Time domain program at the ASTRI Mini-Array

Antonio Stamerra – INAF - Osservatorio Astronomico di Roma
for the ASTRI Project

5th Astro-Colibri multi-Messenger Astrophysics Workshop



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

The ASTRI Mini-Array

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



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

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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)















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

The ASTRI Mini-Array

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

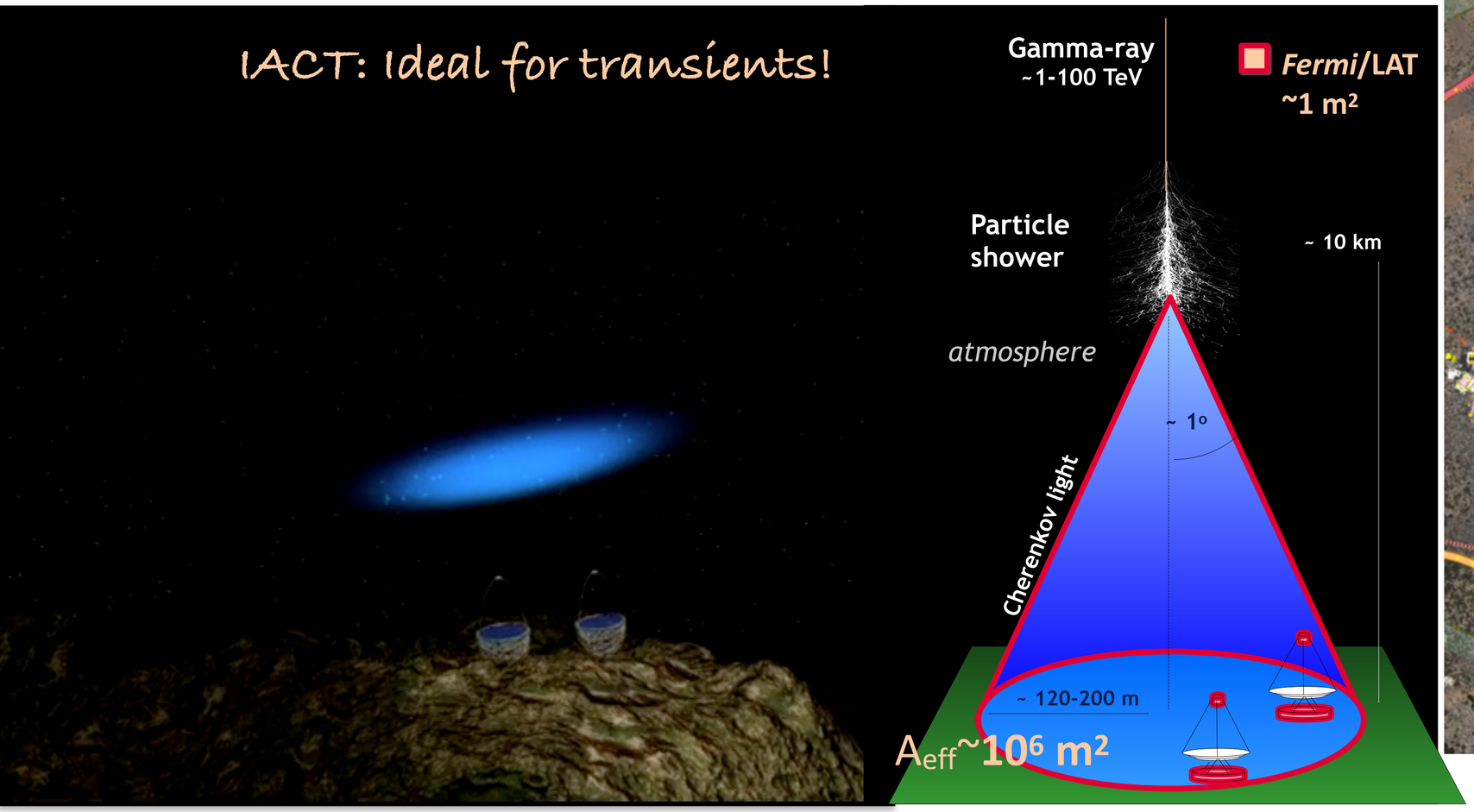


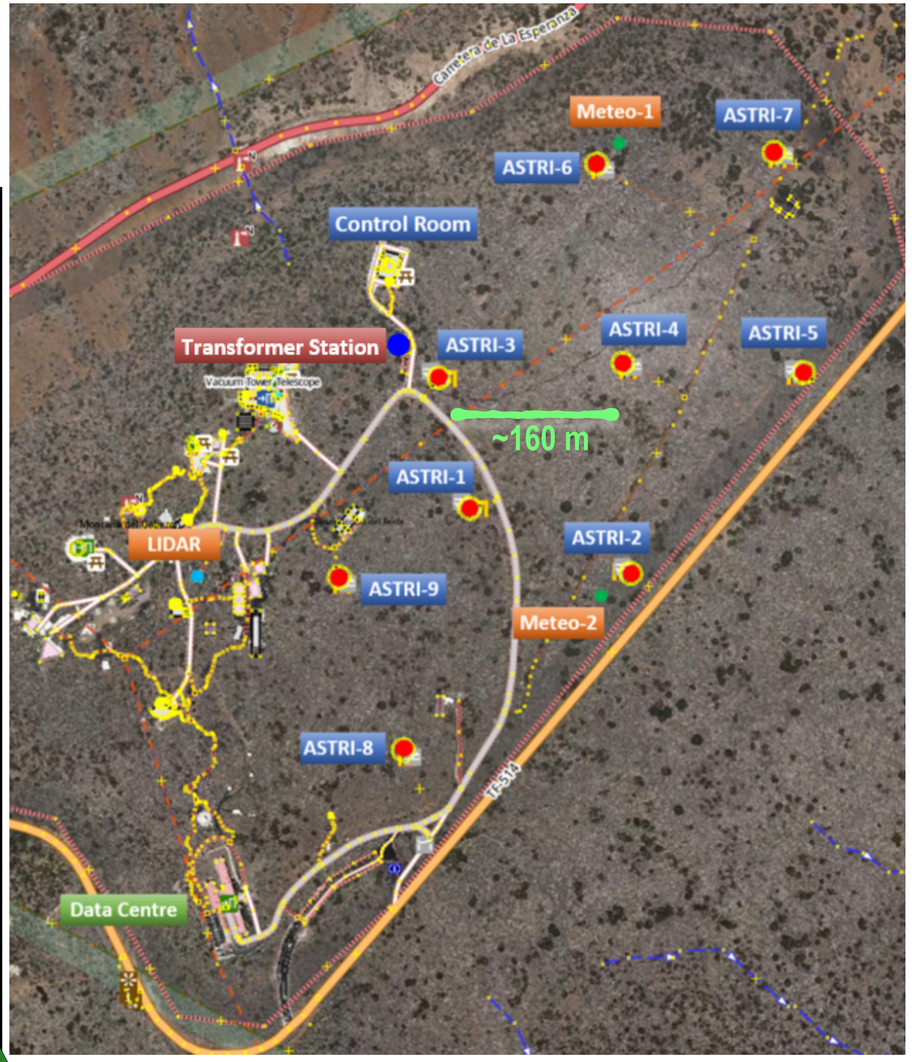


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The ASTRI Mini-Array

- Array with 9 Cherenkov telescopes (IACTs) 4-m class
- IACTs: **Big effective area** ➠ photon statistics

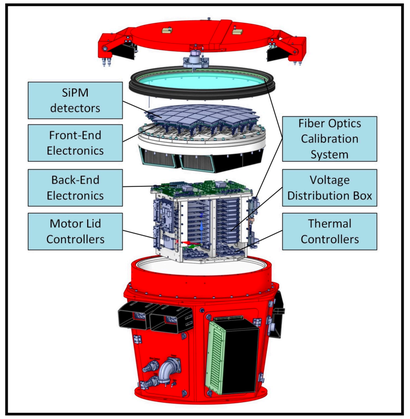


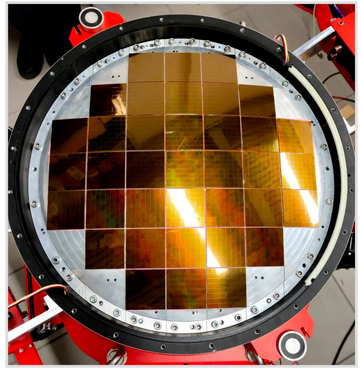


https://www.astri.inaf.it/

The ASTRI Mini-Array

- Array with 9 Cherenkov telescopes (IACTs) 4-m class
  - 9 telescopes on site fully assembled

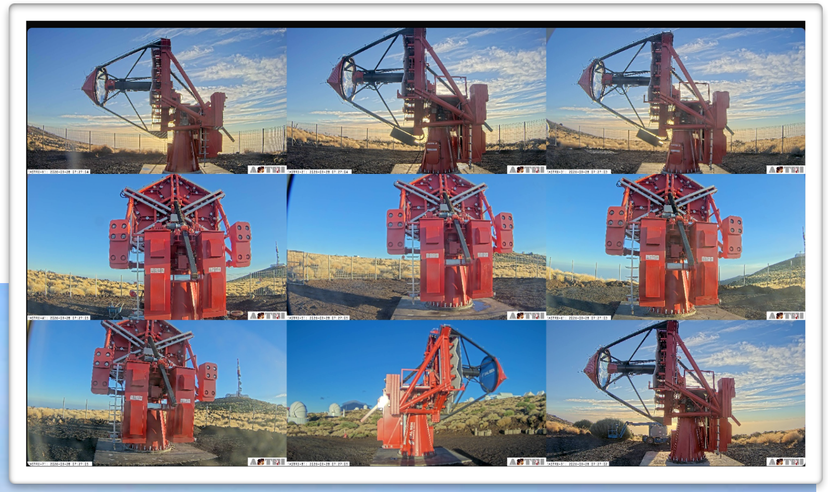




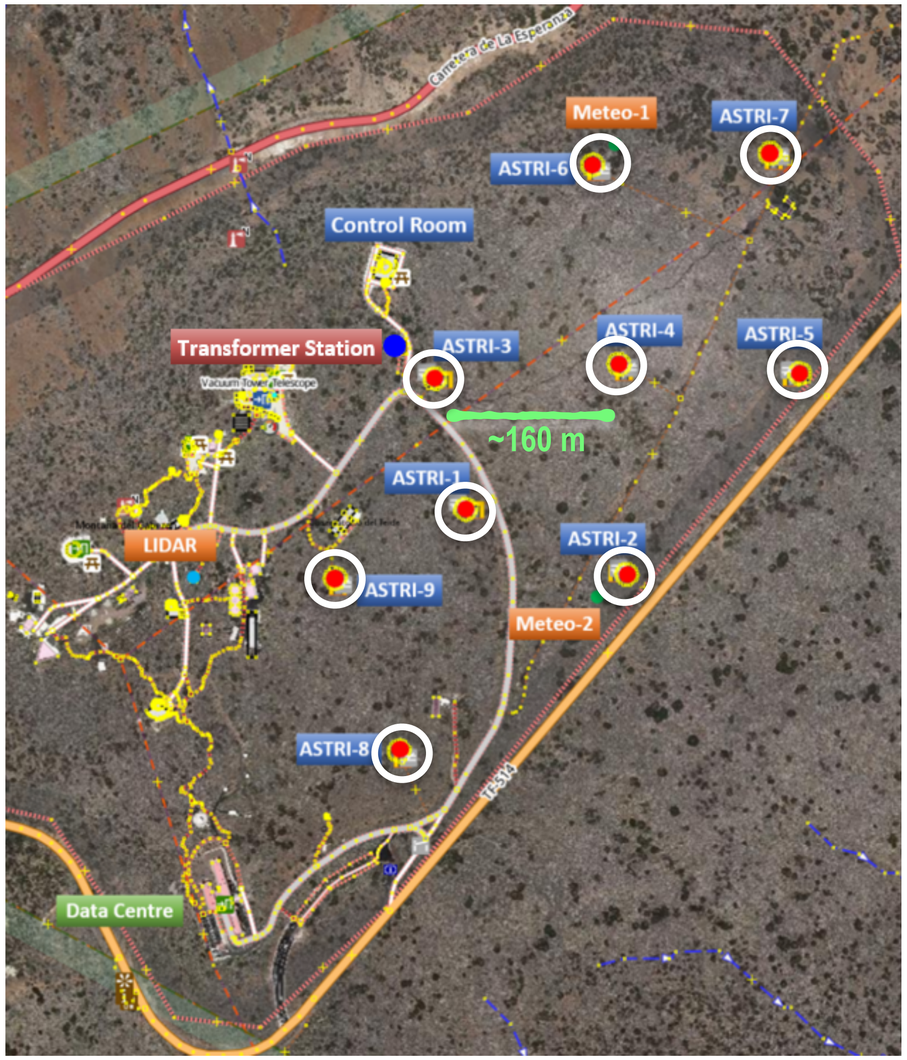
Energy range: (~1-300 TeV)

