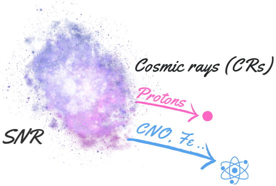
On the spectral shape of Supernova Remnants

Sensitivity of CTA to heavy nuclei in Cosmic Rays



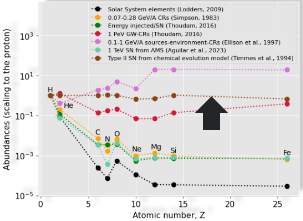
Particle distribution :

$$f(E) = \mathbf{f}.A_p.(E/E_0)^{-\alpha}.\ e^{-(E/\mathbf{Z}.E_c)^{\beta}}$$

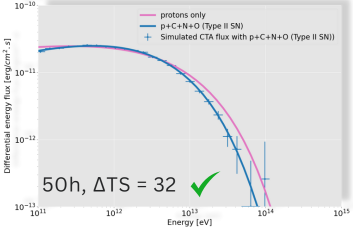
Are protons and heavier nuclei accelerated efficiently by SNRs?

f → abundances taken at the SNR source (**type II SN**)

Abundances of CRs composition

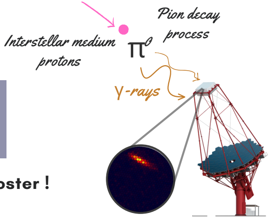


Simulated CTA flux with p+CNO model compared to proton model



Can CTA detect CRs from SNRs by observing γs from pion decay?

γ spectrum of the SNR **RX J1713.7−3946**
simulated for CTA with *Gammapy*:



CTA could distinguish whether CRs coming from SNRs are composed of protons only or protons and heavier nuclei (CNO, Fe)

2nd **study on the sharpness of the proton spectrum in my poster !**

Coline Dubos, Tiina Suomijärvi

CTAO Science Symposium, April 2024

IUSS
Scuola Universitaria Superiore Pavia

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Morphology Study of PeVatron Candidate Cygnus OB2 with the ASTRI Mini-Array

UNIVERSITY OF TRENTO

A. Bonollo[1 2 3], P. Esposito[1 2], A. Giuliani[2], S. Crestan[2], M. Rigoselli[2], G. Galanti[2], S. Mereghetti[2]

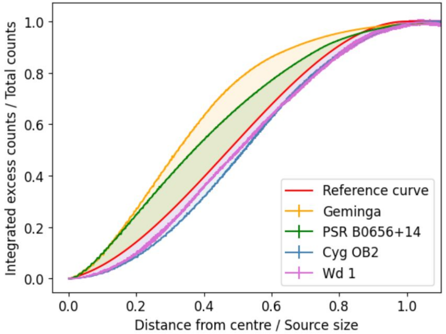
1. IUSS Pavia; 2. INAF/IASF - Milano; 3. University of Trento

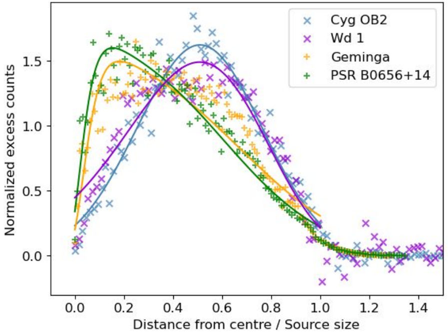
Finanziato
dall'Unione europea
NextGenerationEU

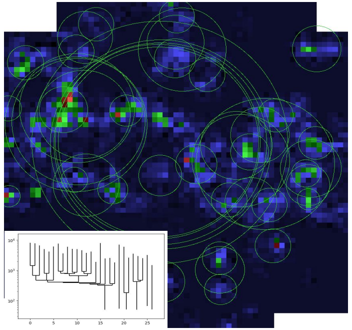
We studied the morphology of the **Cygnus OB2** and **Westerlund 1** YMSCs as explanatory cases of how next-generation ground-based cherenkov telescopes like ASTRI Mini-Array and CTA will be able to observe the secondary γ-ray radiation.

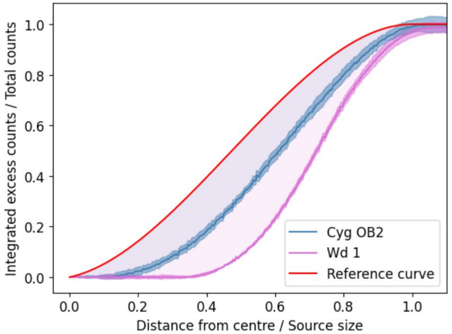
We based our **morphological analyses** on the YMSCs model introduced in *Morlino et al. (2021)* and we:

- computed the hadronic spectrum.
- compute the γ-ray spectra.
- produced numerical simulations using the *50 hr* IRF.
  of the ASTRI Mini-Array.









We inspected the **radial profiles** and the **integrated counts profiles** of the YMSCs and the Geminga and Monogem **TeV halos**. We found:

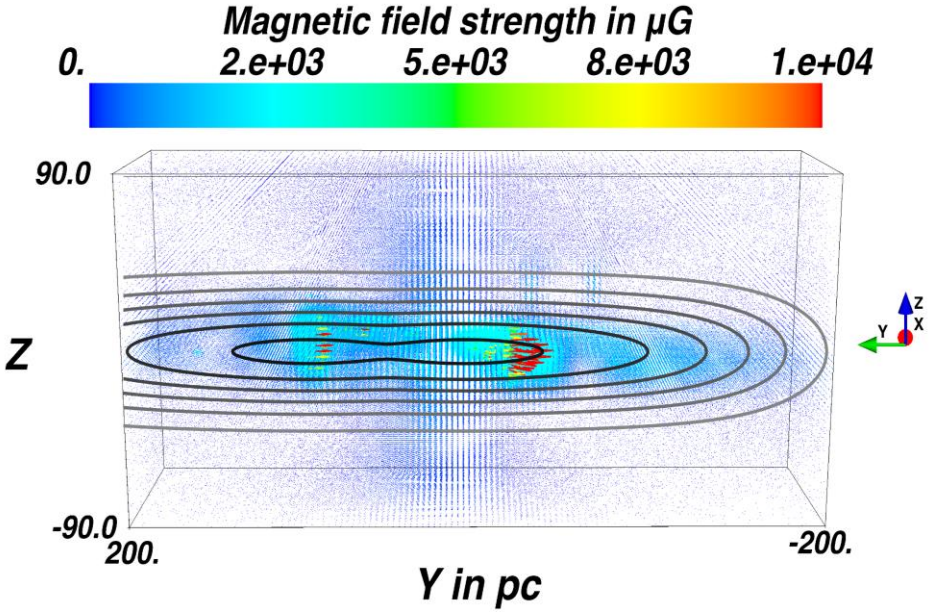
- different emission peaks and peak anisotropies.
- a function that separates the YMSCs from the TeV halos.

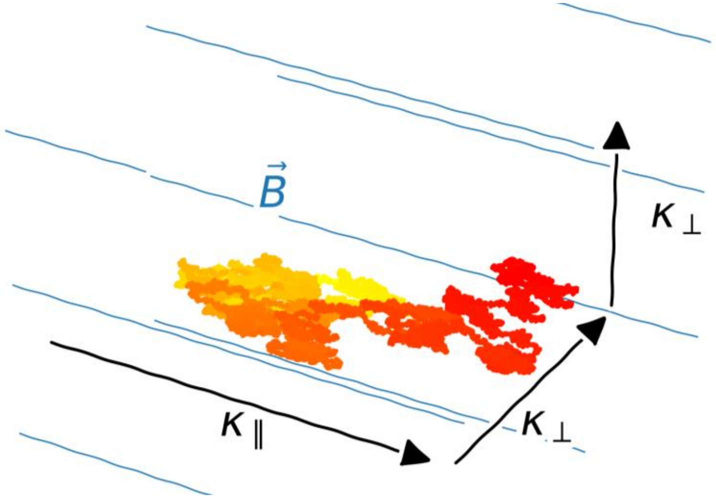
We simulated the hadronic γ-ray emission assuming a **uniform** ISM distribution and a one following the the position of **molecular hydrogen clouds**.

Implications from 3-dimensional modelling of gamma-ray signatures in the Galactic Center

