Detection of OP313 at z=0.997 with LST-1: the most distant VHE blazar to date

Mireia Nievas (IAC)
CTAO LST Collaboration
26.08.2024

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
AGENCIA ESTATAL DE INVESTIGACIÓN
Cofinanciado por la Unión Europea

CTAO

Cherenkov Telescope Array Observatory.

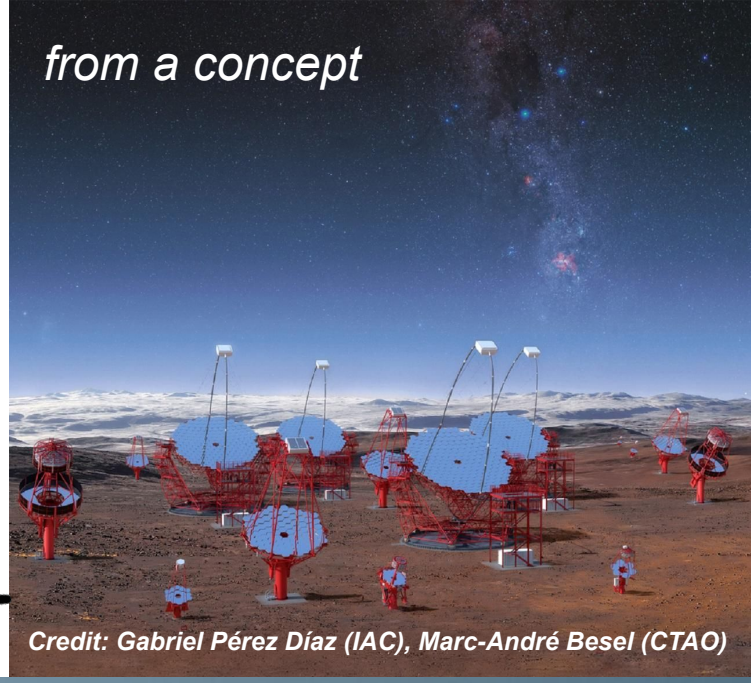
~1500 members (~150 institutes, 25 countries).
Aiming to detect ~10^3 VHE (E>100 GeV) gamma-ray sources.

Two sites:

- CTAO-North: Roque de los Muchachos Observatory (La Palma, Spain)
- CTAO-South: Paranal Observatory (Atacama Desert, Chile)

Three telescope sizes

- Large-Sized Telescopes (LSTs)
- Medium-Sized Telescopes (MSTs)
- Small-Sized Telescopes (SSTs)



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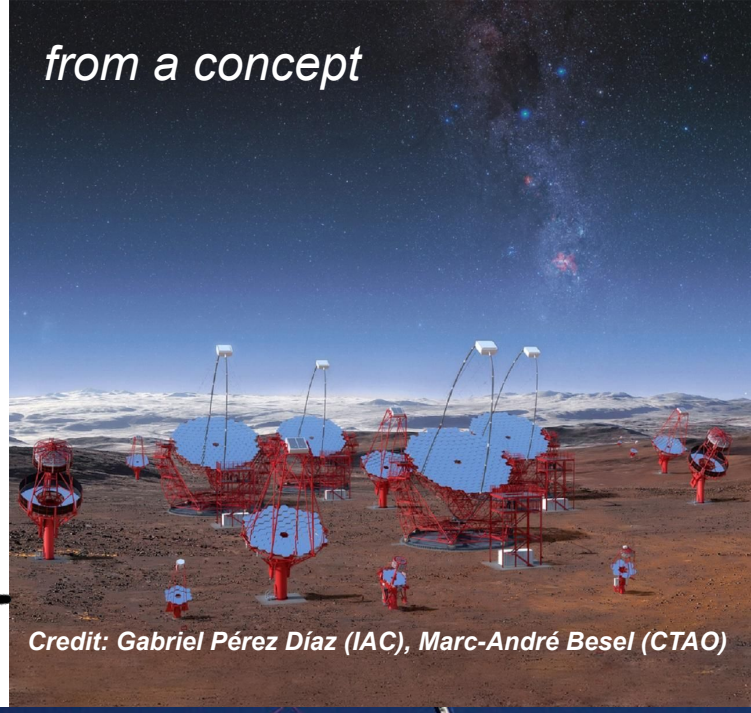