Angular resolution: ~0.1 deg @1TeV

γ-ray Acceptance: ~ 8-9 deg



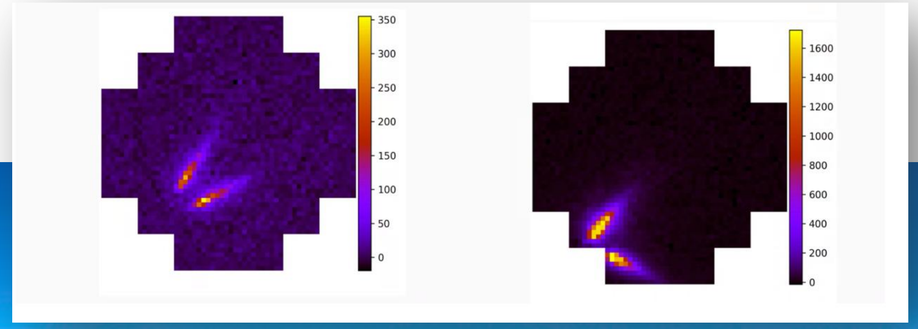


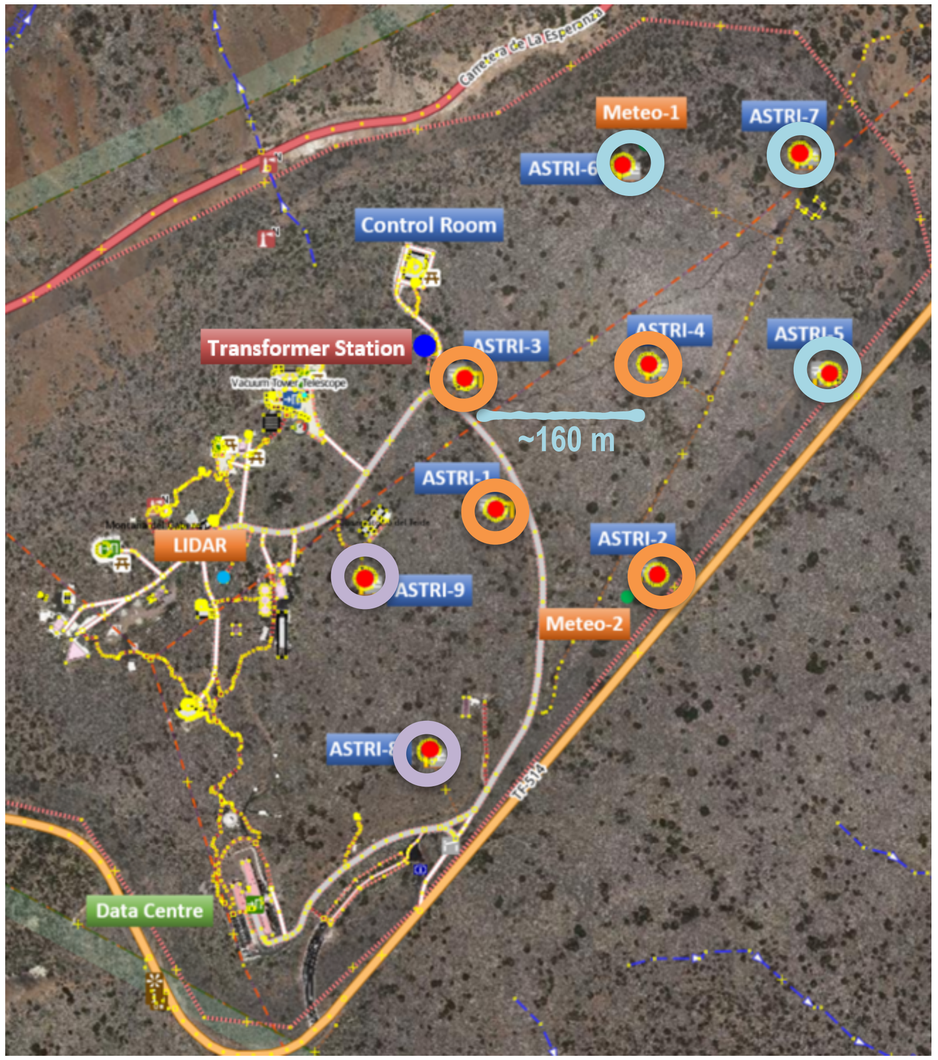


https://www.astri.inaf.it/

The ASTRI Mini-Array

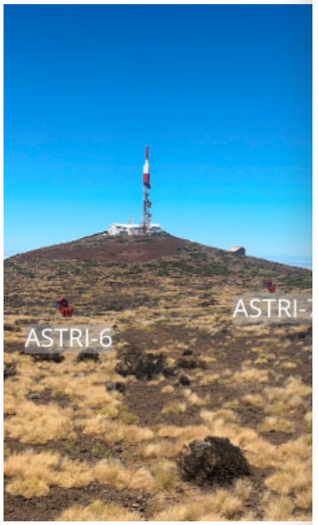
- Array with 9 Cherenkov telescopes (IACTs) 4-m class
  - 9 telescopes on site fully assembled
  - 4 telescopes operating in stereo

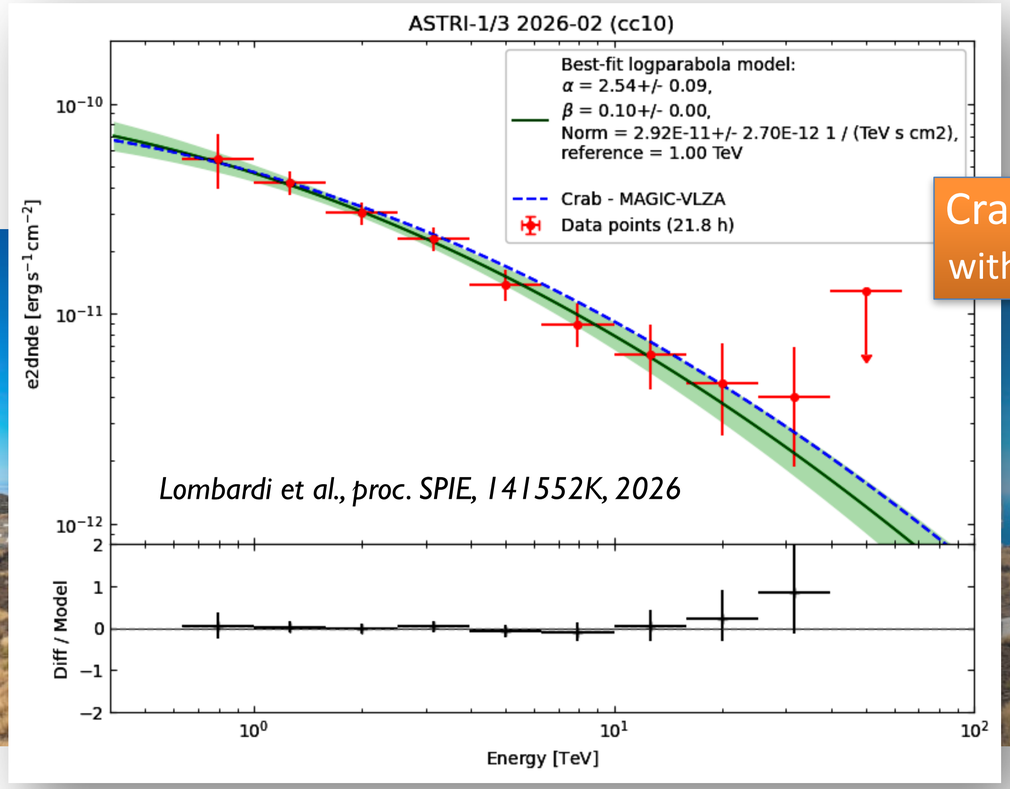




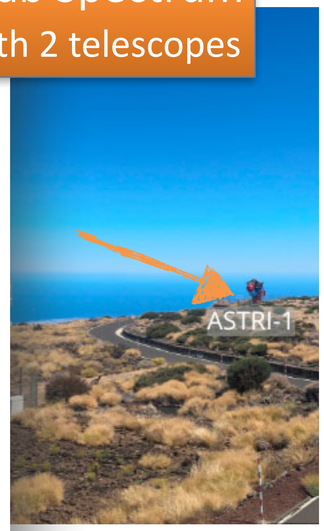
The ASTRI Mini-Array

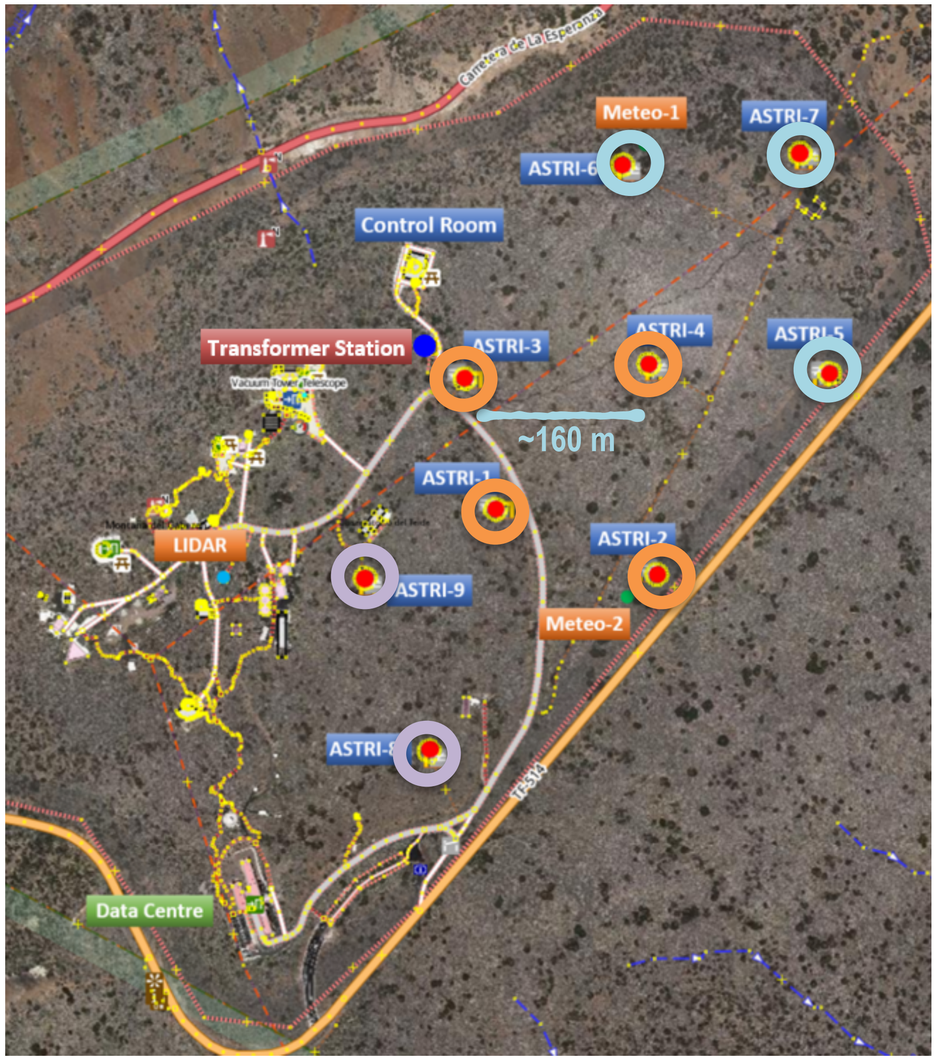
- Array with 9 Cherenkov telescopes (IACTs) 4-m class
  - 9 telescopes on site fully assembled
  - 4 telescopes operating in stereo