Julien Dörner – Ruhr University Bochum

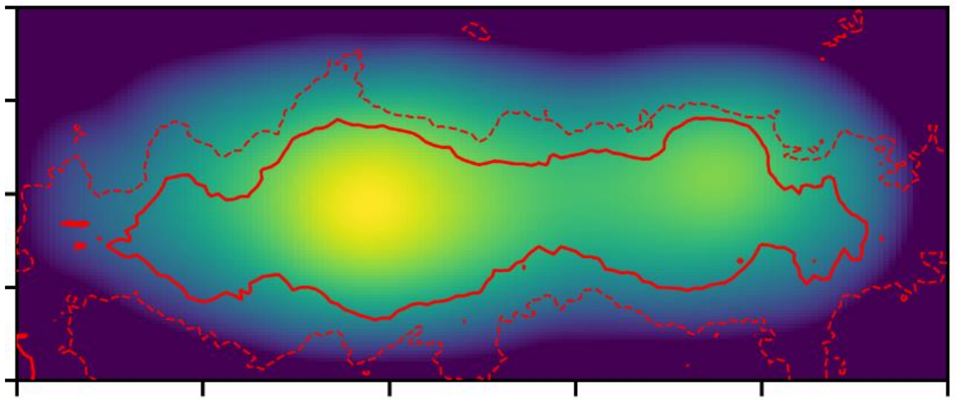
3D magnetic field +
3D gas distribution



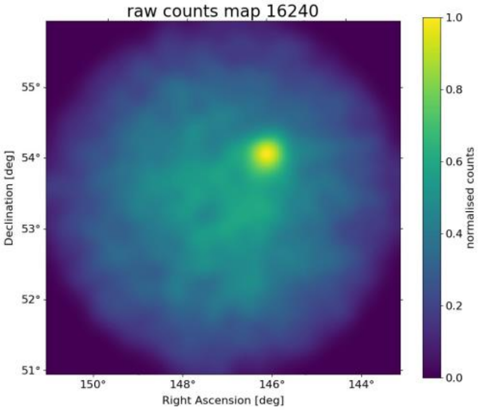


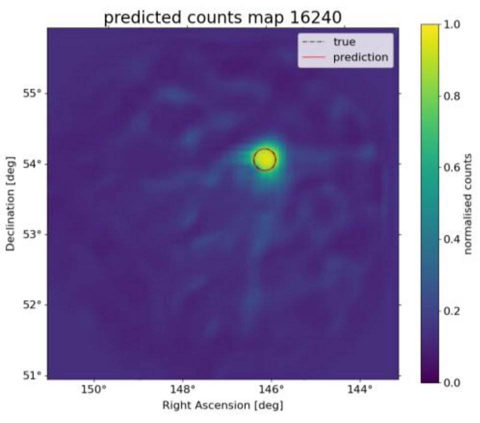
Anisotropic CR transport

Secondary gamma ray distribution



A machine learning toolkit for high-level analysis of Cherenkov telescopes data





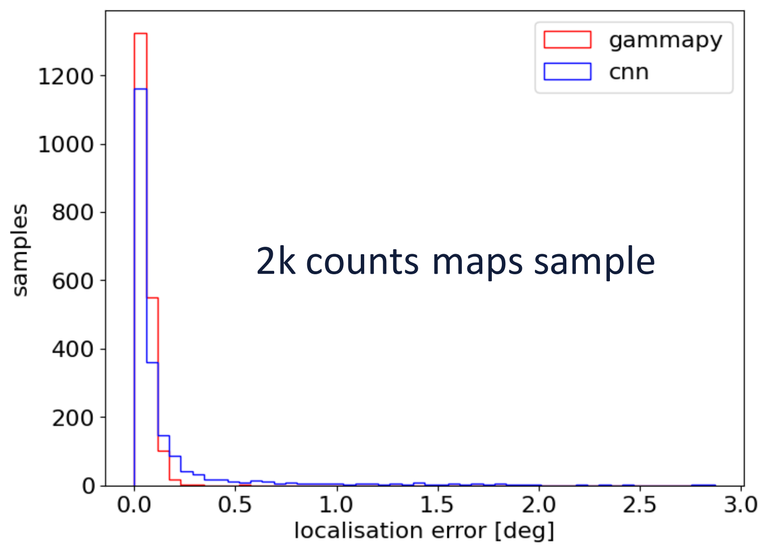
CNN auto-encoder:

- Image denoising
- Online inference
- No IRF required
- No target required
- Improves regression

CNN 2D-regressor:

- Candidates search
- Online Inference
- No IRF required

- CNN tailored to 20° zenith (4LST)
- SAG pipeline with 20° zenith IRF (4LST)



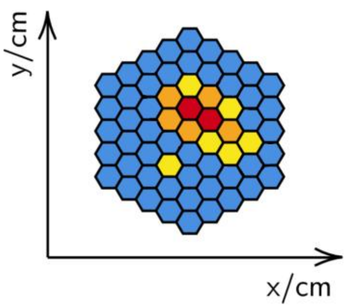
Ambra DI PIANO

ambra.dipiano@inaf.it

Boosting the Resolution of the Cherenkov Telescope Array with Hybrid Machine Learning-Likelihood Reconstruction

Georg Schwefer, Robert Parsons, Jim Hinton

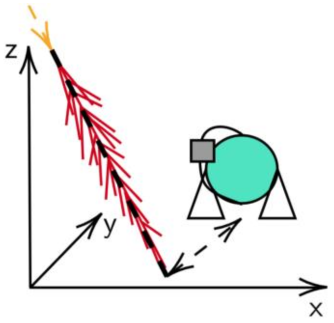
MAX-PLANCK-INSTITUT
FÜR KERNPHYSIK



Charge Image

$$\mathcal{L} = \prod_{i=1}^{N_{\mathrm{tel}}} \prod_{j=1}^{N_{\mathrm{pix}}} p(c_{ij} | \vec{r}^{\,ij}_{\mathrm{pix}}, \vec{r}^{\,i}_{\mathrm{tel}}, \vec{\eta})$$

Image Likelihood



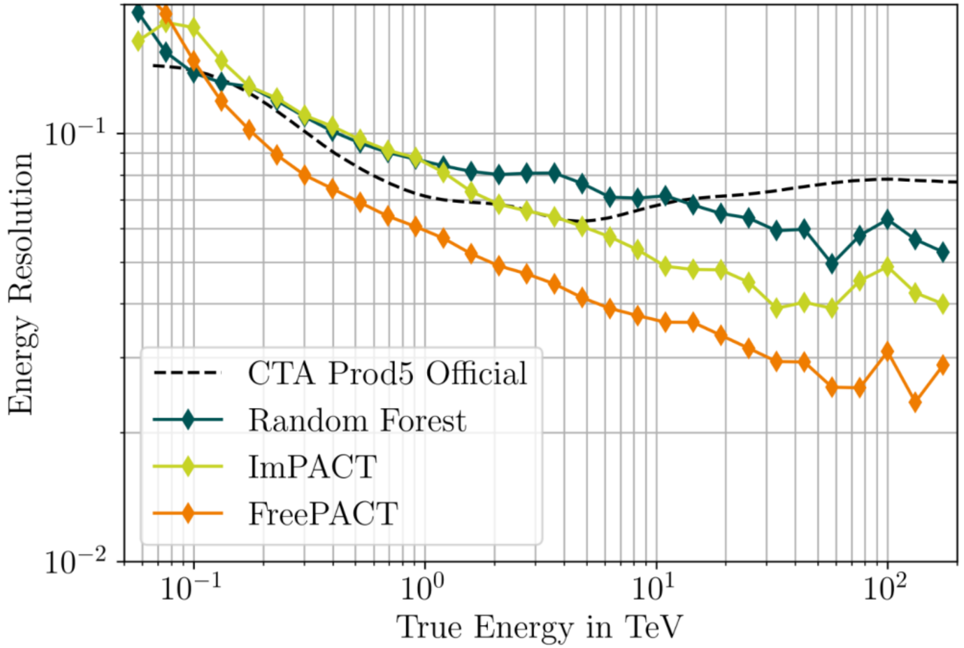
Shower Parameters

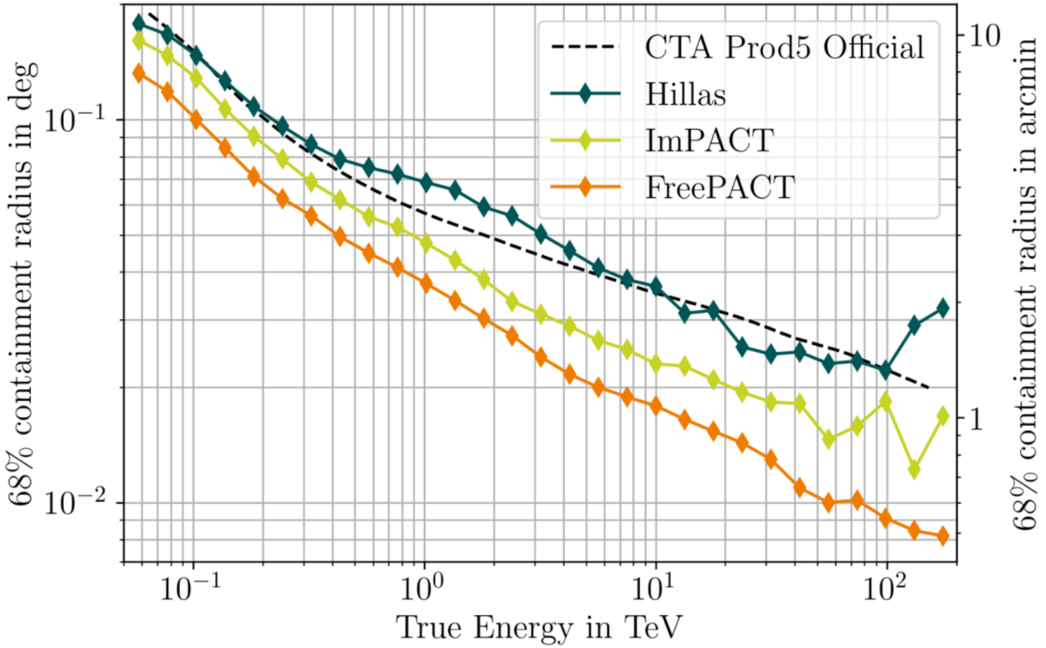
Formulation of likelihood is crucial!

Currently: Analytical likelihood (ImPACT)