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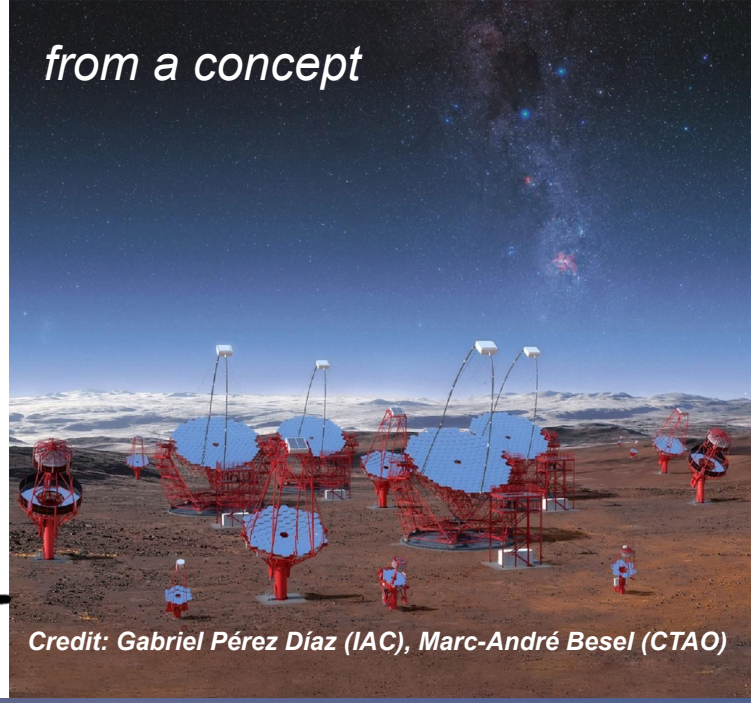