Crab Spectrum with 2 telescopes





Credit: S. Lombardi and Data Analysis team

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

The ASTRI Mini-Array

- Array with 9 Cherenkov telescopes (IACTs) 4-m class
  - 9 telescopes on site fully assembled
  - 4 telescopes operating in stereo

🎬 **Ready for the Early Science!**

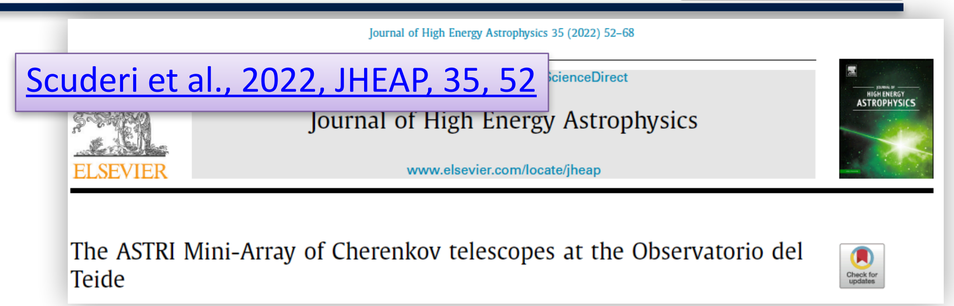
❖The observation program will follow the Core Science targets during the first 4 years

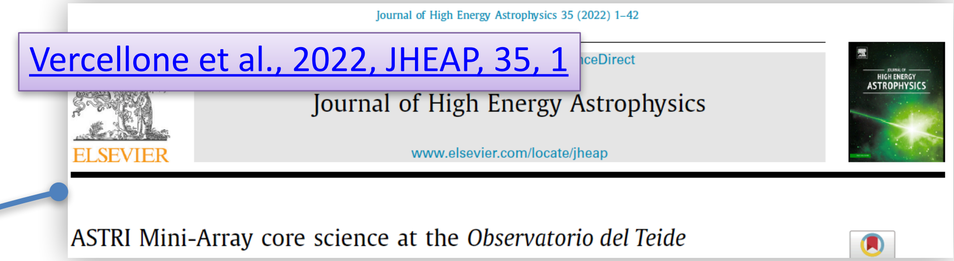
Includes transients, GRB, GW, HE-ν

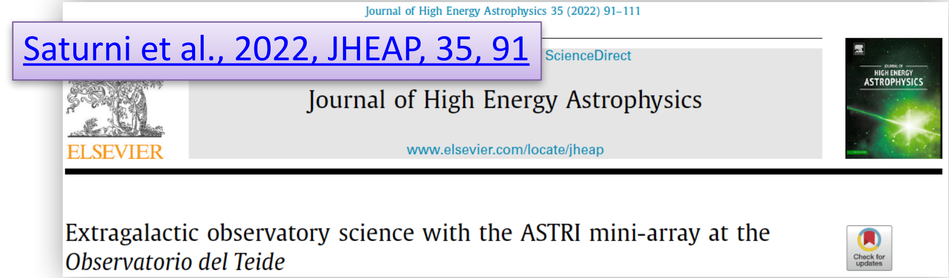
Do it yourself!

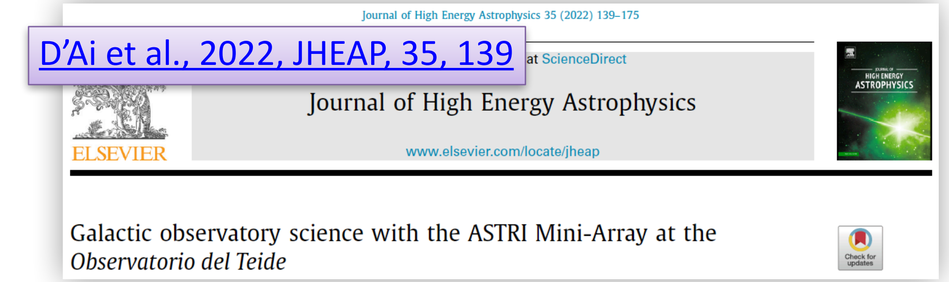
IRF files (Prod2, V1.0) can be retrieved from Zenodo:
https://zenodo.org/record/6827882#.Y_N34-zMJ60

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





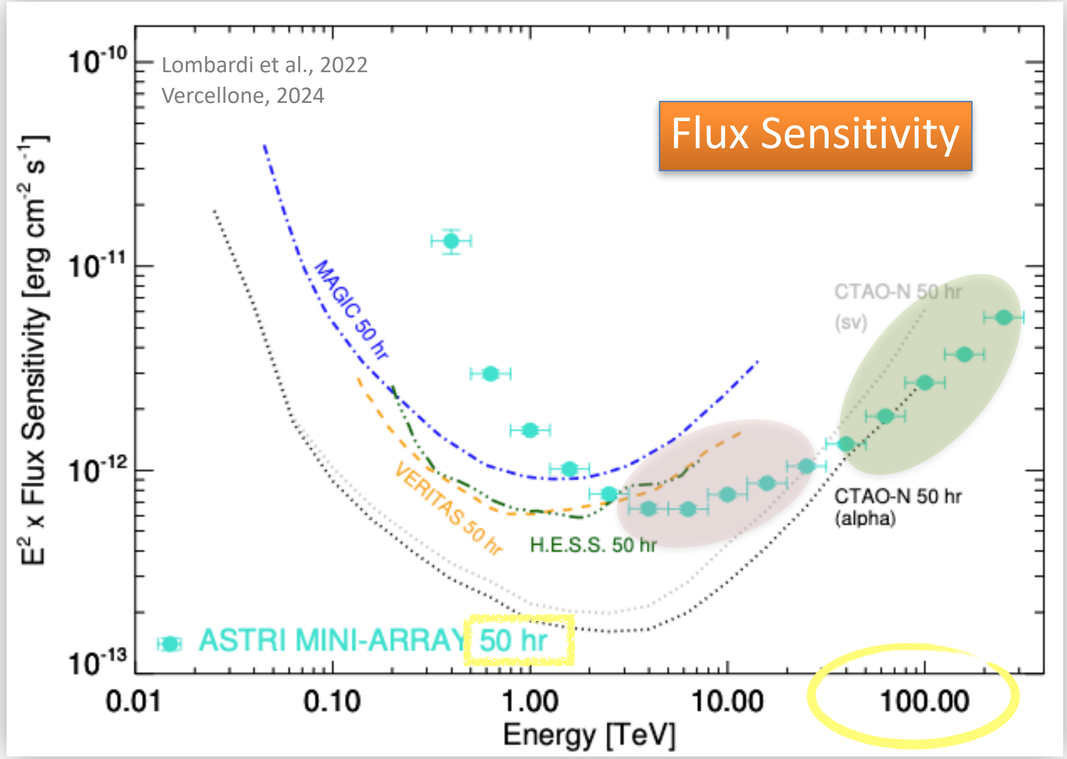


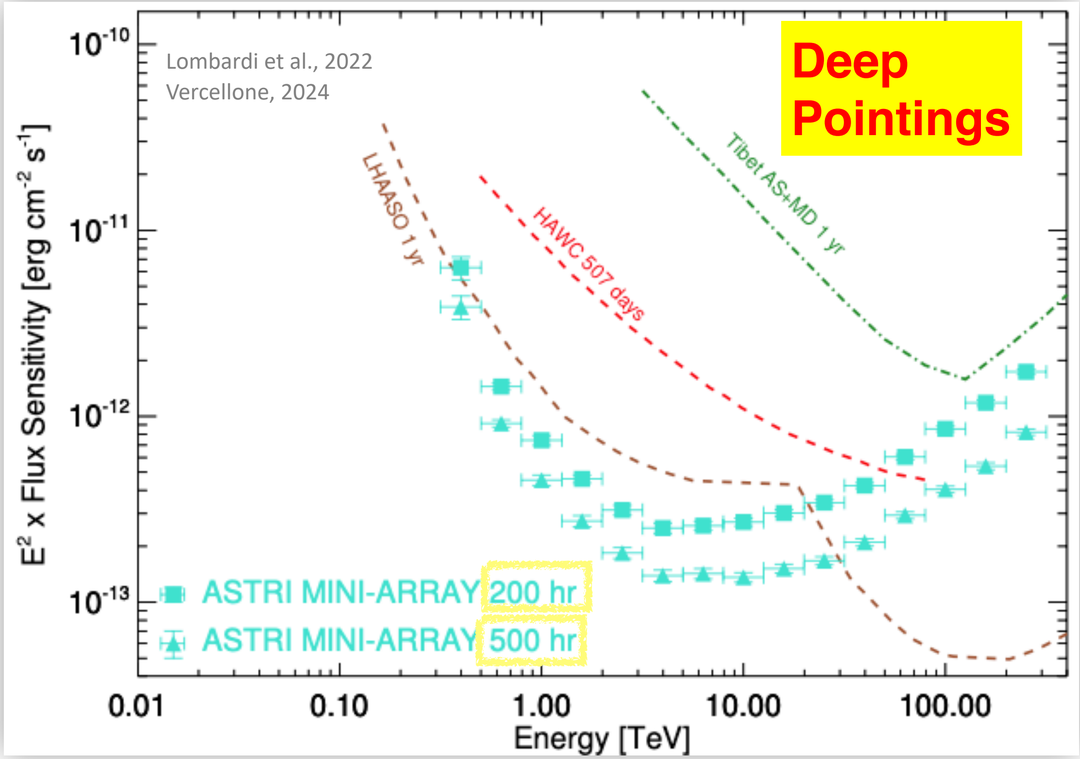


The ASTRI Mini-Array: early science

🎬 Ready for the Early Science!