New Method: FreePACT

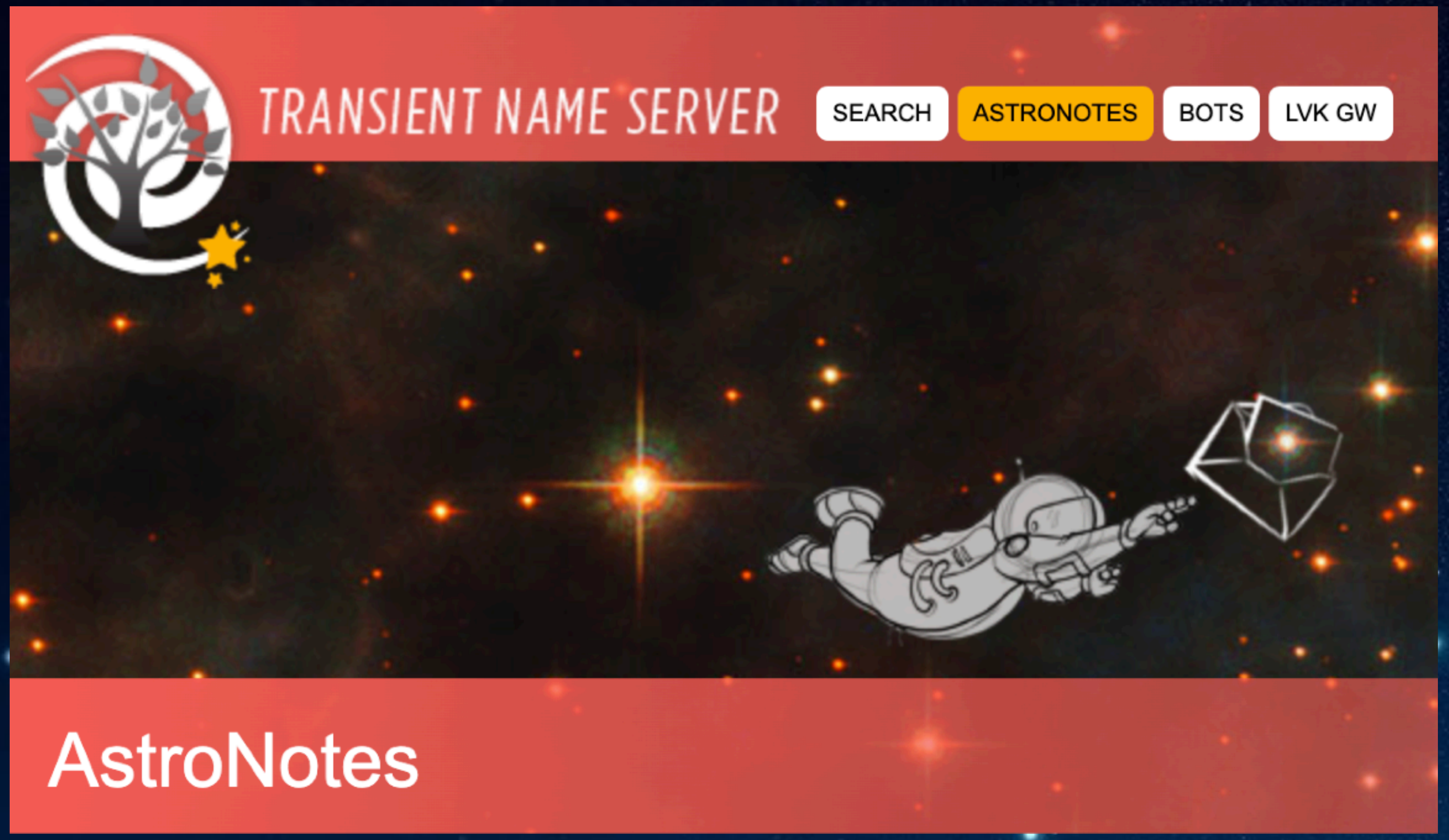
- Use likelihood-free inference techniques
- Likelihood-proxy from Neural Network

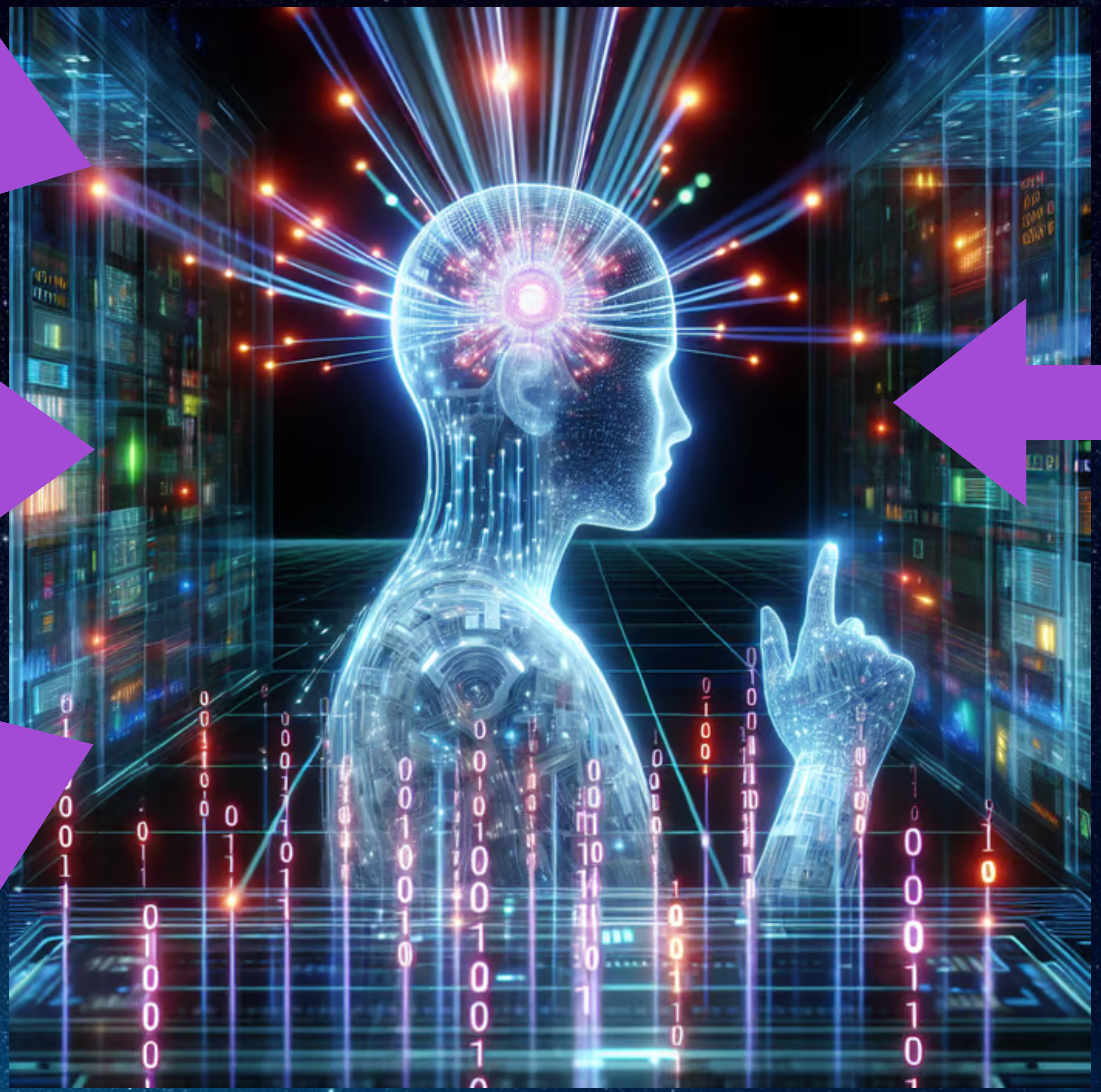




General Coordinates Network Circulars

The Astronomer's Telegram





Language Models and Information Extraction Techniques in the Era of Multimessenger Astronomy

- *astroECR: annotated corpus of observation reports*
- *astroNLPy: pipeline for information extraction*
- *NIMBIS: prompting of LLMs*

Atilla Kaan Alkan, A. Chaikova, D. Kostunin, V. Sotnikov, F. Schüssler

IRFU + LISN
Desy-Zeuthen
JetBrains Research

Muon Image Analysis for the Large-Sized Telescope with the Cherenkov Telescope Array

This work will introduce an approach for muon candidate flagging and muon image cleaning from the parent hadronic shower. Such an approach offers improvements of a factor of 10 in reducing input data stream size and cleaning can enlarge the number of reconstructed muons with a factor of 5. The feasibility of these algorithms is demonstrated as a comparison between simulated and real LST data.

Muon candidate tagging

This tagging alforithm will choose events that contain muon rings with some precision, that is better with comparison to current tagging algorithm.

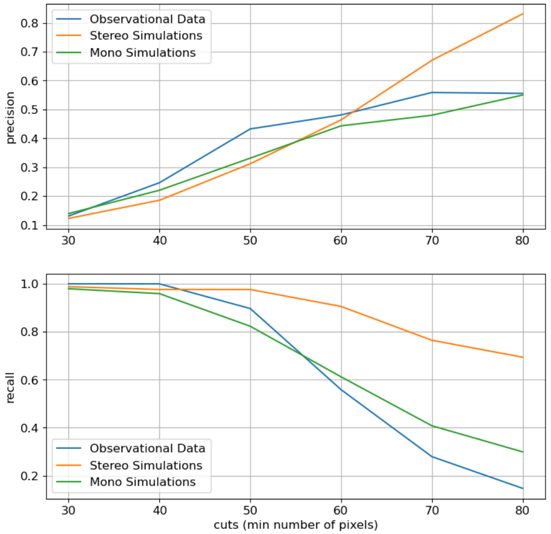
Performance:

We can achieve good performance for observational data :

<u>Cut = 50 pixels</u> -> *Precision = 44% with recall = 90%*

Or if we need to preserve more muon rings (which is not very important in terms of optical efficiency calculation):

<u>Cut = 40 pixels</u> -> *Precision = 25% with recall 100%*

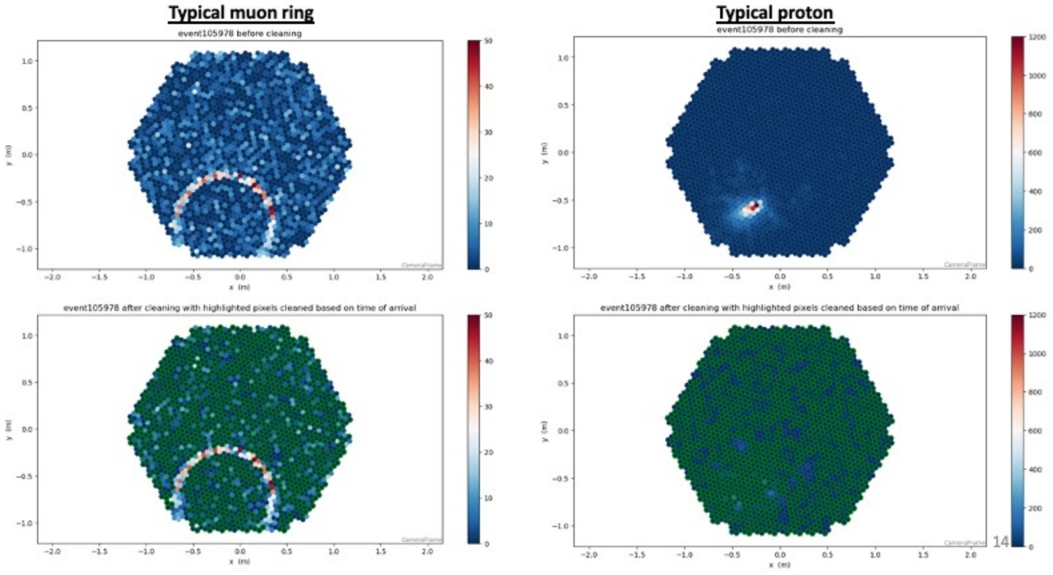


Muon cleaning algorithm

This algorithm don't touch pixels with muon light and clean pixels with hadronic shower light.

