus region.
- ✓ Perspectives on transients, GRB (also HE neutrinos and GW follow-ups) are ongoing.

If you are interested in collaborating, get in touch with the PI, Giovanni Pareschi, the Science Coordinator, Stefano Vercellone, or the Science Working group coordinators.



From *Core* Science to *Observatory* Science

For the first 4 years the ASTRI Mini-Array will be run as an experiment

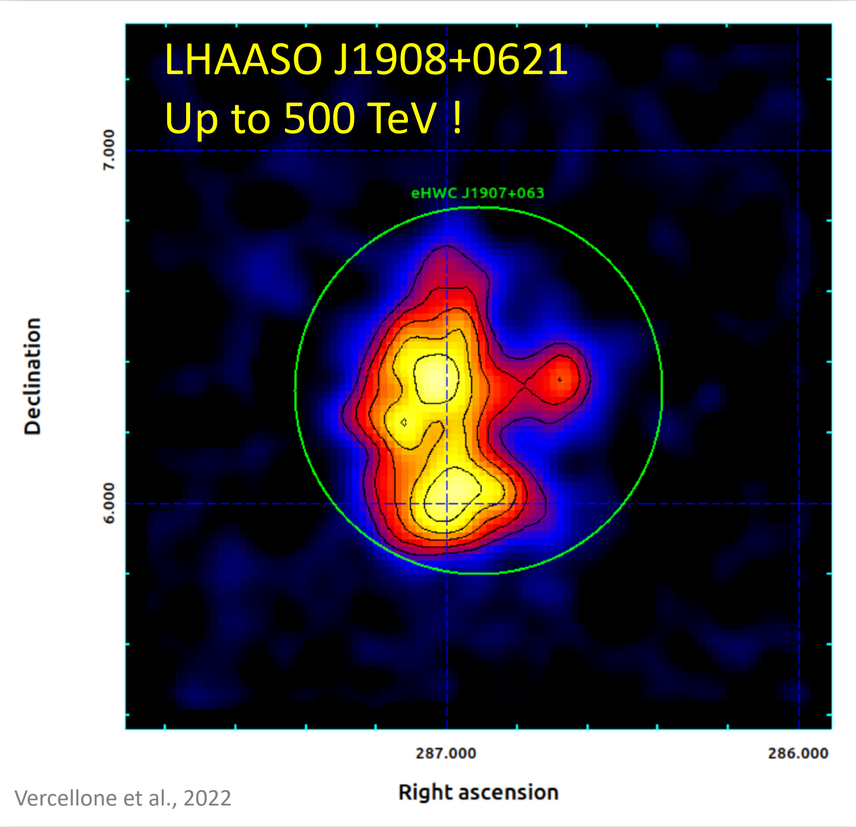
It will be dedicated to the Core Science Topics

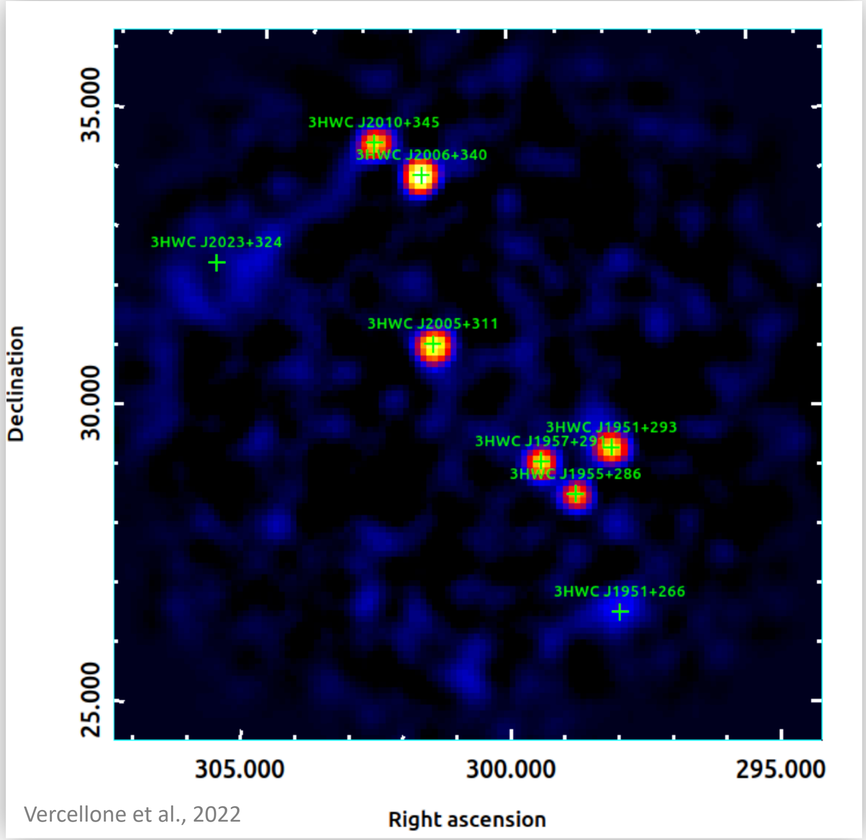
Smooth transition towards an Observatory period

Open to observational proposals from the scientific community

Based on the experience and results from the Core Science

Angular resolution and large field of view





ASTRI Mini-Array **200 hr simulation (up to E~200 TeV)** of the region **of the Galactic source 2HWC J1908+063**. The light green circle marks the ~ 0.52° HAWC error-box for E > 56 TeV

ASTRI Mini-Array **200 hr simulation of the Cygnus Region**. Green crosses mark the positions of the 3HWC sources in a 10° × 10° field of view

PeV-emitting sources – where to look at

LHAASO [Cao et al., 2021]

Discovery of **12 sources emitting at several hundreds of TeV**, up to 1.4 PeV

The the majority of sources represent **diffuse γ-ray structures with angular extensions up to 1°**

The **actual sources** responsible for the ultra high-energy γ-rays **have not yet been firmly localized and identified**

ASTRI Mini-Array:
- **precise identification**
- **morphology and spectra**

SNRs

No smoking gun from them, yet (Cas A, Tycho…)
Maybe detectable only in their early stages

Core-collapse SN

Could be PeVatrons just after the explosion

Massive young stellar clusters

LHAASO detected emission at 1.4 PeV from a region consistent with the Cygnus Cocoon + a few other YMC

Galactic Center

Which is the PeV source?

TeV Halos

Geminga, Monogem, J0622+3749

Cygnus region mini-survey

Strategy

- **50 different pointings**, at the same Galactic latitude and spaced by 0.4° in Galactic longitude, from (l, b) = (64,0) to (l, b) = (84,0), **1, 2, and 4 hours for each pointing**

Exposure

- Total of **50, 100 and 200 hours**

Results

- 13 simulated 3HWC sources, **10 sources are always significantly detected** even at the shortest 50 hr exposure.