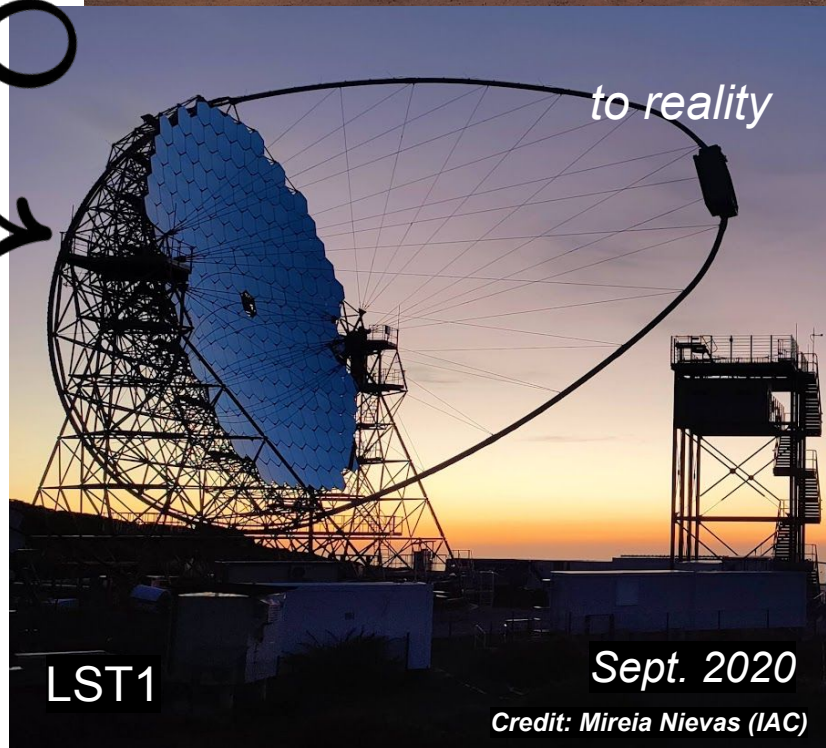

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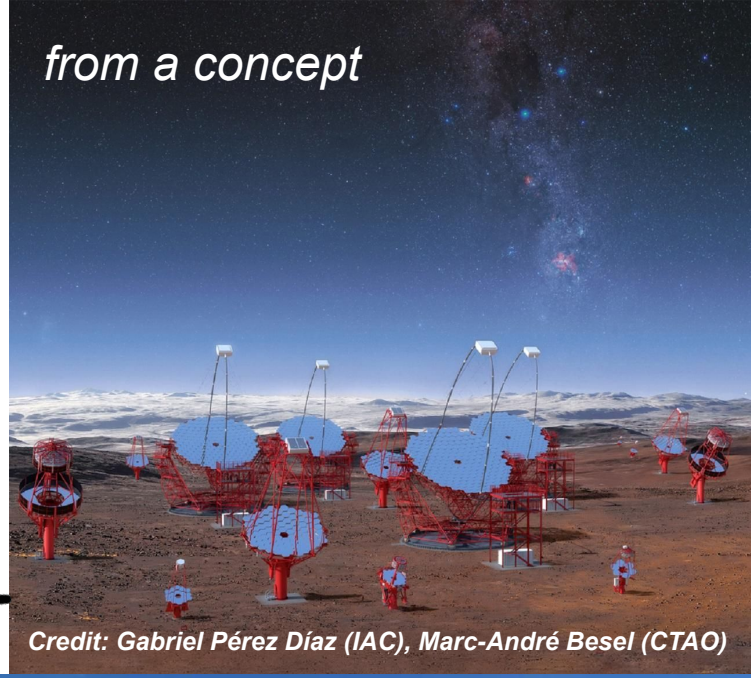

Credit: Gabriel Pérez Díaz (IAC), Marc-André Besel (CTAO)

Credit: Alice Donini (INAF)

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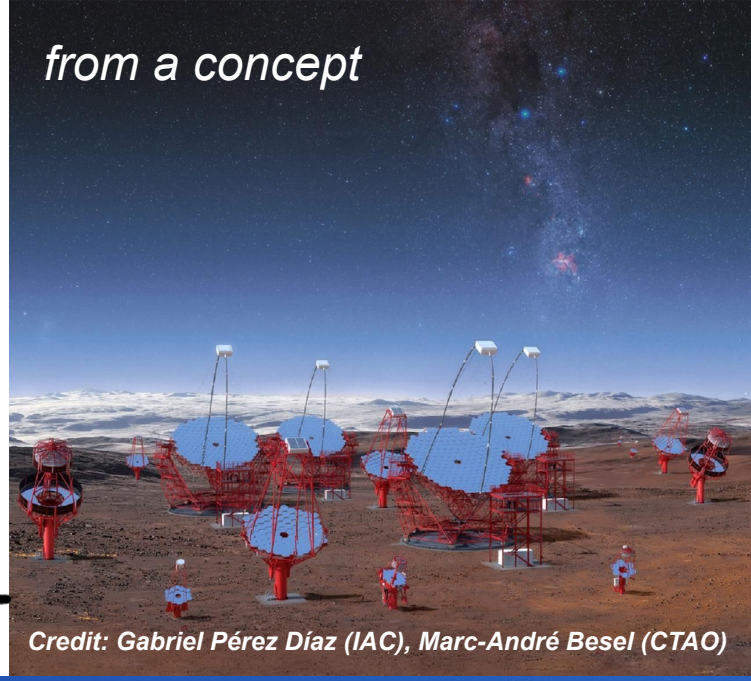