Before cleaning:

After cleaning:



UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

Estimation & mitigation of systematic uncertainties of the CTAO

cta
cherenkov telescope array

Scope of the study

Estimation of the systematic uncertainties budget in CTAO scientific performance in terms of

- Energy scale
- Flux estimation
- Source localisation
- PSF
- Telescope’s time calibration

Energy scale first to be addressed

$$\left(\frac{\delta E_{scale}(E)}{E}=10\,\%\right)\sim\left(\frac{\delta E_{atmosphere}(E)}{E}=8\,\%\right)\oplus\left(\frac{\delta E_{telescopic\ part}(E)}{E}=5\,\%\right)\oplus\left(\frac{\delta E_{analysis}(E)}{E}=4\,\%\right)$$

Telescope components

- Corsika dataset to be reprocessed by various telescope configurations
- In each configuration a single parameter is varied within its uncertainty limits
  - Telescope teams have been contacted & started providing feedback
- Production will run in parallel with prod6 (~20TB)

Atmosphere

- Variations of molecular profiles, absorbing molecules, aerosols, clouds, under study
- Tools that monitor the atmosphere and produce input files for simulations (Corsila input, extinction profiles) are developed or under active development (ozone, clouds) within the Calibration pipeline
- Simulations to provide induced uncertainties from seasonal/tailored profiles are planned

More studies under planning

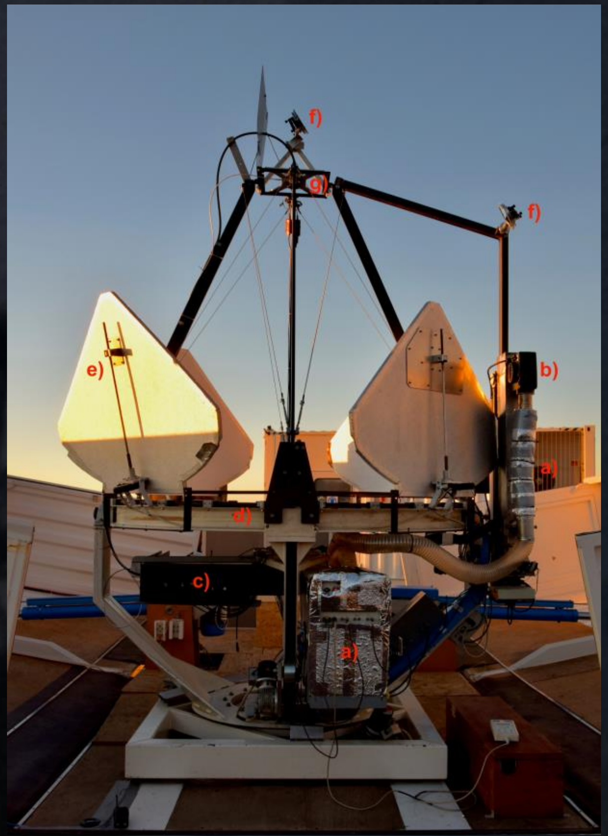
- Uncertainties due to non-simulated fluorescence, scattered Cherenkov light in the FoV, simulation simplifications...

Observation of the Calima above the Observatorio del Roque de los Muchachos with the Barcelona Raman Lidar

Darko Kolar for CTAO North Raman Lidar Pathfinder group
Center for Astrophysics and Cosmology, University of Nova Gorica, Nova Gorica
Contact: darko.kolar@ung.si

The Cherenkov Telescope Array Observatory (CTAO)

- Reconstruction of energy and direction strongly depends on the current atmospheric conditions
    - Lidar atmospheric monitoring and calibration are crucial for reaching the expected capabilities of CTAO
    - CTAO-N Raman Lidar Pathfinder, also known as Barcelona Raman Lidar (BRL)

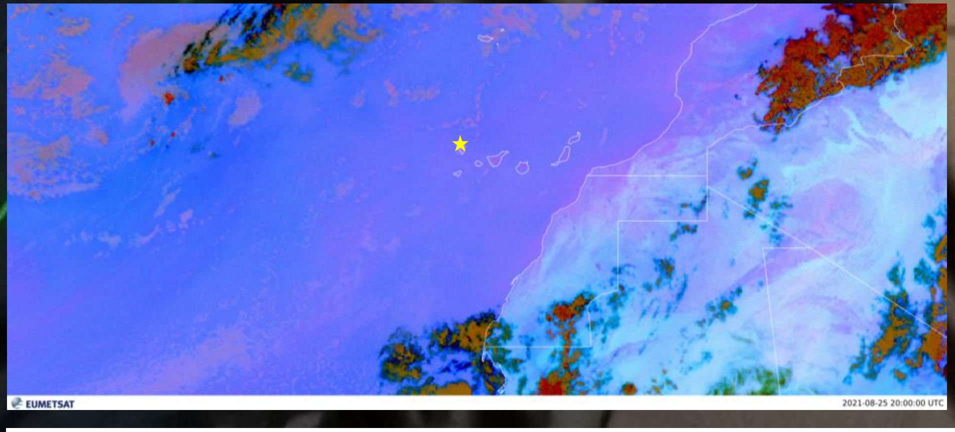


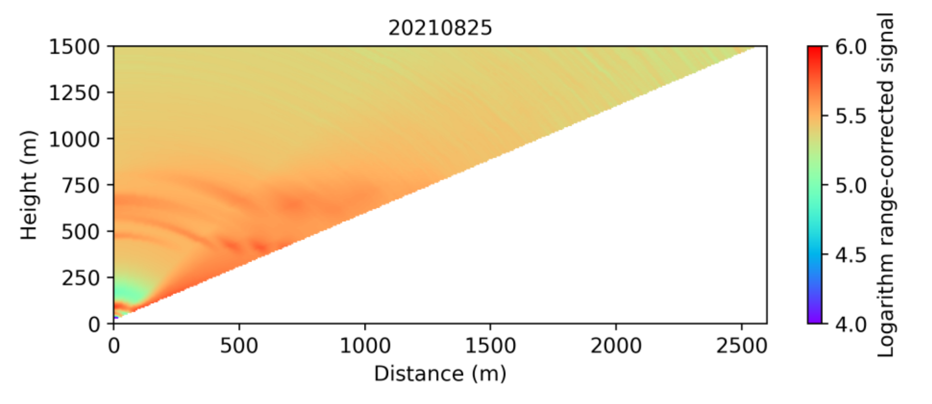
BRL components:

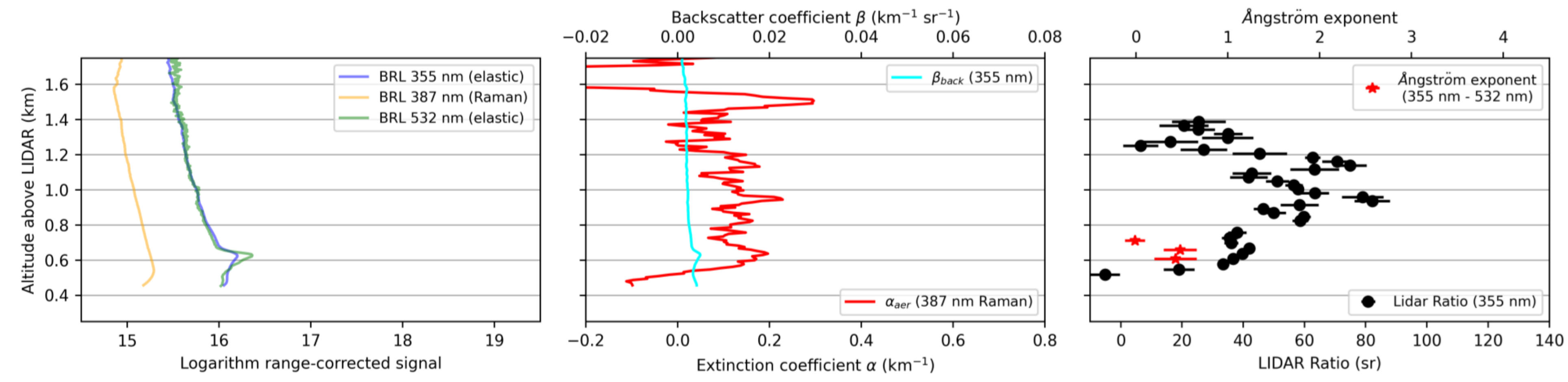
(a) laser power and laser head
(b) heater for laser operation under cold ambient temperature conditions
(c) polychromator
(d) main mirror
(e) petals
(f) guiding dichroic mirrors for the transmitter
(g) shutter for the optic fiber.

Results

- The BRL deployed at Observatorio del Roque de los Muchachos (ORM,★) for extensive on-field tests
- In the fourth and fifth week of August 2021, an approximately ten-day-long Saharan dust intrusion, so-called Calima, occurred
- A more accurate analysis performed on data collected in the evenings of 25 and 26 August 2021
    - Average lidar ratios between 40-50 sr + Ångström exponent below 1.0 -> implication of scattering on large, irregularly-shaped particles, such as mineral dust
    - Non uniform distribution of dust seen on scan from 25 August
- Despite the specific design of the BRL for atmosphere characterization, it also functions very well as a meteorological lidar, capable of basic identification and classification of aerosols (size and shape)