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





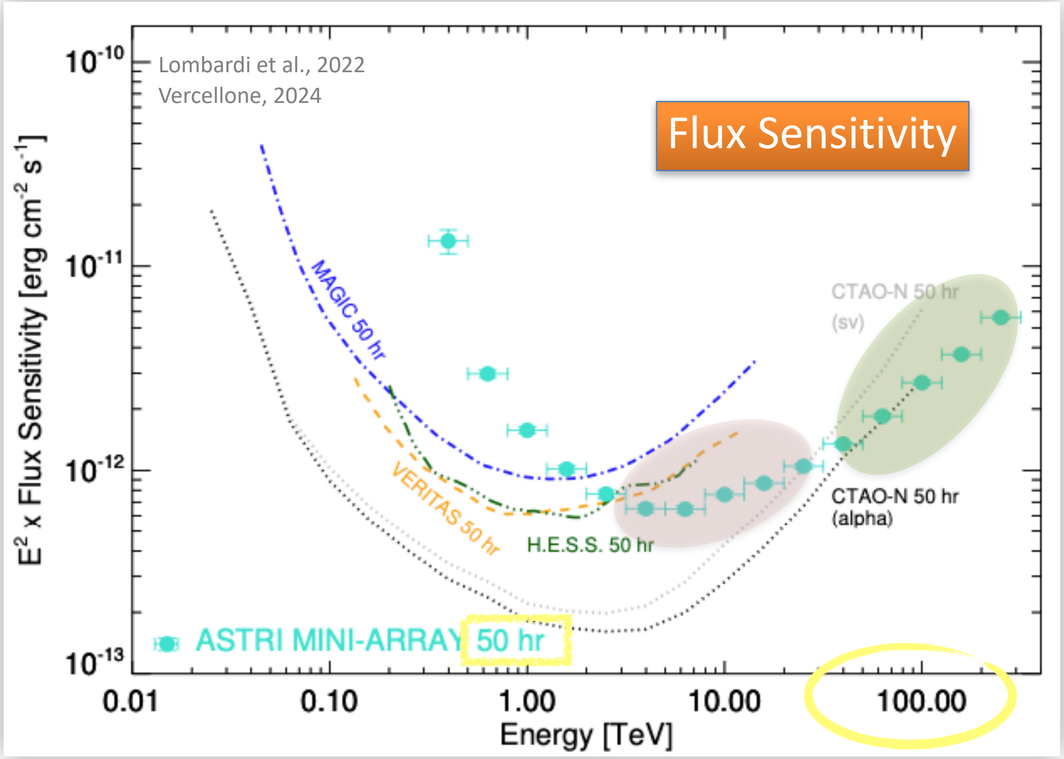
Credit: S. Vercellone

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

The ASTRI Mini-Array: early science

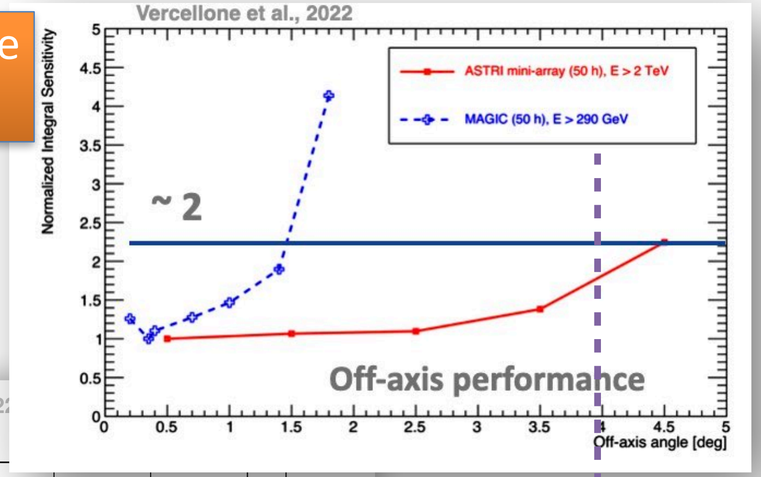
🎬 Ready for the Early Science!

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

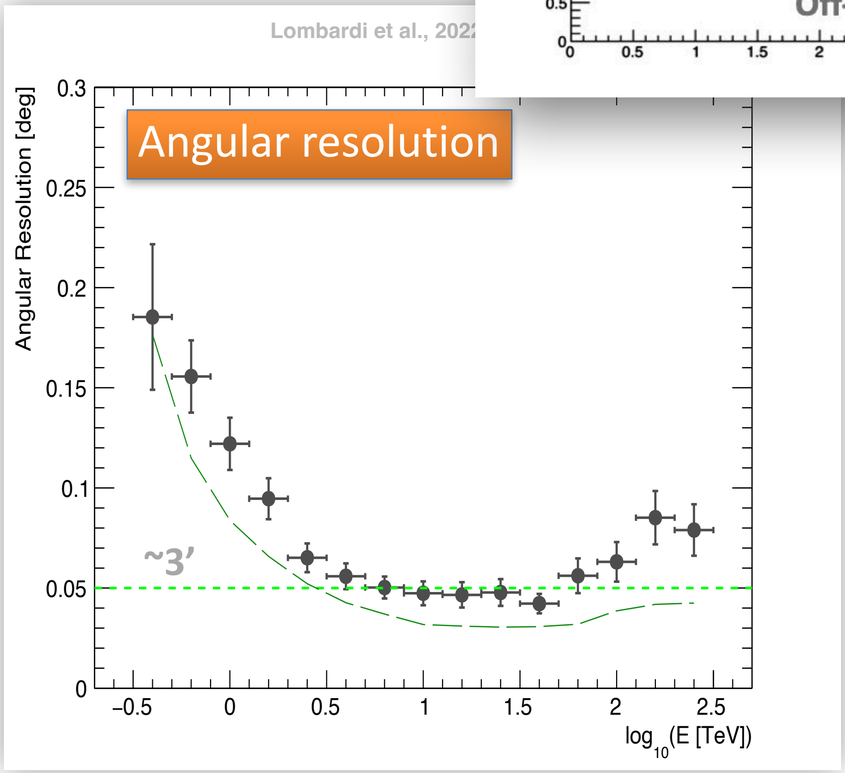


Credit: S. Vercellone

γ-ray acceptance ~8-9 deg



4 deg radius



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

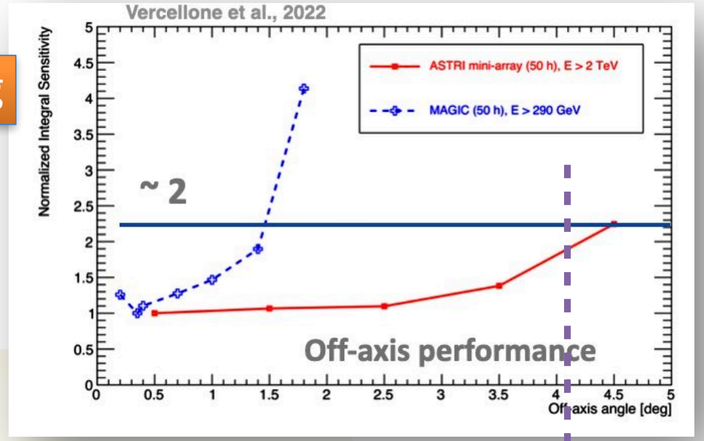
The ASTRI Mini-Array: early science

Mini-Array

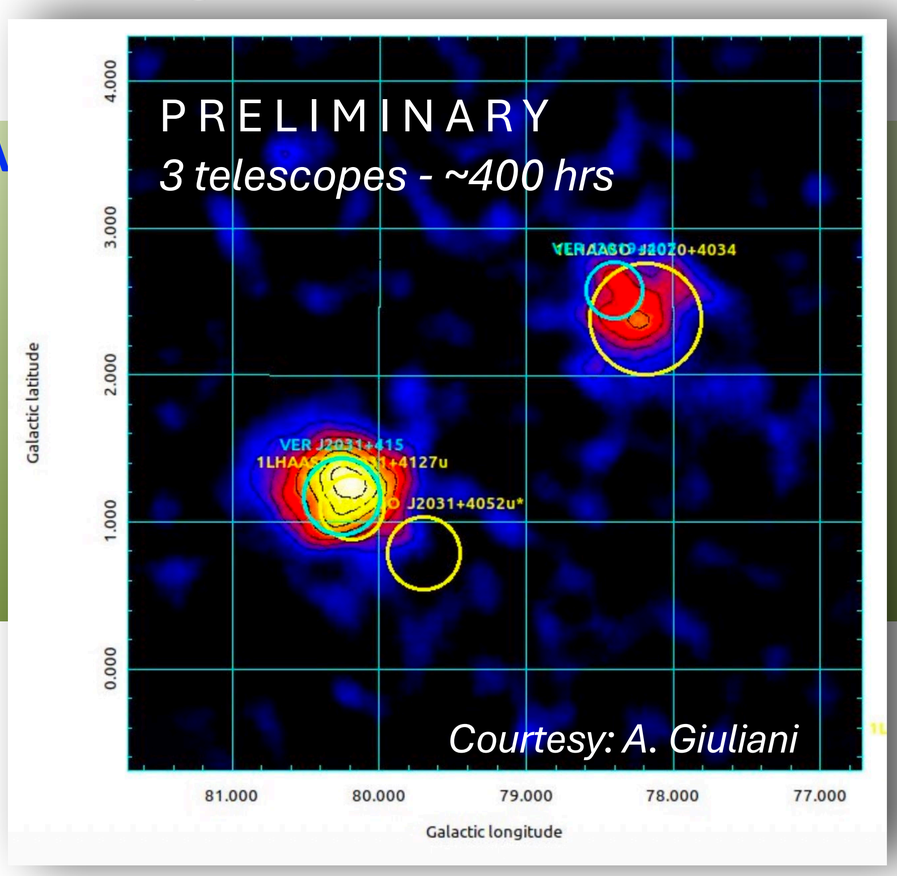
🎬 Ready for the Early Science!

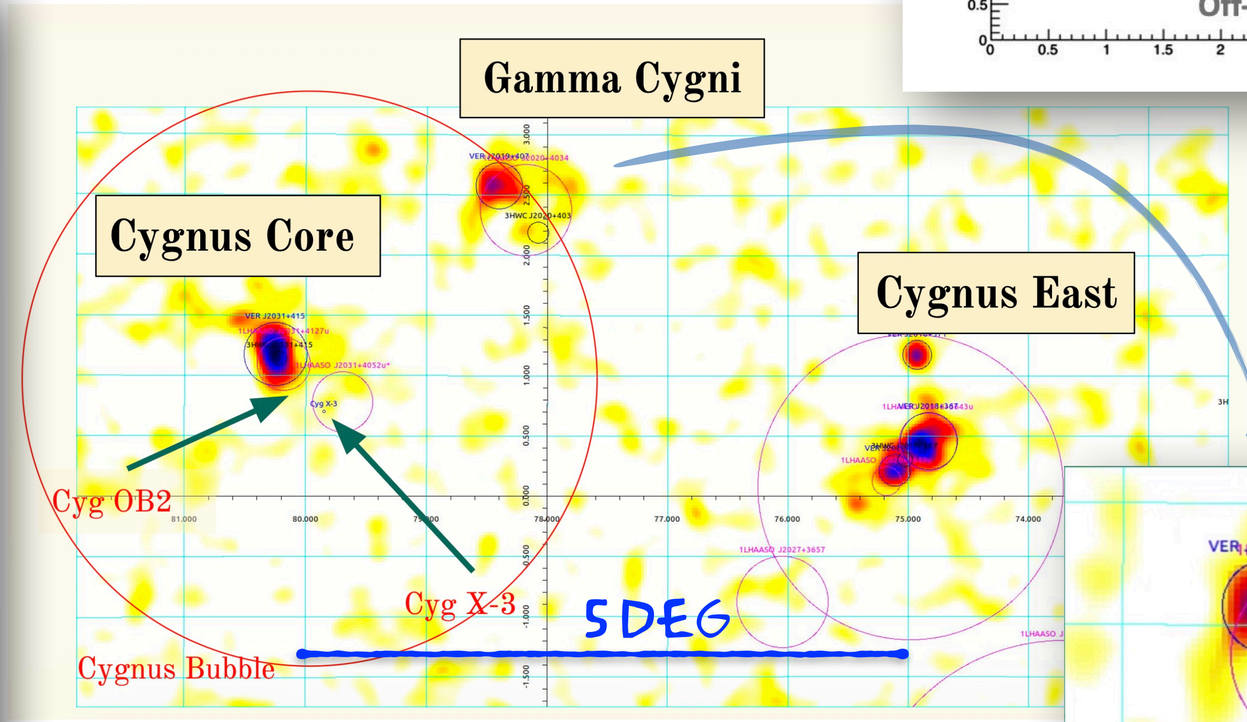
- ASTRI Mini-Array sensitivity in the 1 to >100 TeV range
- Angular resolution and wide Field of View

FoV ~8-9 deg

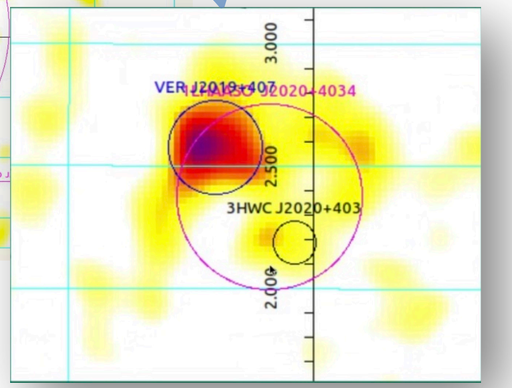


4 deg radius





Credit: A. Giuliani



Simulations with ASTRI 3-telescopes IRF ongoing

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

The ASTRI Mini-Array: early science

🎬 Ready for the Early Science!