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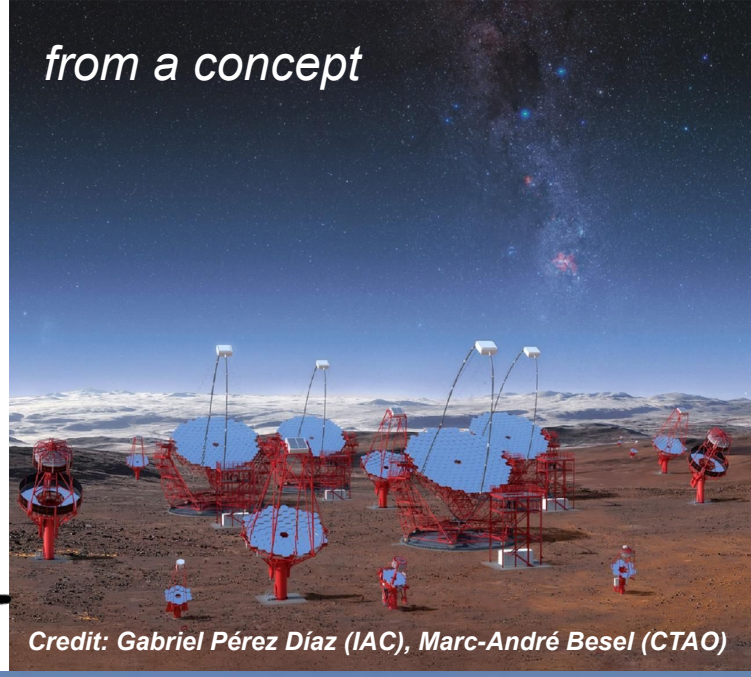