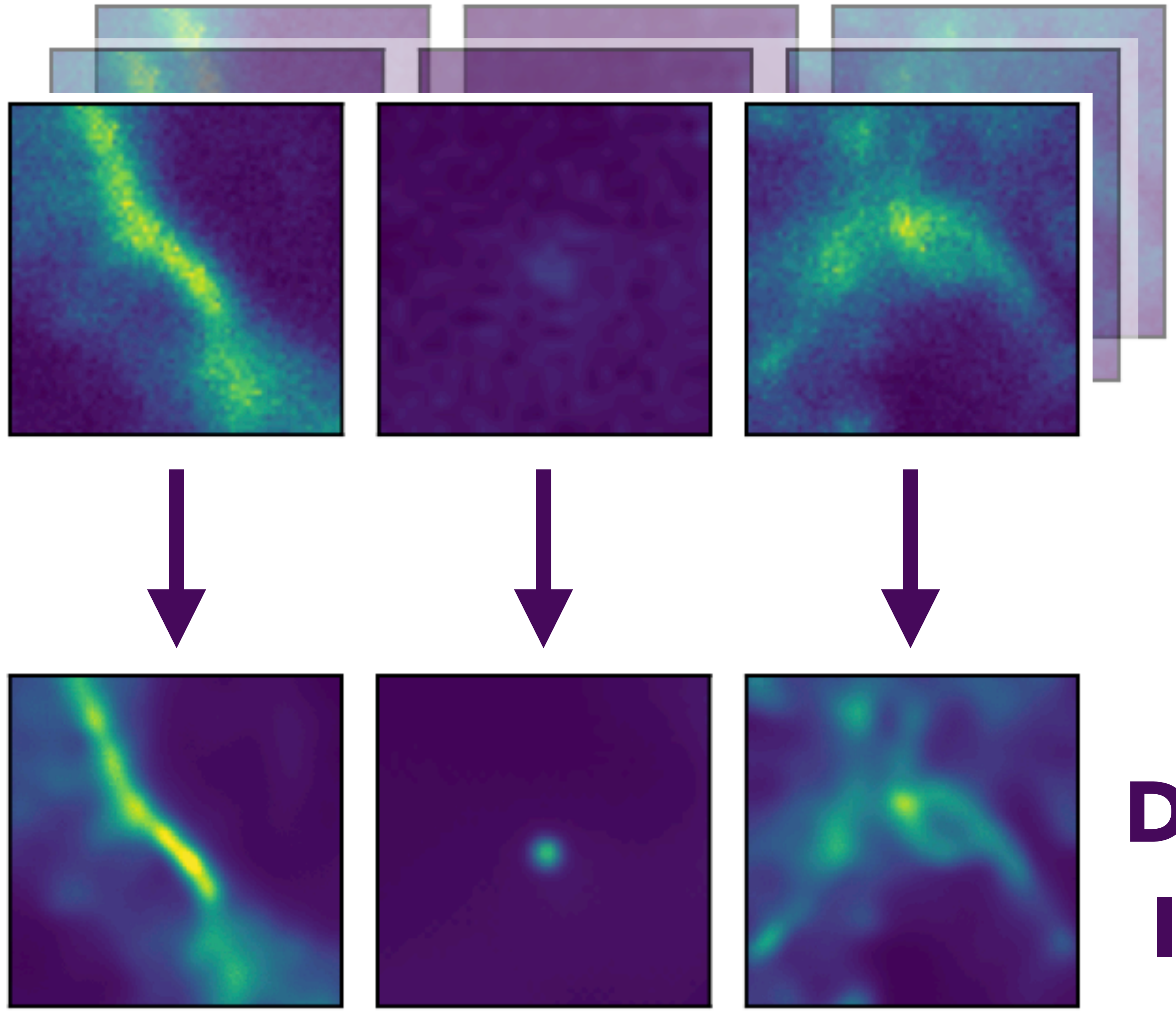




Analysis of data taken on 25 August 2021 around 20:00 UTC:

Top left - Satellite image of mineral dust (in pink) over Western Africa and the Atlantic
Top right - Spatial distribution of clouds and aerosol loading above the ORM
Bottom - Atmospheric properties. Left: Range square corrected lidar returns in the three analog channels. Center: The backscattering coefficient and the extinction coefficient of aerosols. Right: Ångström exponent profile and the lidar ratio.

Jolideco



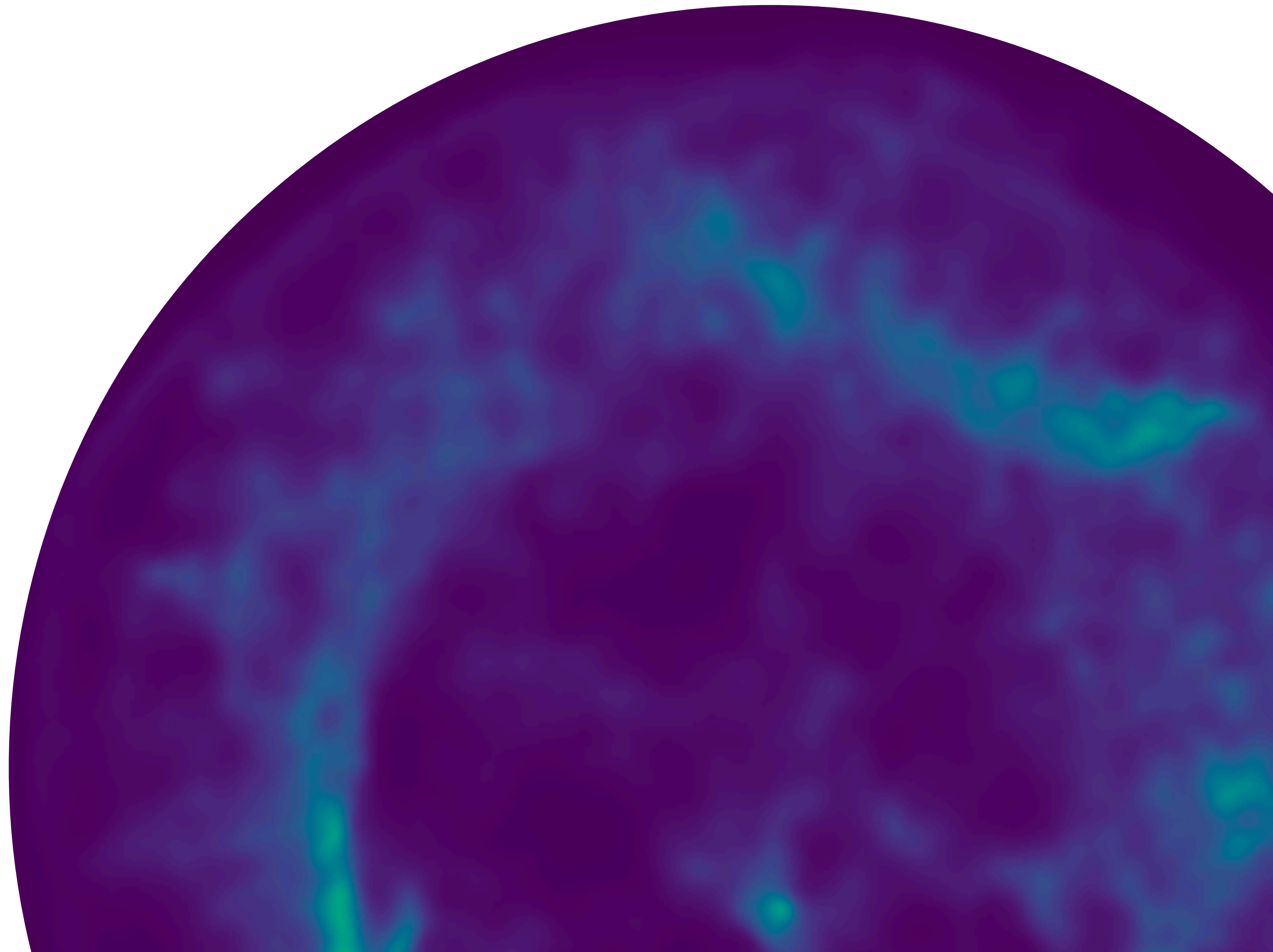
Multiple Observations with Poisson Noise

Single, de-noised and de-convolved flux image

https://github.com/jolideco/jolideco

https://jolideco.readthedocs.io/en/latest/

Deblurring and denoising of Images with Poisson noise!



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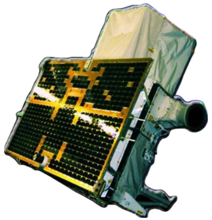
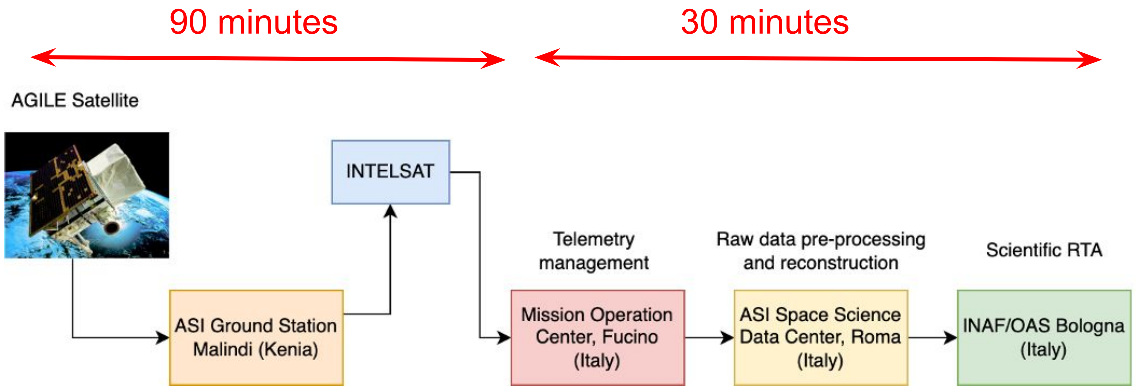
OSSERVATORIO DI ASTROFISICA
E SCIENZA DELLO SPAZIO DI BOLOGNA

OAS
BOLOGNA



The AGILE Real-Time Analysis software system



90 minutes

30 minutes

AGILE Satellite

INTELSAT

ASI Ground Station Malindi (Kenia)

Telemetry management

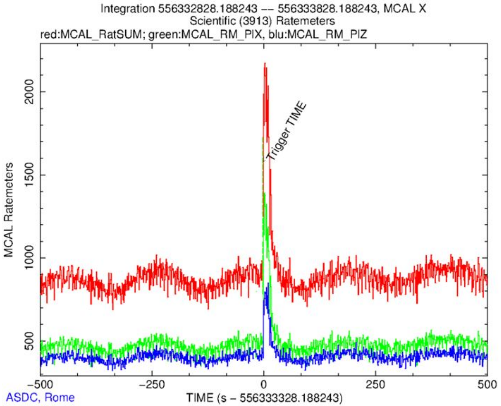
Mission Operation Center, Fucino (Italy)

Raw data pre-processing and reconstruction

ASI Space Science Data Center, Roma (Italy)

Scientific RTA

INAF/OAS Bologna (Italy)

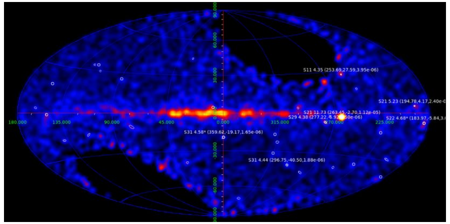


AGILE ratemeters for the GRB210818A

AGILE Team transient communications:

- >240 ATels
- >300 GCN Circulars
- 97 automated GCN Notices

The know-how will be used for the next generation of high-energy facilities such as the Cherenkov Telescope Array, the ASTRI Mini-Array, and the COSI space mission.