- ASTRI Mini-Array sensitivity in the 1 to >100 TeV range
- Angular resolution and wide Field of View
- First ATel on a flare by Mrk421
- Mrk501 Coordinated observations MAGIC

Mrk 421

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

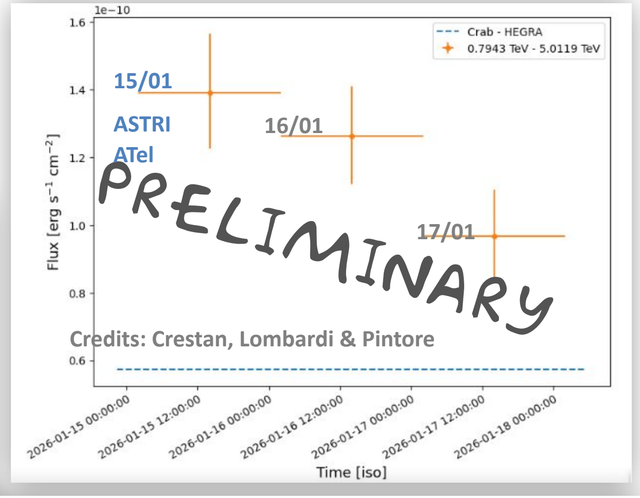
ATel #17602; *S. Crestan (INAF/IASF Milano), C. Quartiroli (INAF/IASF Milano), A. Sunny (INAF/IAPS Roma), S. Lombardi (INAF/OAR Roma), F. Lucarelli (INAF/OAR Roma), F. Pintore (INAF/IASF Palermo), for the ASTRI Project*
on 15 Jan 2026; 17:41 UT
Credential Certification: Fabio Pintore (fabio.pintore@inaf.it)

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

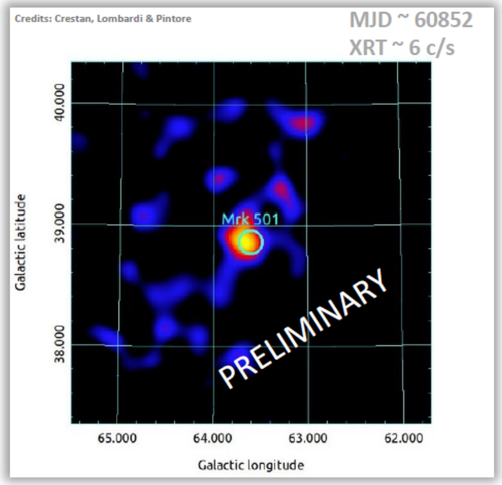
Referred to by ATel #: 17622

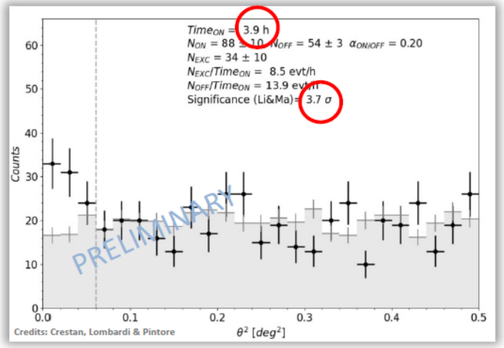
Tweet

The ASTRI-1 telescope has observed an increase in the very high-energy gamm
from the blazar Mrk 421 (z = 0.031). Observations were performed between 202
2:00 UTC (MJD 61055.08) and 04:40 UTC (MJD 61055.20) for a total effective o
time of approximately 2.5 hr. A preliminary analysis of the collected data reveals
significant detection of 11 sigma. The detected gamma-ray flux between 0.8 and
estimated to be 2.3 +/- 0.3 (stat) Crab Units.



Mrk 501





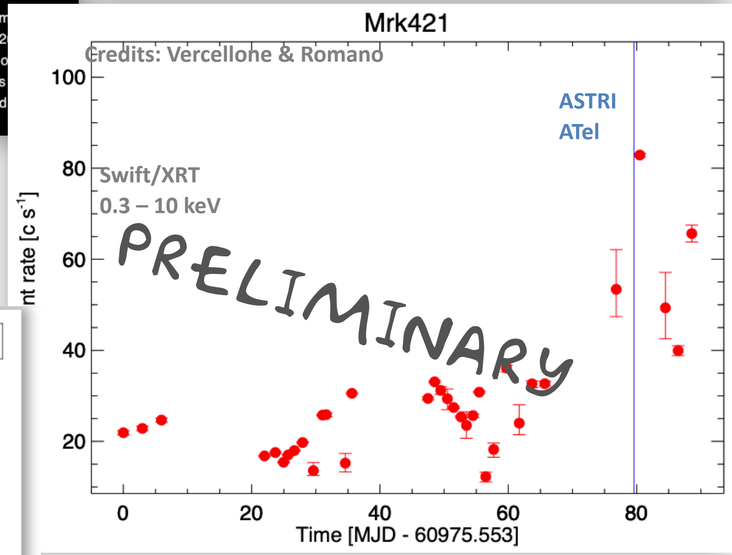
Hint of detection of Mrk 501 (~ 0.5 Crab) 26-06-2025

In preparation

Astronomy & Astrophysics manuscript no. output ©ESO 2026
July 3, 2026

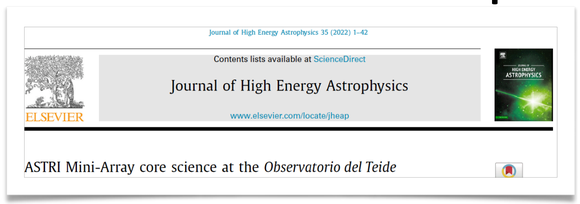
ASTRI Mini-Array and multi-wavelength observations of Mrk 421 during the January 2026 flare

S. Vercellone[1]*, F. Pintore[2], S. Lombardi[3], S. Crestan[4], A. Giuliani[4], P. Romano[1], F. Tavecchio[1], F. Casaburo[3,5,6], C. Bartolini[7,8,9], S. Ciprini[6,10], G. La Mura[11], J. Becerra González[12,13], M. Capalbi[3], G. Bonnoli[1], G. Pareschi[1], C. Quartiroli[4,14], A. Sunny[15,16], F. Lucarelli[3], V. F. Ramazani[17], F. Wierda[17,18], A. Marchini[19], G. Verna[19], S. Leonini[20], M. Conti[20], P. Rosi[20], L. M. Tinjaca Ramirez[20], A. Nastasi[21], S. Masiero[21], A. Squilloni[21], and *Many Many Many Others...*



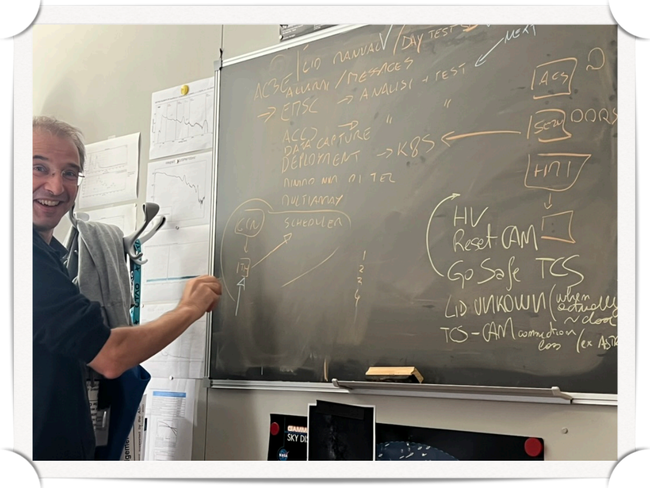
Implementation of Transient follow-ups

Gamma-ray bursts along with follow-ups of high energy neutrino events (from IceCube and KM3Net) are important pillars of the ASTRI observation program as part of the core program by the ASTRI Mini-Array.



ASTRI follow-up strategy

- Dedicated Target-of-Opportunity program
- Follow-up of external transient alerts (GRB networks, MM alerts)
  - Transient handler developed (A. Carosi), being implemented →
- Observation window: minutes to hours after trigger
- Typical exposure: hour-scale observations



A. Bulgarelli

Reactivity and performance

- Mechanical repointing time < 1 minute (1st phase: started by operators)
- Enables prompt follow-up even for rapidly fading transients
- Requires good observing conditions and visibility constraints

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

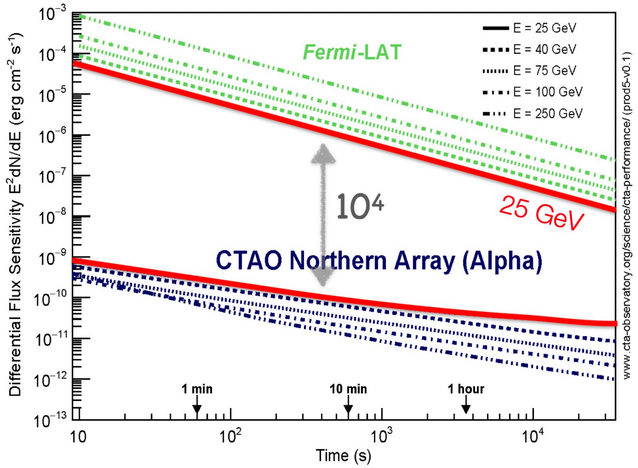
Gamma-ray bursts with ASTRI

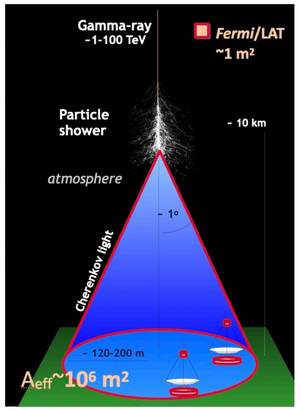
- Cherenkov telescope are ideal for transients!
- GRBs have been detected up to 13 TeV
- GRBs emit up and beyond 1 TeV