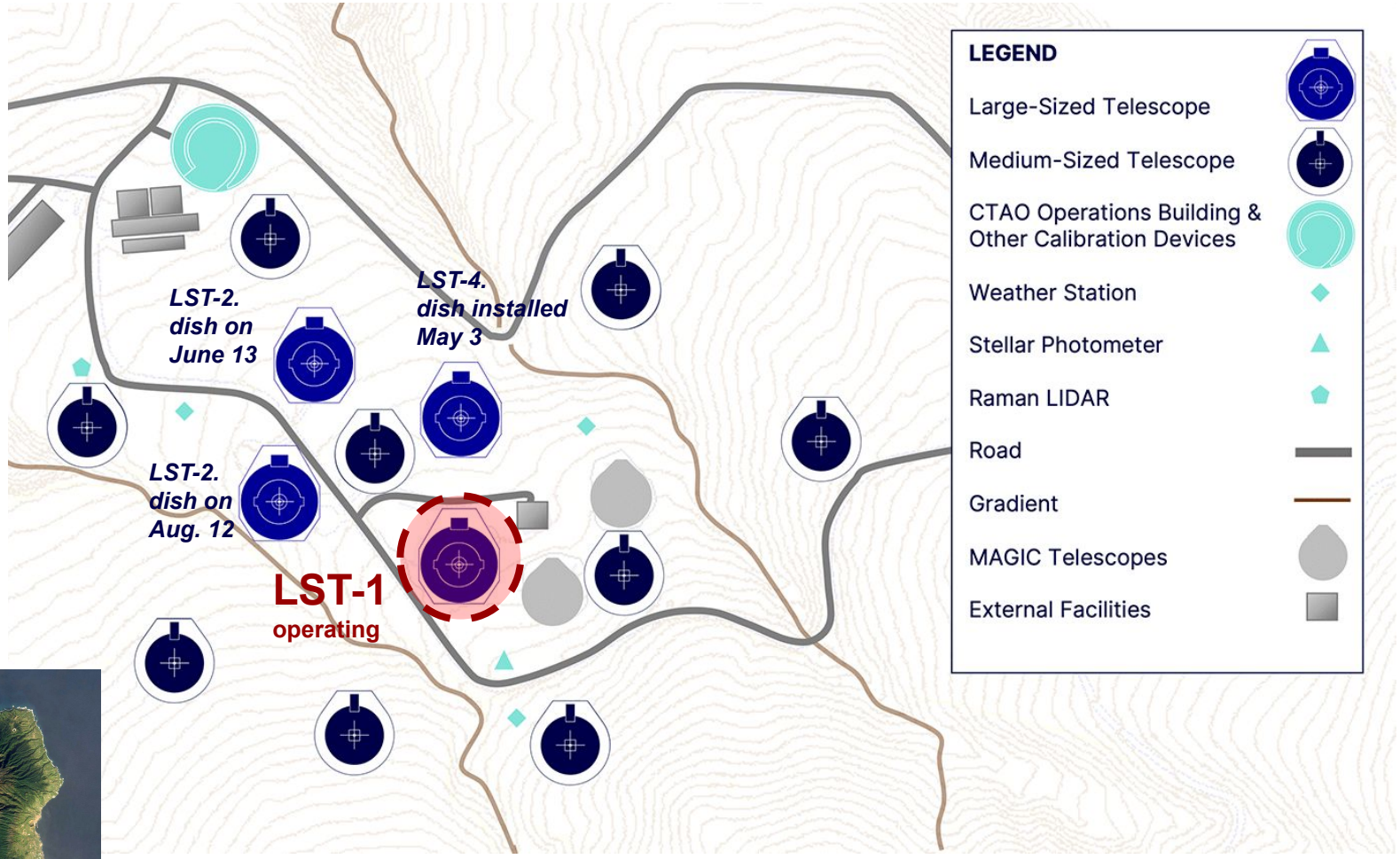
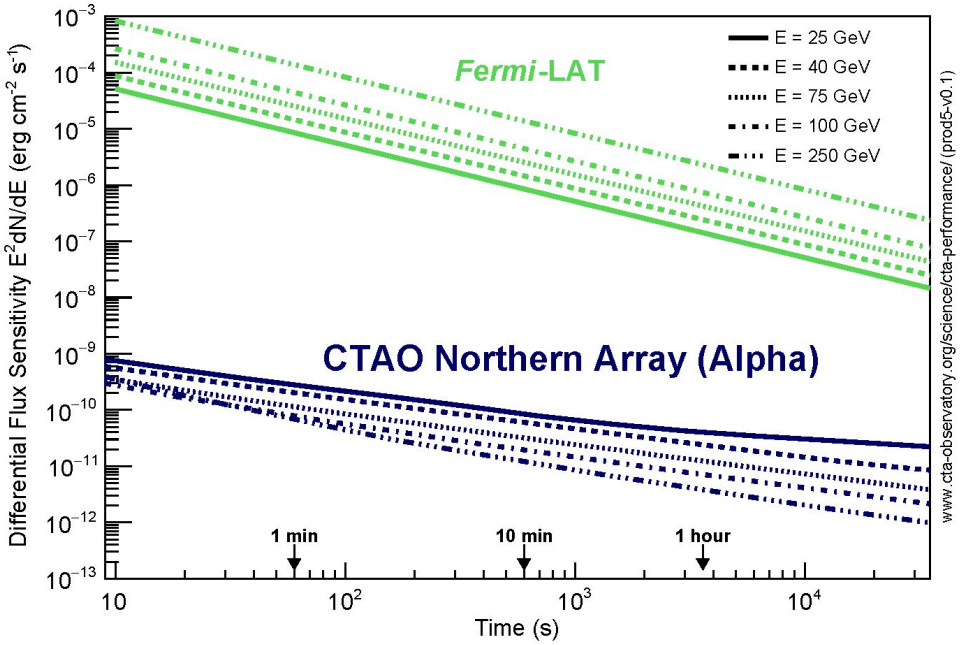