AGILE/GRID counts map - 2 days of exposure with automated candidate detections.

N. Parmiggiani on behalf of the AGILE Team

Astro-COLIBRI

A tool for transient and multi-messenger astronomy

Mathieu de Bony, Fabian Schüssler, Patrick Reichherzer, Atilla Alkan, Jayson Mourrier

PKS0736+01
GeV flare
RA/Dec: 114.82°/1.62° (± 0.02°)
2023-06-29 09:55:55

SN 2023mdv
Supernovae (optical)
RA/Dec: 149.78°/-34.22°
2023-06-29 00:15:40

S230628ax
Gravitational wave
RA/Dec: 142.66°/46.57°
2023-06-28 23:12:00

GRB 230628E
Gamma-ray burst
RA/Dec: 171.85°/-11.46° (± <0.00°)
2023-06-28 22:29:56

GRB 230628D
Gamma-ray burst
RA/Dec: 175.02°/12.29° (± 1.59°)

S230628ax
Gravitational wave

RA / Dec: 142.66° 46.57°
source: S230628ax
radius: 1°

Detailed info about selected source:

VoEvent : XML VoEvent : JSON

name: S230628ax
Detection time: 2023-06-28 23:12:00
RA [deg] : 142.66 Dec [deg] : 46.57
RA : 9h30m38.79s Dec : 46d34m18.65s
observatory: LVC instrument: H1,L1 discovery name: S230628ax
notice: Initial pipeline: pycbc
classification: BBH: 1.00
FAR: 1.00e-2/yr → significant event
distance: 2047 ± 585 Mpc
50% area: 183 deg² 90% area: 692 deg²

Search for ATels!

visibility: 2023-07-07
weather: forecast seeing

Visibility at H.E.S.S.
S230628ax
(RA = 142.7° , DEC = 46.6°)

GraceDB
Information on the gravitational wave event

TreasureMap
Follow-ups of GW events

GCN Viewer
Access to GCN notices and circulars

GCN-n
GCN notices: rapid alert message

ALADIN
Displays event in an interactive sky atlas

MS230110g
RA/Dec: 122.34° / 23.89°
2023-01-10 06:05:42

SN 2022bf
RA/Dec: 20.86° / 49.97°
2022-01-03 21:07:12

GRB 220103A
RA/Dec: 36.86° / -15.70°
error: 8.4°
2022-01-03 21:03:12

HAWC-220103A
RA/Dec: 156.33° / 1.83°
error: 0.599°
2022-01-03 08:01:56

ed: GRB 220107A

astro-colibri.science

- Cone search, visibility, link to external platforms
- GW scheduling using tilepy
- Link with BHTOM to trigger follow-up campaigns
- ….

Funded by the Horizon 2020 Framework Programme of the European Union Grant Agreement No. 871158

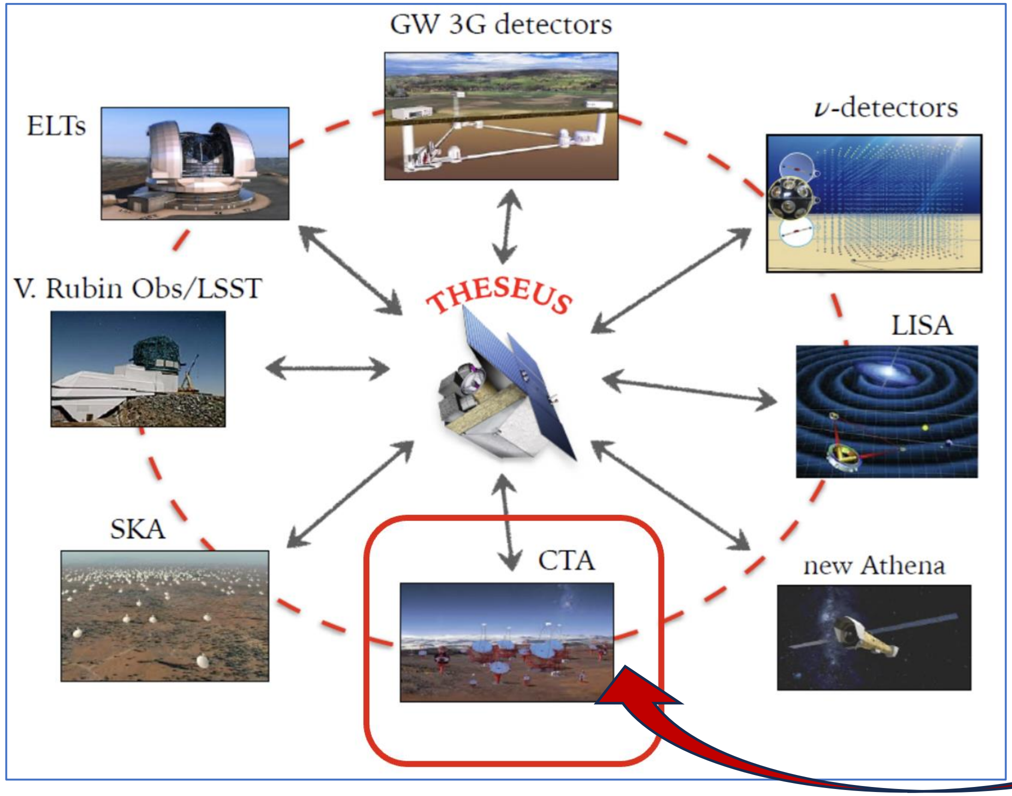
The THESEUS mission and its great synergy with CTA

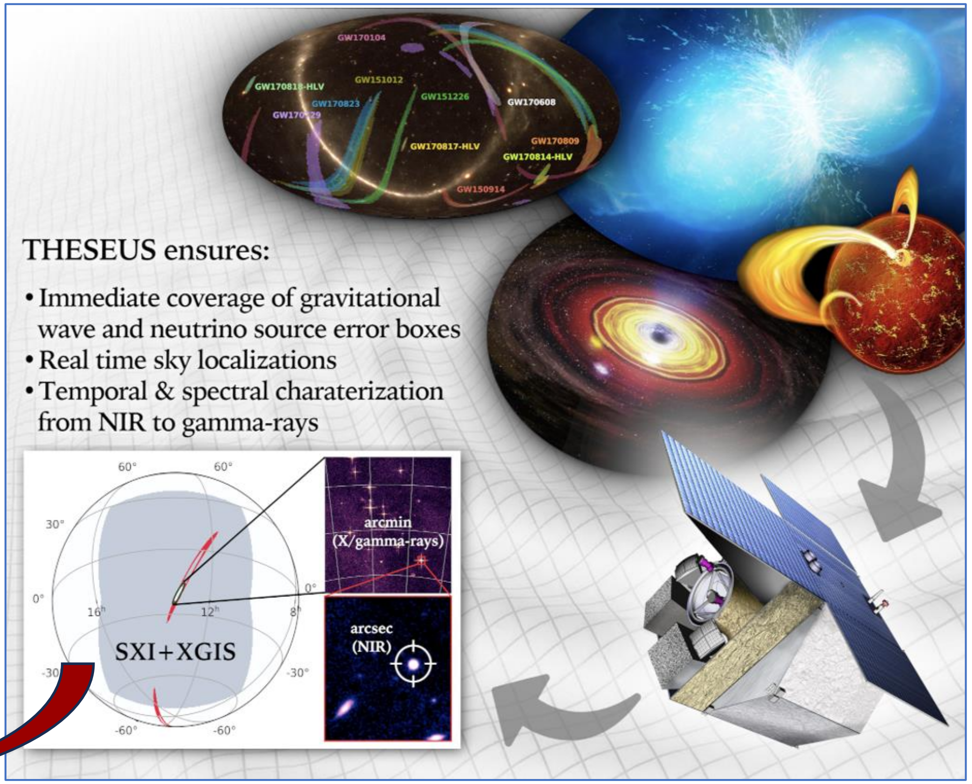
- ESA M7 mission candidate <u>in Phase A</u> study (launch by 2037)
- X-ray/γ-ray Sky Surveyor with core science:
  1) Cosmology with GRBs
  2) Multi-messenger astrophysics

THESEUS will provide to CTA:

- X-ray and gamma-ray transient triggers + accurate sky localization
- NIR to MeV simultaneous spectral coverage

https://www.isdc.unige.ch/theseus/





THESEUS ensures:

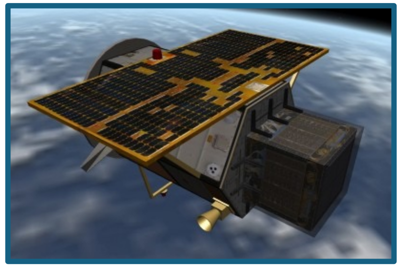
- Immediate coverage of gravitational wave and neutrino source error boxes
- Real time sky localizations
- Temporal & spectral charaterization from NIR to gamma-rays