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





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

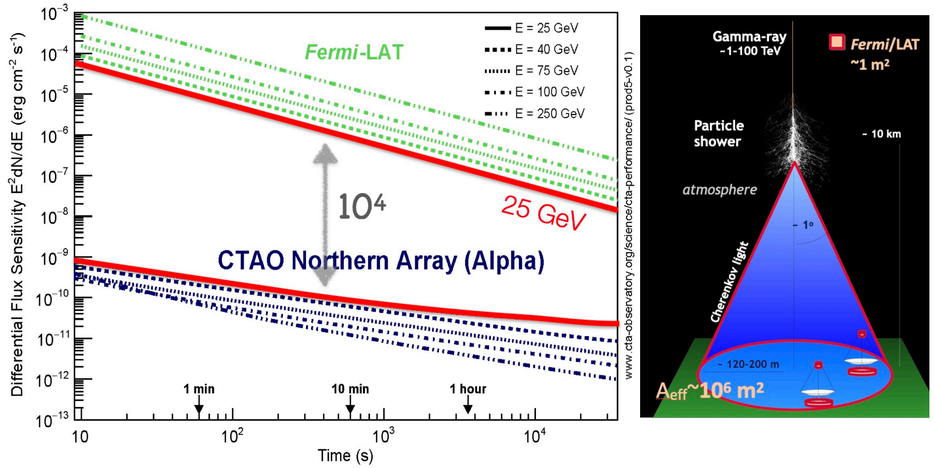
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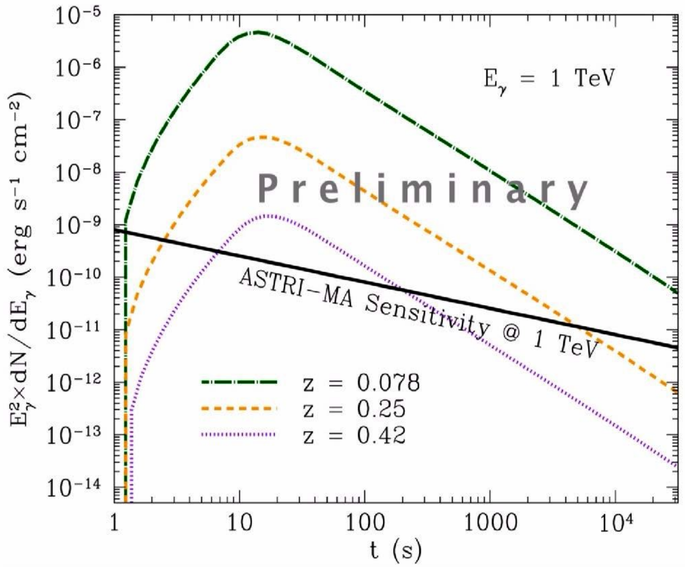


SIMULATED LIGHTCURVE AND SPECTRA OF THE SYNTHETIC GRBS

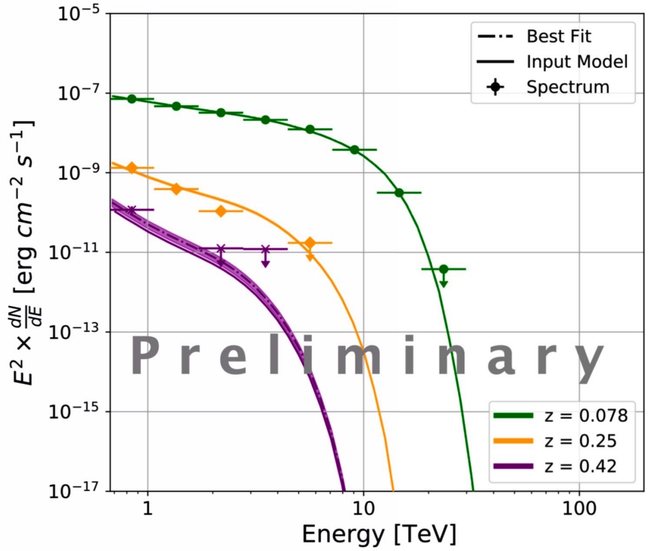
Spectra at T-T0 = 2 min

(ASTRI Coll. JHEAP, 2022, 35, 1 , A. Stamerra, ICRC 2021)

lightcurve



Spectrum



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

Gamma-ray bursts with ASTRI

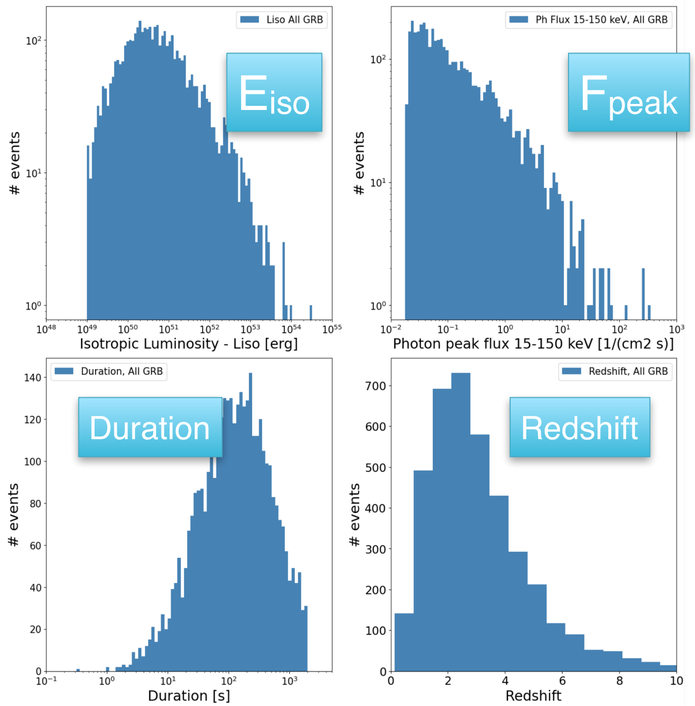
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ASTRI MA GRB Sim Pipeline

Synthetic GRB Population

ASTRI MA Follow up strategy

IRFs + Gammapy for simulations

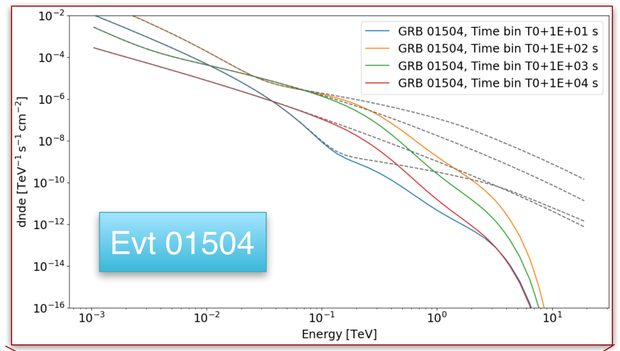


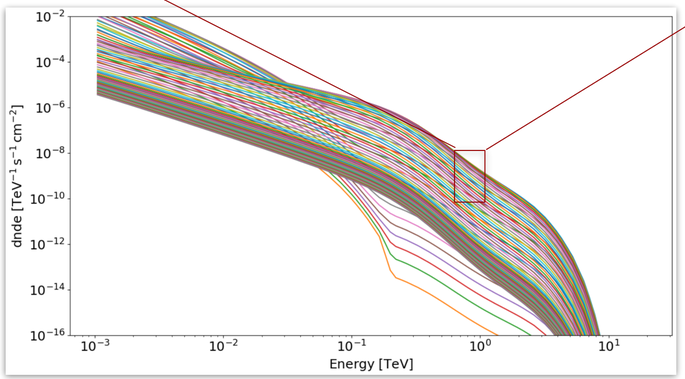
Ghirlanda et al. 2015, MNRAS, 448, 2514
Ghirlanda & Salvaterra, 2022, ApJ, 932, 10

Jet
- initial kinetic energy Ek
- initial bulk Lorentz factor Γ0
- redshift z

External medium
- number density n0

Acceleration process
- fraction of energy in electrons εe
- fraction of energy in magnetic field εB
- energy index of the electron spectrum p





Credit: A. Carosi

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

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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

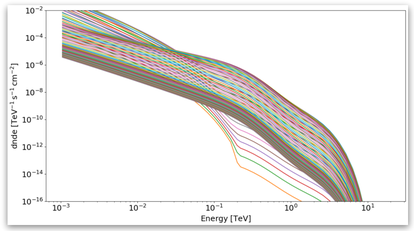
Synthetic GRB Population

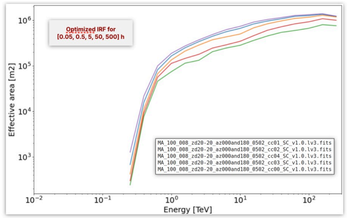
↓

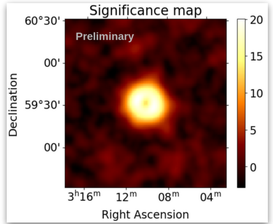
ASTRI MA Follow up strategy

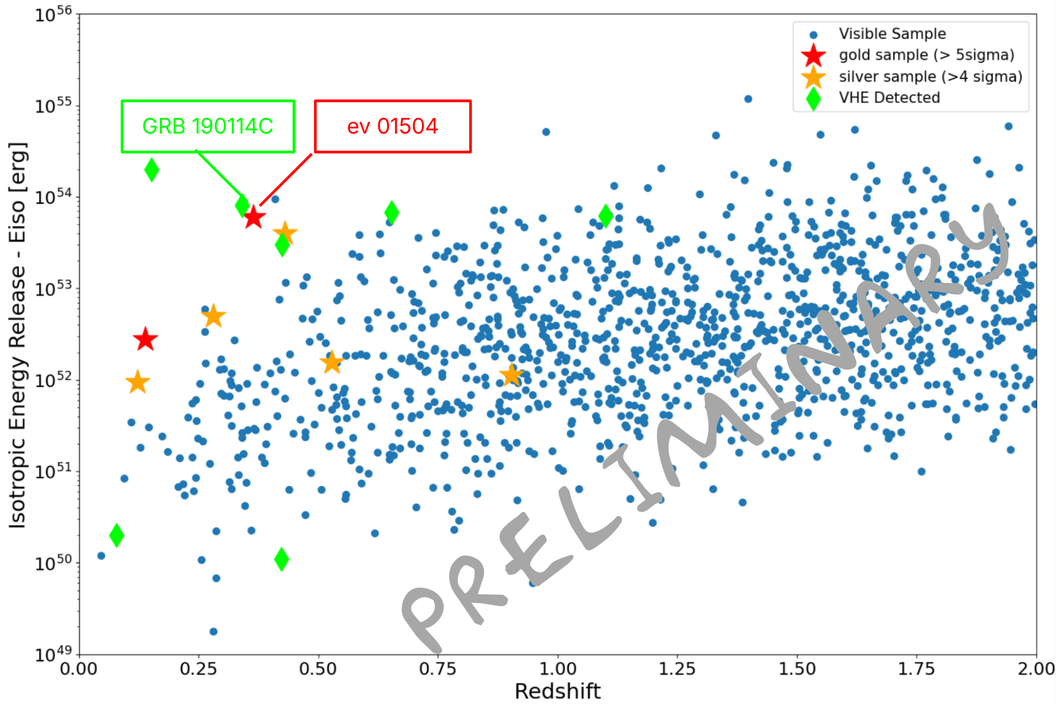
↓

IRFs + Gammapy for simulations









ASTRI-MA can respond to alerts in ~60 s

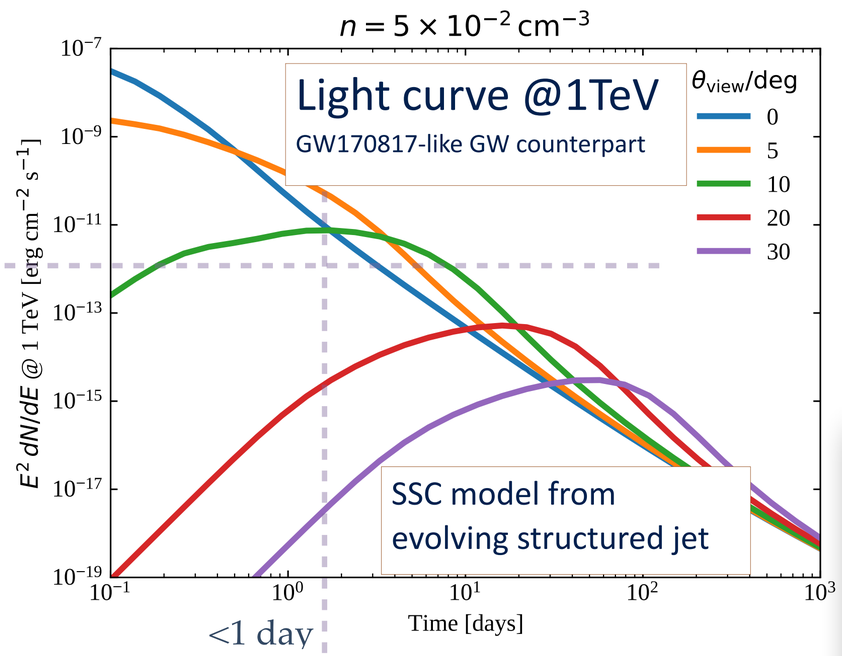
The total detection rate depends on the specific instrument providing the alert.
Work is ongoing to establish the expected rate based on a framework with possible multiple alert chains (Swift, GBM, SVOM…)