CTAO | LST COLLABORATION

CTAO-North

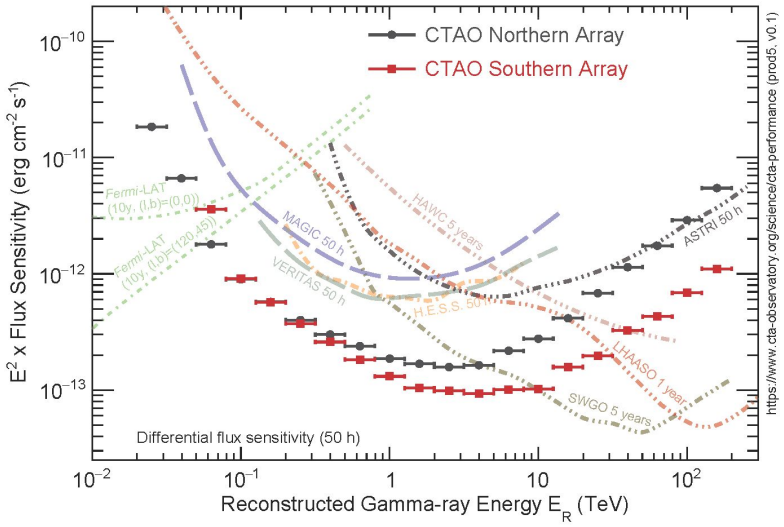

LST-2.
dish on
June 13
LST-4.
dish installed
May 3
LST-2.
dish on
Aug. 12
LST-1
operating
LEGEND
Large-Sized Telescope
Medium-Sized Telescope
CTAO Operations Building &
Other Calibration Devices
Weather Station
Stellar Photometer
Raman LIDAR
Road
Gradient
MAGIC Telescopes
External Facilities

CTAO-North performance



CTAO: Improved sensitivity (x10), angular and energy resolution w.r.t to current generation IACTs (MAGIC, H.E.S.S., VERITAS)

- CTAO-South: More MSTs, +SSTs.
- CTAO-North: More LSTs (En. threshold)



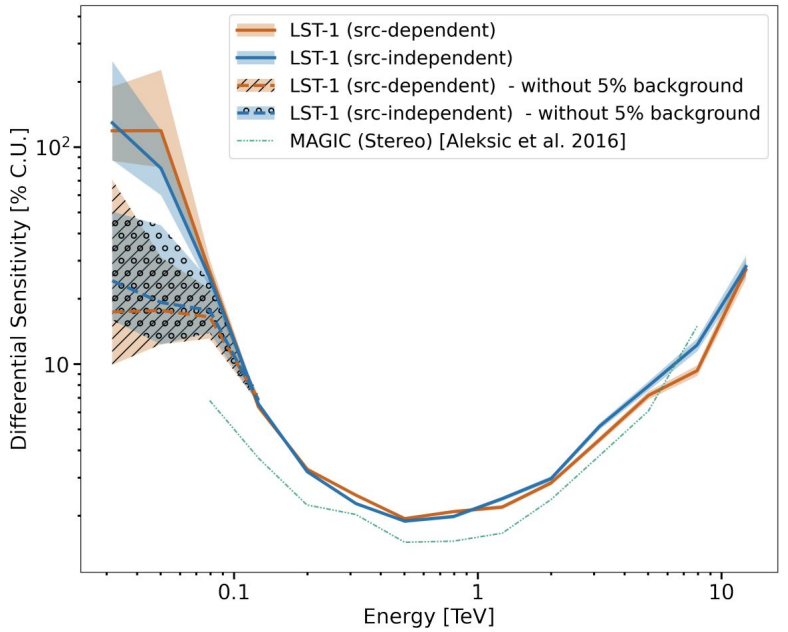
https://www.ctao.org/for-scientists/performance/

LST-1

Prototype for CTAO LST and first telescope in the northern array.