https://sci.esa.int/documents/34375/36249/Theseus_YB_final.pdf

The BOAT: GRB 221009A as detected by AGILE

G. Piano[1], L. Foffano[1], M. Tavani[1] on behalf of the AGILE Team

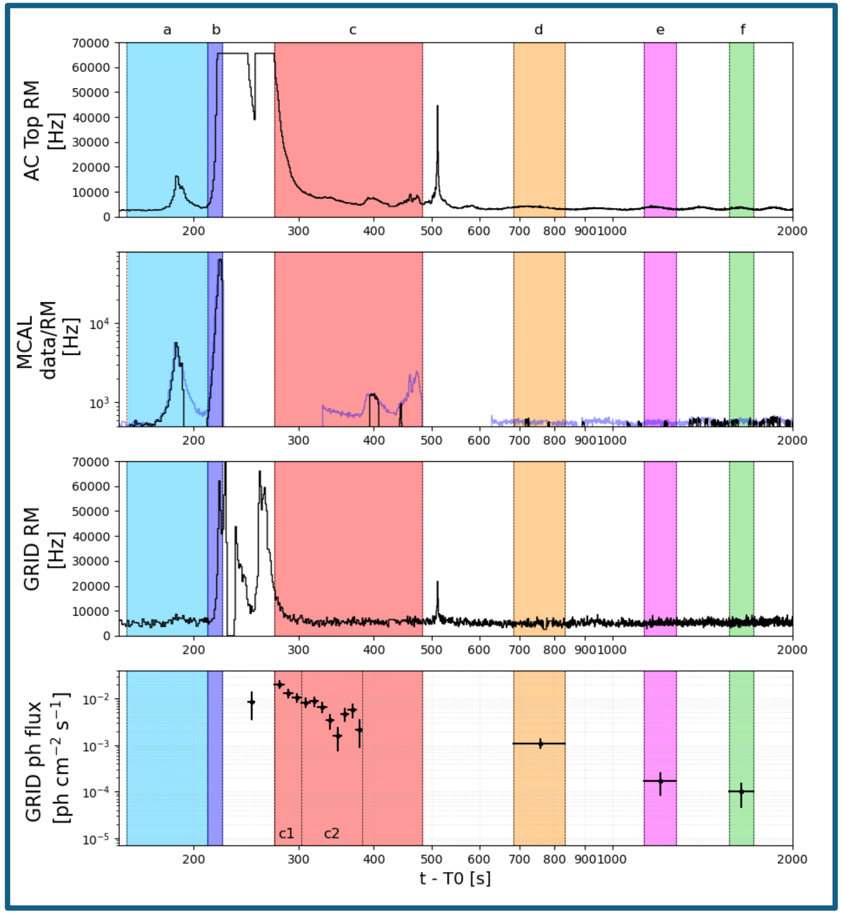
[1] INAF-IAPS, Via del Fosso del Cavaliere 100, I-00133 Roma, Italy
contact: giovanni.piano@inaf.it



- October 9, 2022 (T_0 = 2022-10-09 UT 13:16:59.99):
  - Swift/BAT reported the detection of GRB 221009A, the “brightest of all time”.
  - Afterglow emission observed from radio to VHE gamma-rays (LHAASO).
  - Redshift: z = 0.15 → distance ~750 Mpc

- GRB 221009A simultaneously detected by AGILE with:
  - GRID [30 MeV – 50 GeV]: γ-ray imager
  - MCAL [350 keV – 10 MeV]: calorimeter
  - Scientific Ratemeters [RMs, 50-200 keV]

- Prompt/afterglow overlapping emission observed by AGILE:
  - quasi-continuous monitoring of the GRB up to ~20 ks
  - light curves and spectral evolution
  - crucial constraints to the emission models (see L. Foffano’s talk)



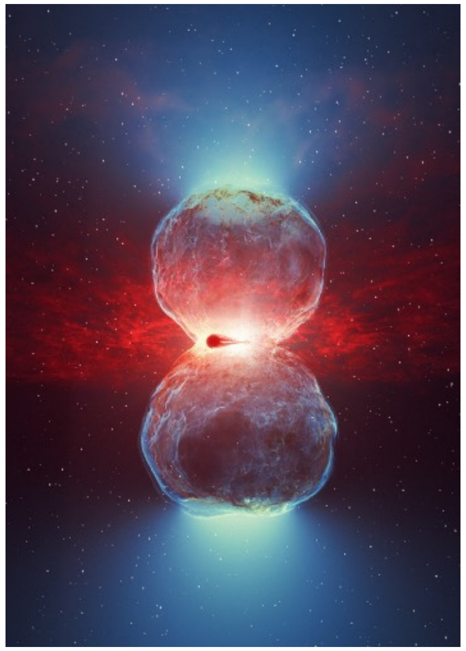
“AGILE Gamma-Ray Detection of the Exceptional GRB 221009A”
Tavani, M., Piano, G., Bulgarelli A., et al.
ApJL 956, L23 (2023)

CTAO Symposium, Bologna, Italy
April 15-18, 2024

Two decades of time domain observations with H.E.S.S.

Flaring stars

CVs / Novae



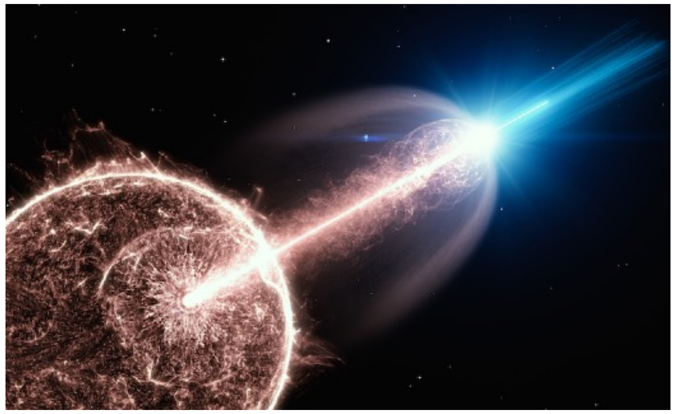
Supernovae

Gamma-ray Bursts

Gravitational Waves

Gamma-ray Binaries

Microquasars



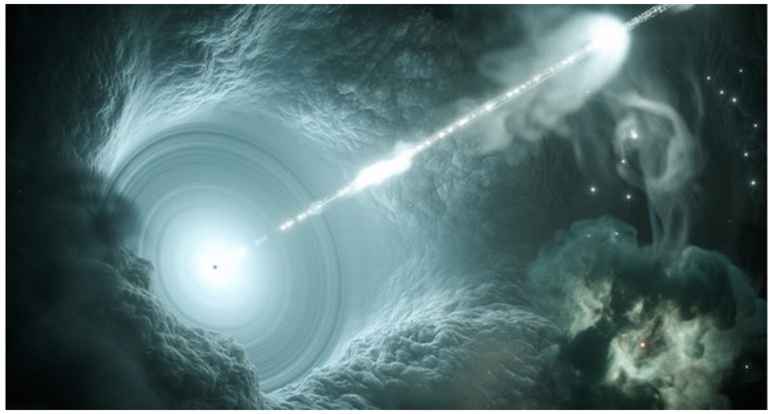
Fast Radio Bursts

Soft Gamma-ray Repeaters

Active Galactic nuclei

Tidal Disruption Events

Neutrinos



H.E.S.S., Desy,
Science Communication Lab

Yun-Lei Huang
[Yuna Wong]

Catching bright GRBs with TeV gamma-ray observatories

Yunlei Huang, Soebur Razzaque, Lili Yang

Bright GRBs

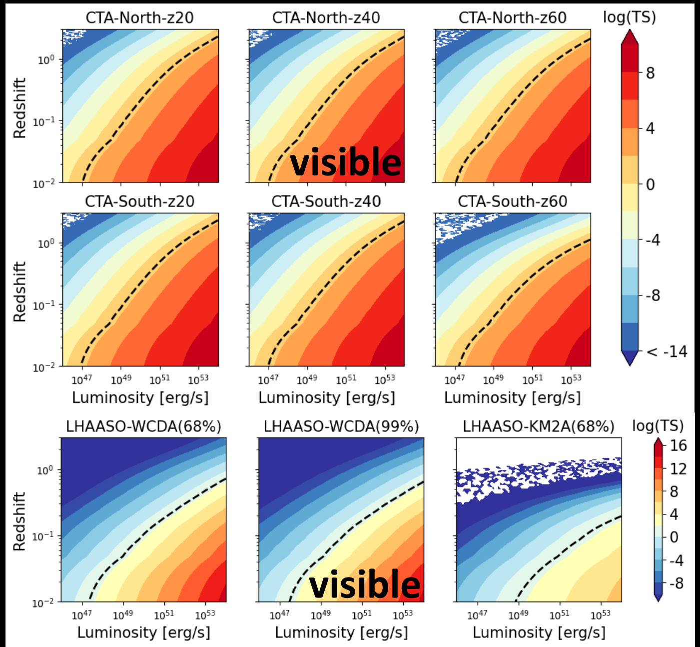
- Same intrinsic spectrum as GRB221009A
- GRB luminosity and redshift distribution(Banerjee et al.)

Propagation

- Redshift effect
- EBL absorption (Saldana-Lopez et al.)

Ground-based gamma-ray experiments

- Get N_{bkg} and N_{src} for a spectrum
- $TS > 25$ -> can be seen



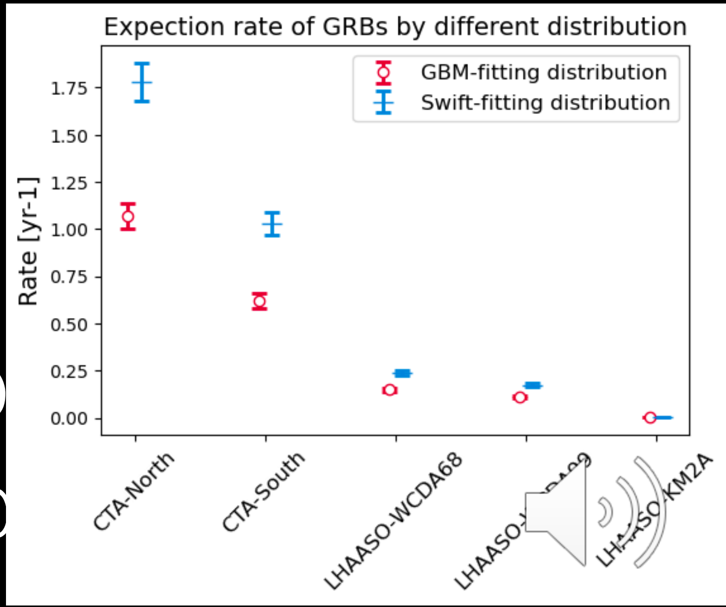
Result

TS map of GRBs with different L and z

Detection rate of CTA and LHAASO

CTA: z ~ 2.5 ; $L > 1.2\times10^{51} erg/s$(z=0.5)
1.1-1.8/yr (Northern); 0.6-1.0 /yr (Southern)

LHAASO: z ~ 0.7 ; $L > 1.2\times10^{52} erg/s$(z=0.5)
0.15-0.24 (WCDA) ; 0.004 (KM2A)



The Intergalactic Magnetic Field and Gamma Ray Bursts with CTAO

Téméman Keita teneman.keita@cea.fr

The IGMF, relic field from the Big-Bang

- Indirect evidence for specific Early-Universe phenomena
- Too weak for traditional measurements