Credit: A. Carosi

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

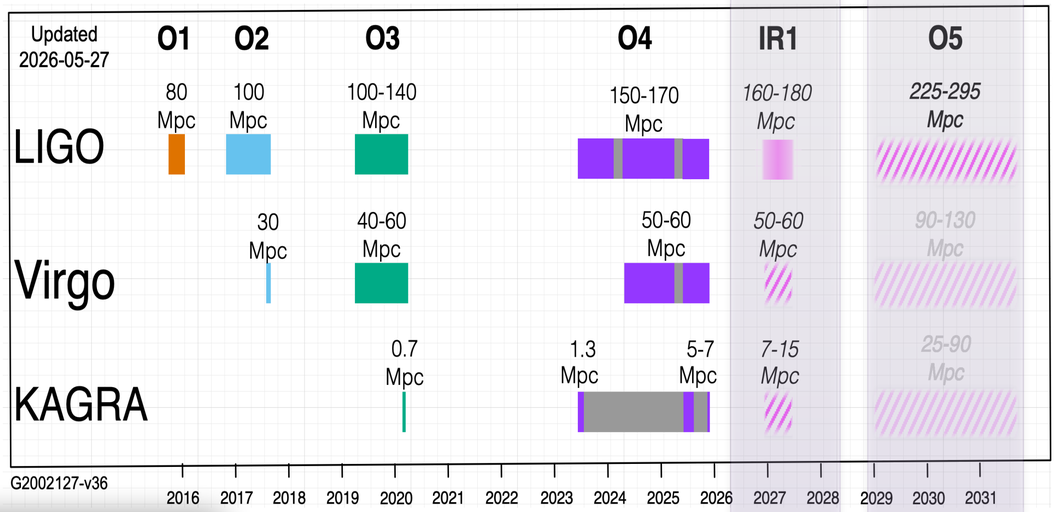
Multi messenger follow ups with ASTRI

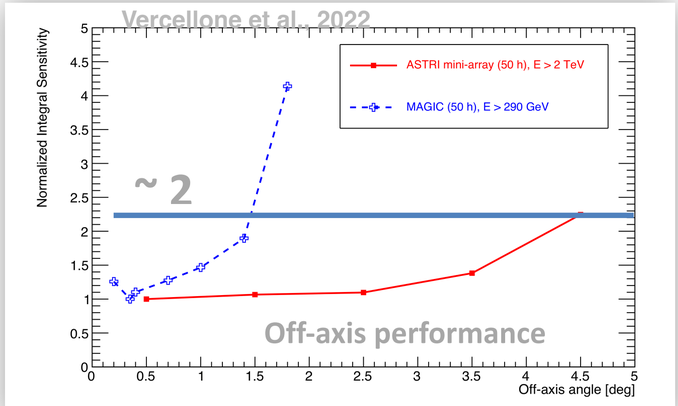
ASTRI Collaboration is getting ready for the next GW observational run (start November 2026) and to the follow-up of interesting events detected by the HE neutrino experiments, IceCube and Km3Net.

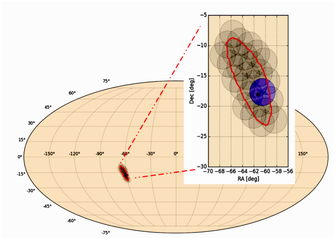


AS&Salafia et al., 2021, ICRC,
https://pos.sissa.it/395/944/

GW

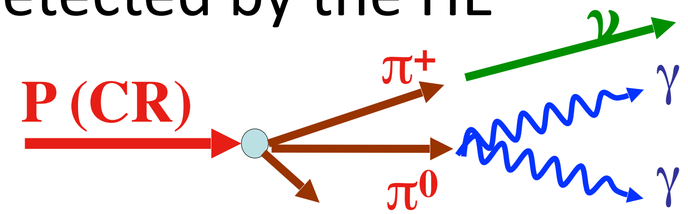






Multi messenger follow ups with ASTRI

ASTRI Collaboration is getting ready for the next GW observational run (start November 2026) and to the follow-up of interesting events detected by the HE neutrino experiments, IceCube and KM3Net.



HE-ν

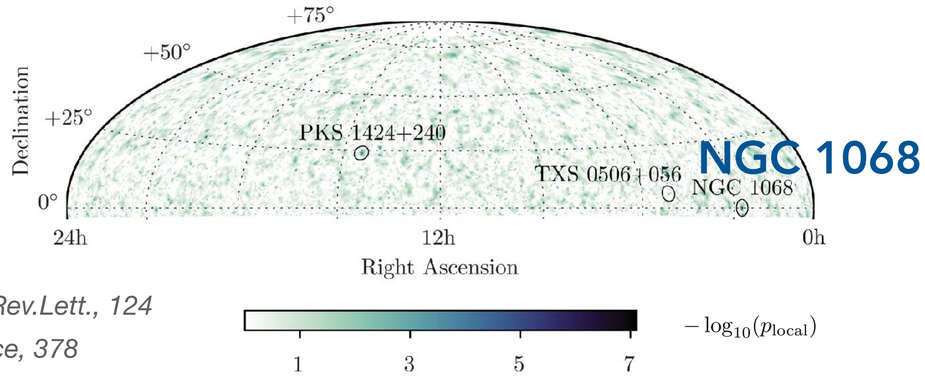
NGC 1068: Starburst galaxy, AGN driven

- Significant (4.2σ) hotspot in IceCube in ~8 years

➡ No TeV emission —> gamma internal absorption (e.g. Y. Inoue+, 2020, ApJL, 891)

➡ strong constrains on the wind models parameters and the corresponding neutrino emission (V. A. Acciari et al 2019 ApJ 883 135).

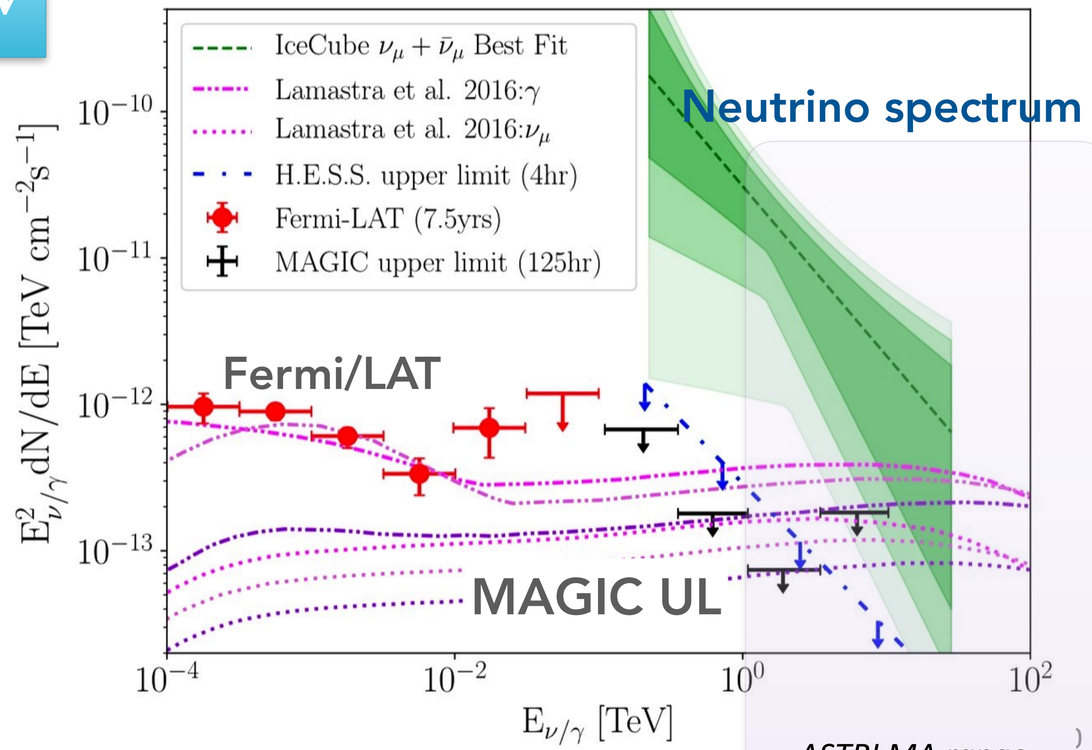
ICECUBE



NGC 1068

IceCube coll., 2019, Phys.Rev.Lett., 124

IceCube coll., 2022, Science, 378



ASTRI MA range

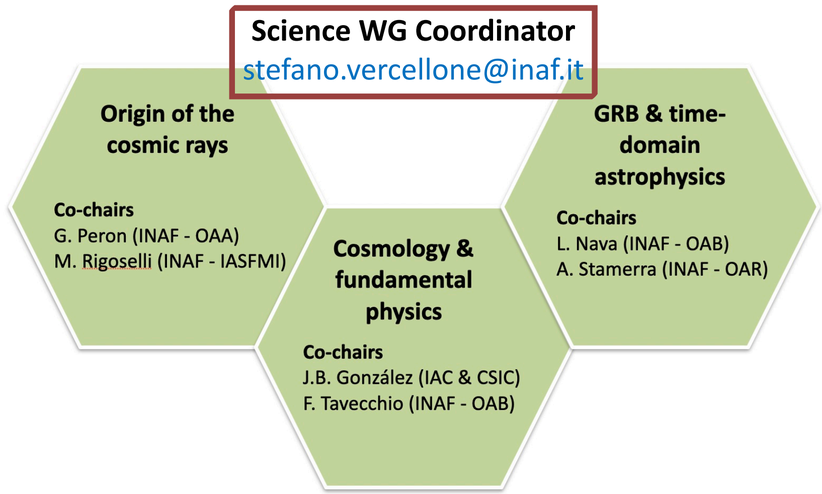
https://www.astri.inaf.it/

Take away messages

- ✓ ASTRI Mini-Array, 9 Cherenkov telescopes; a subset already in operation. Full steam in 2027.
- ✓ Early science commenced!
- ✓ First 3/4 telescopes currently dedicated to deep exposures (3-400 hrs) on the Cygnus region.
- ✓ The transient reaction pipeline is in advanced stage of development, allowing transients follow-ups on GRBs, HE neutrinos and GW alerts by the end of 2026 - start 2027.