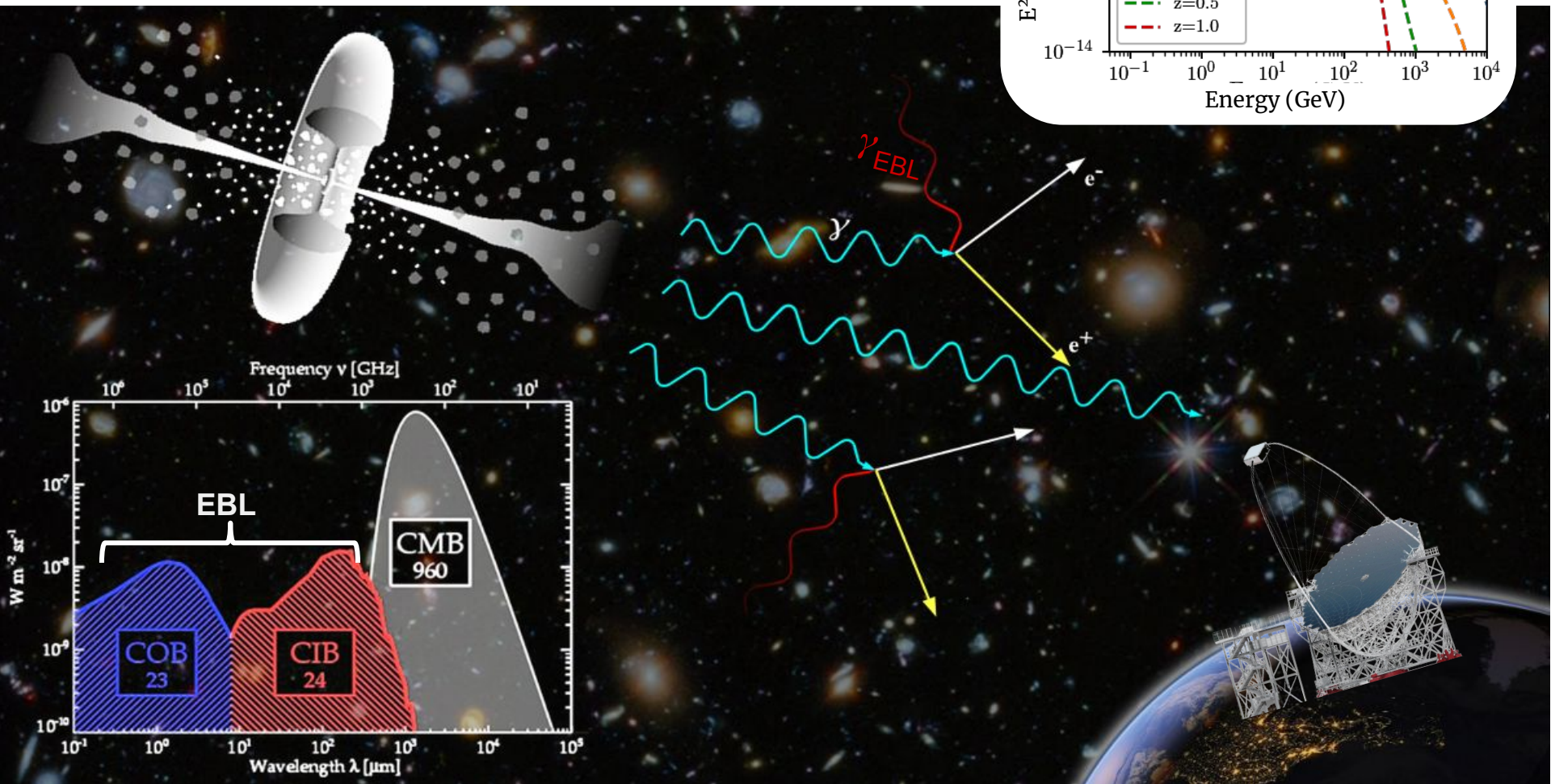
- In operation since 2020.
- Lowest energy threshold among Cherenkov telescopes: ~ 30 GeV