γ-rays + IR background in the Universe → cascades with IGMF signature

⇒ Lower energy secondary γ-rays
⇒ Extended halo
⇒ Time delay

GRBs are promising probes for cosmology

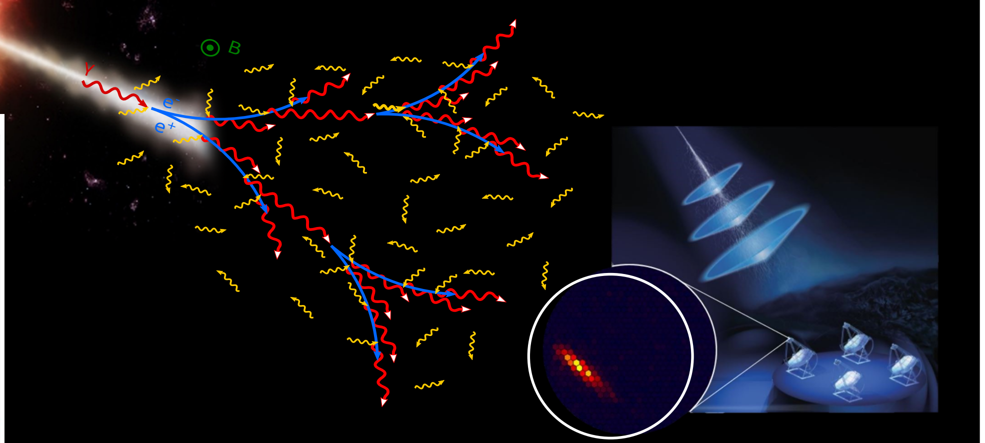
- Detected over large z ranges, at GeV-TeV
- Explosive events → temporal effect
- Complementary to AGN

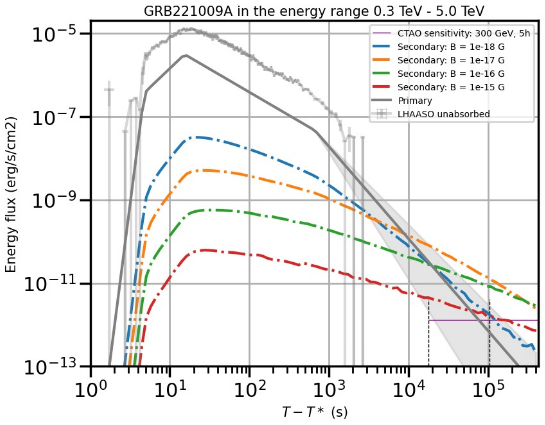
⇒ IGMF using time delays in CTAO

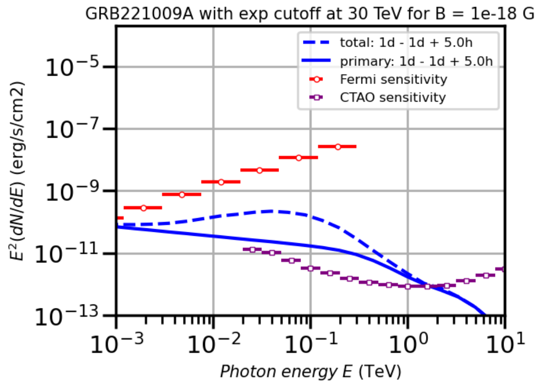
Application on a particularly bright event: GRB221009A

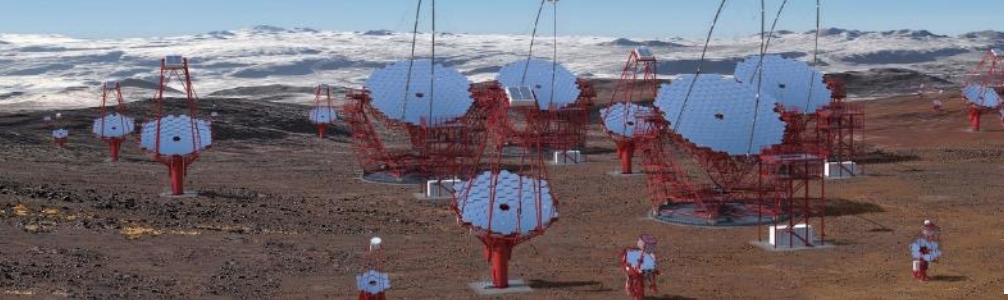
$\gamma_{HE} + \gamma_{LE} \rightarrow e^{+} + e^{-}$

$e^{\pm} + \gamma_{LE} \rightarrow e^{\pm} + \gamma_{HE}$









- **Shower modeling**
- **CTAO sensitivity estimation**
- **Light curves and Energy spectra**
- **Test for multiple IGMF values**
- **Data**
  - ✓ LHAASO measurements

AGILE Contribution to Electromagnetic Counterpart Search of Gravitational Wave Events

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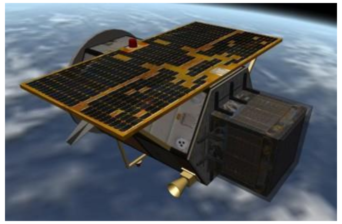
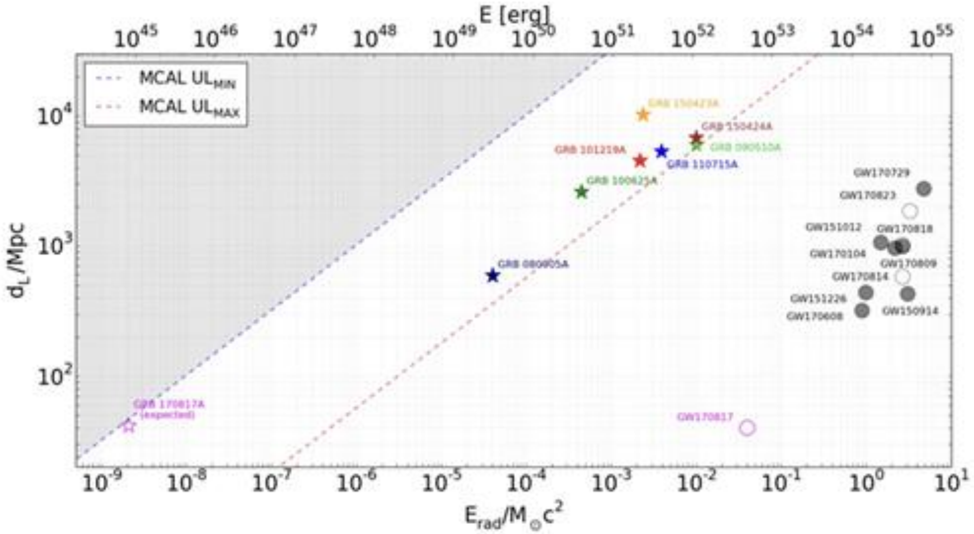


- State of GW observations and AGILE's participation in them:
  - AGILE satellite and its on-board detectors;
  - AGILE dedicated pipeline for GW follow up;
  - AGILE updates from O1 to O4a.
- AGILE observations of GWTC-1 catalog events:
  - Selection of all the interesting GW event;
  - MCAL and GRID data analysis;
  - Summary of the results.
- Future works taking into account the end of the AGILE mission:
  - GWTC-2, GWTC-3;
  - O4a candidates events analysis: AGILE refined analyses (GCN 33826);



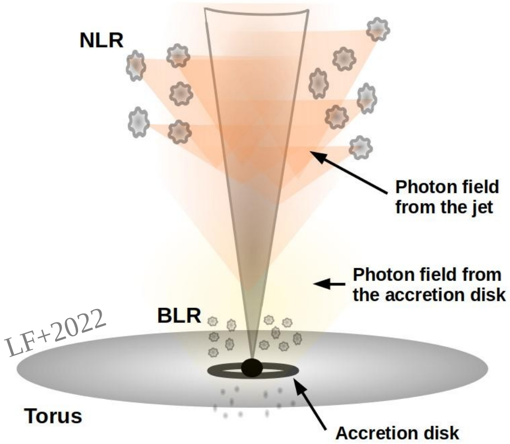
'' AGILE Observations of the LIGO-Virgo GW Events of the GWTC-1 Catalog''
Ursi, Verrecchia, Piano, Casentini et al.,
ApJ 924 80 (2022)

CTAO Symposium, Bologna, Italy
April 15-18, 2024

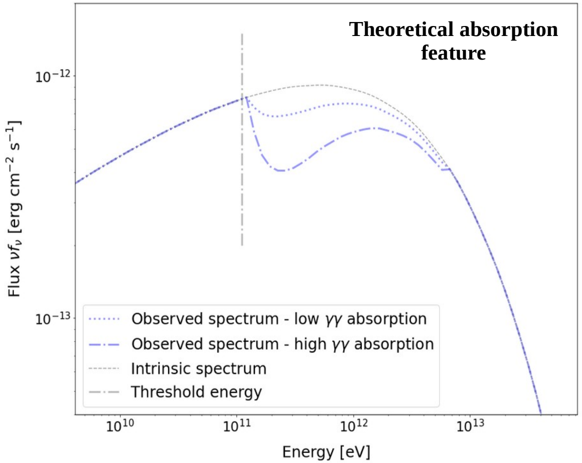
Partially funded also by

Neutrino Emission Channels in BL Lac Objects: Connecting Gamma-Ray Spectra to Large-Scale Environments

Scenario



$$\gamma_{\rm jet} + \gamma_{\rm target} \rightarrow e^+ + e^-$$



$$p+\gamma \rightarrow p_0+\pi_0 \qquad p+\gamma \rightarrow n+\pi^+ \qquad p+\gamma \rightarrow p_0+\pi^++\pi^-$$

Photo-meson reactions → pion decay → neutrinos!

Connection between the gamma-gamma opacity and the photo-meson efficiency:

$$\tau_{\gamma\gamma}(\varepsilon_\gamma^c) \approx 10 \left(\frac{f_{p\gamma}(\varepsilon_p)}{0.01} \right)$$

Absorption feature ⇔ **Neutrino production!**

Take home message

1) New **indirect method to identify environmental large-scale structures in BL Lac objects**, where standard methods cannot be applied.
2) We argue that – if such absorption features are detected and are related to this effect – also **neutrinos** may be produced!