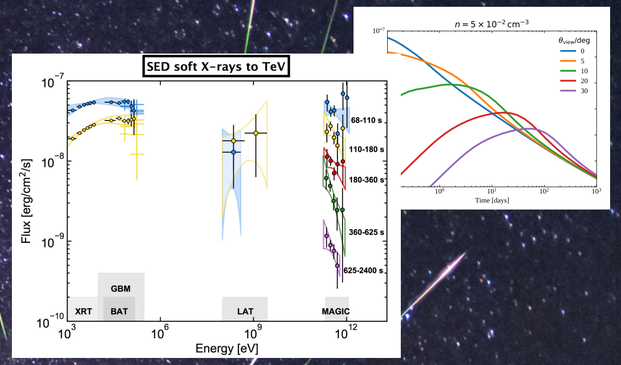
If you are interested in collaborating, get in touch with the PI, Giovanni Pareschi, the Science Coordinator, Stefano Vercellone, or the Science Working group coordinators.




Questions?
Daniel López / IAC

Open questions in the MM field at TeV energies - GRB/GW

- **Do all GRB exhibits a second high-energy component (Gev-TeV)?** 🥰
- **Is this component significant or even dominant, as observed in GRB 190114C? Under what conditions?**
- **What is the connection between this emission and the GRB progenitor or its environment?**
- **Is SSC the dominant emission mechanism? What roles do external Compton, pure synchrotron, or hadronic processes play?**
- **Next observational breakthrough: unambigous TeV detection from short-GRB! GW (BNS)! NS-BH and BBH still uncharted territory…**
- **Which observational strategies in the TeV band are best suited for detecting GW counterparts?**

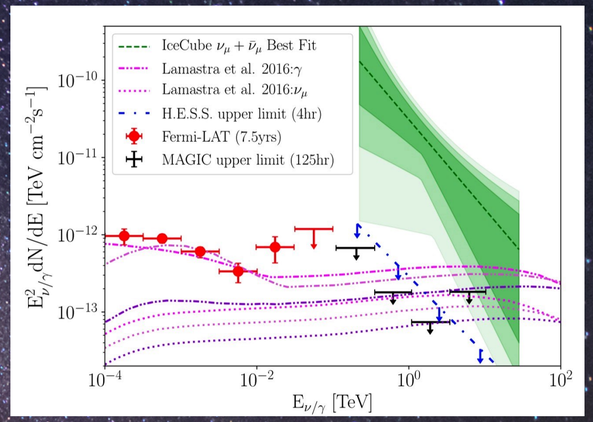


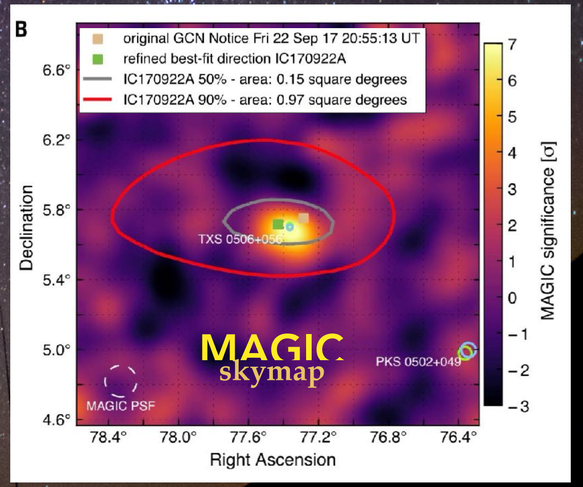
TeV observations can:

- ✓ **Clarify the structure of the environment (density, winds)**
- ✓ **Better constrain SED modeling and parameters**
- ✓ **Identify/discard dominant emission processes in afterglow**
- ✓ **Identify and shed light on the prompt emission physics.**

Open questions in the MM field at TeV energies - neutrinos

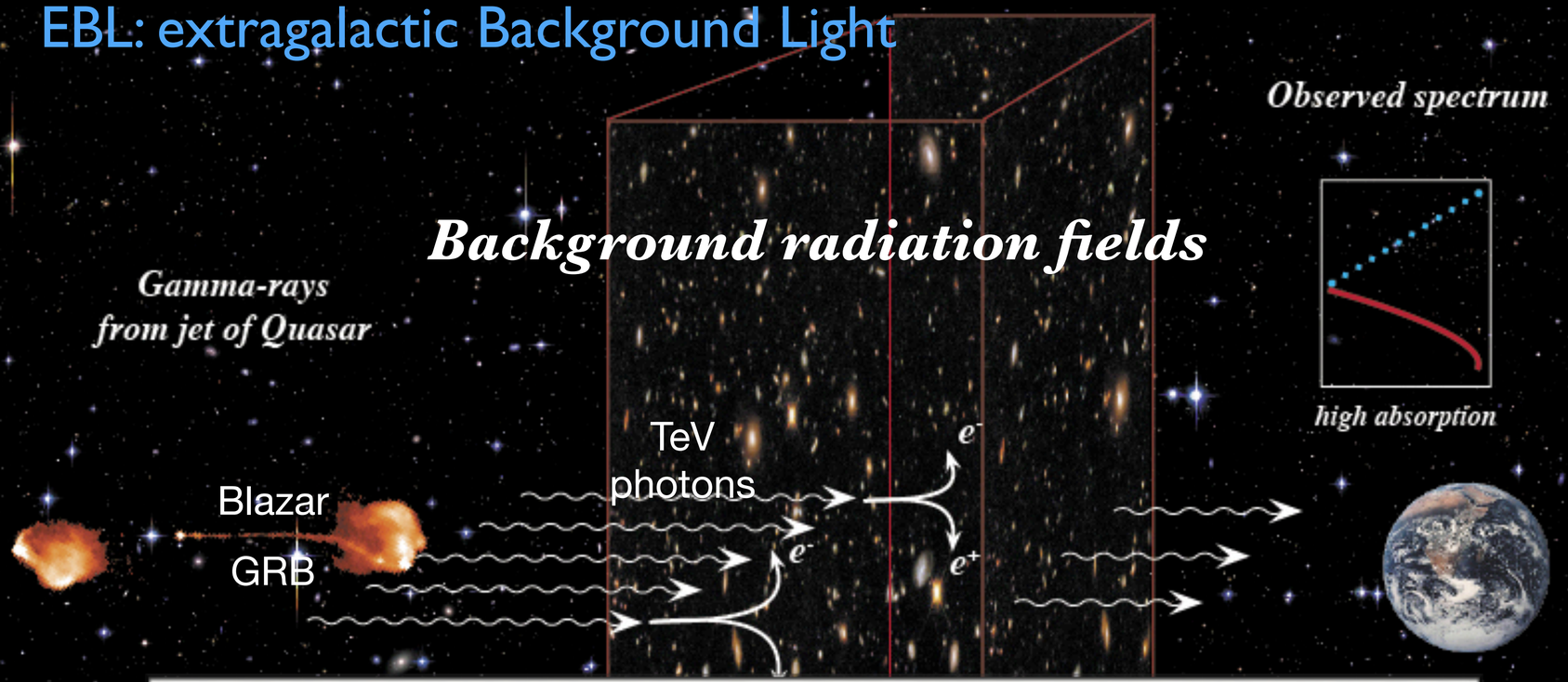
- **Which classes of neutrino sources? Seyfert, blazars (BL-Lac? FSRQ?)?**
- **Which emission region? (Corona emission? Base of jet / standing shocks? Outflow winds?**
- **Confirm the physical connection between neutrino and gamma-ray emission and the interplay with the environment.**
- **Identify TeV hadronic-driven emission processes in the observed SED**
- **Which models? How to better constraint their parameters? Needs precision and MWL measurements.**



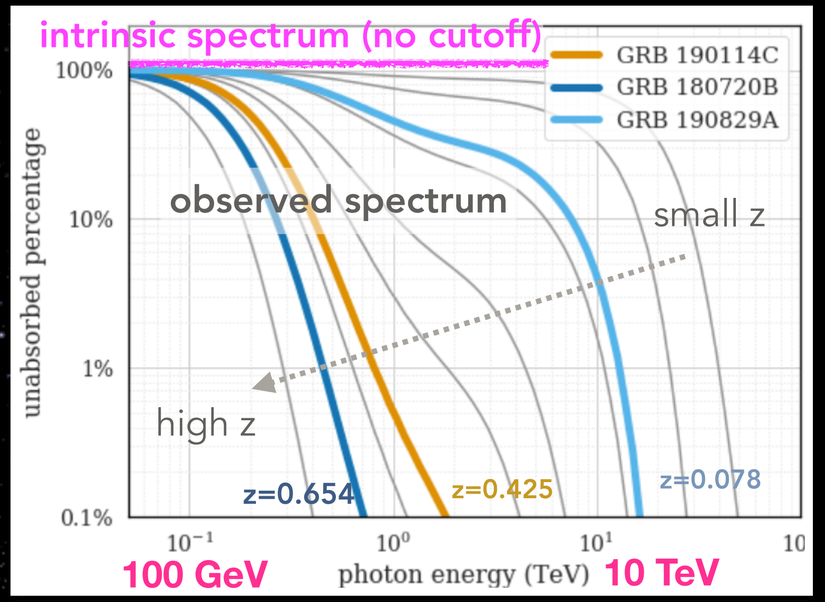


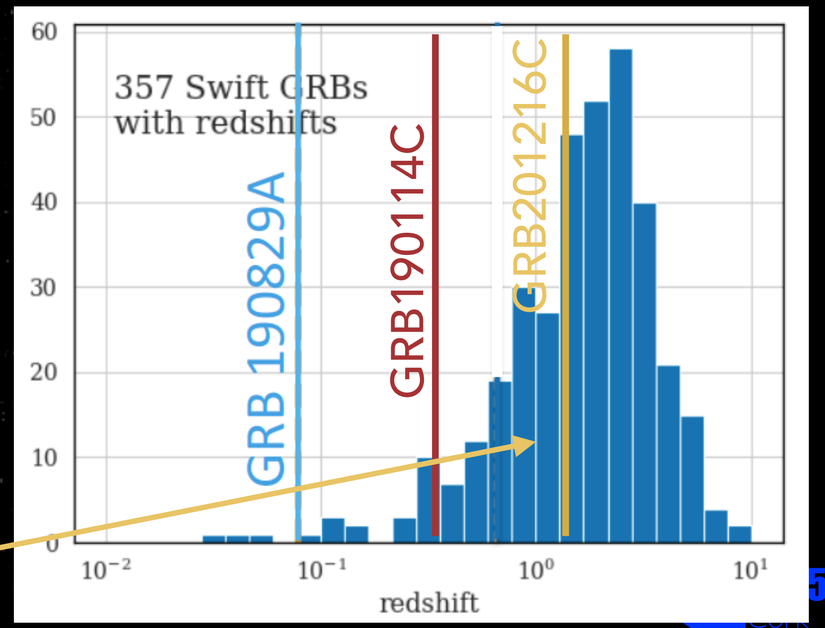
EBL absorption of TeV photons

EBL: extragalactic Background Light



Name	Type	Discoverer	Date	Dist
	...	...		
GRB 190114C	GRB	MAGIC	2019.01	z = 0.4245
GRB 180720B	GRB	H.E.S.S.	2019.05	z = 0.654
GRB 190829A	GRB	H.E.S.S.	2019.08	z = 0.0785
GRB 201216C	GRB	MAGIC	2020.12	z = 1.1
GRB 201015A	GRB	MAGIC	2020.10	z = 0.43
GRB 160821B	GRB	null	2016.08	z = 0.16
GRB 221009A	GRB	LHAASO	2022.10	z = 0.151
1-7				





Farthest TeV source