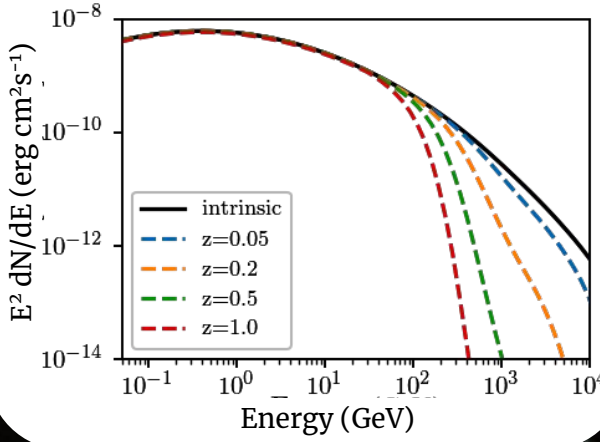
Fast rotation: 180º / 20s



[LST Collaboration 2023, ApJ 956, 2, 80]

LST-1:
extragalactic science and EBL



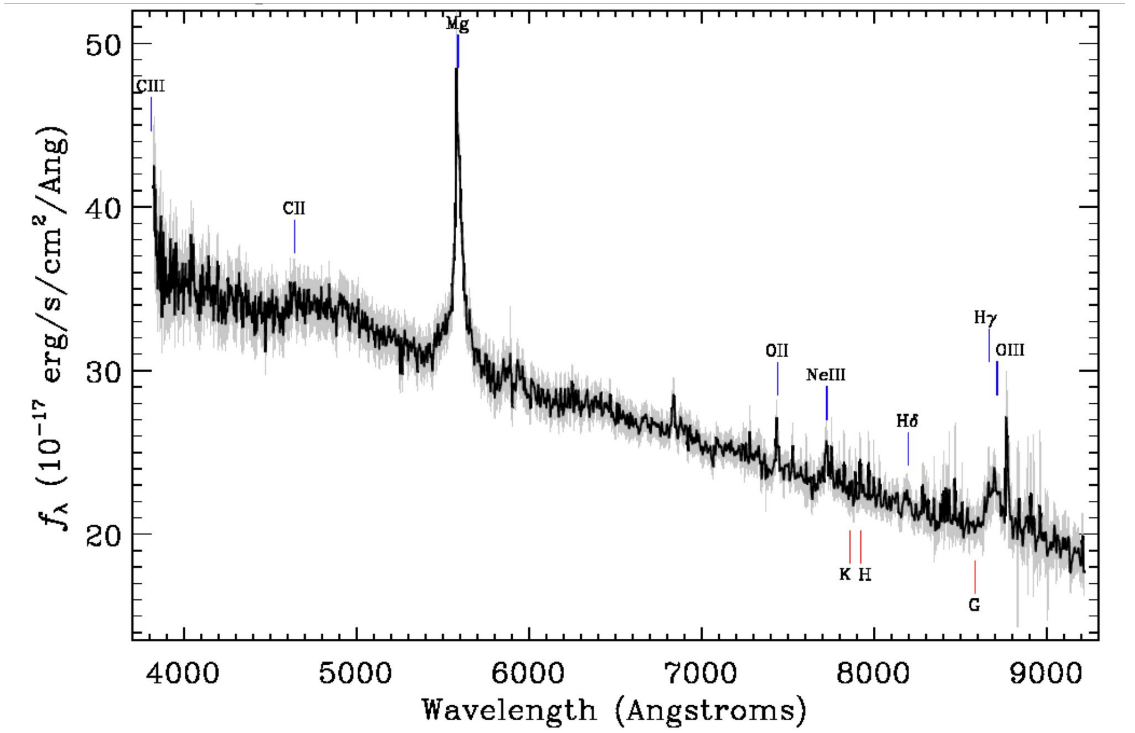


The Flat Spectrum Radio Quasar **OP313**

Most distant quasar detected in VHE (**z=0.9973**) and 10th in the list. Second most distant VHE source after GRB 201216C.

Not detected in VHE before. Attempted by MAGIC (2014, 2019).

Strong attenuation by EBL in the VHE regime. Possible intrinsic γ-γ absorption.



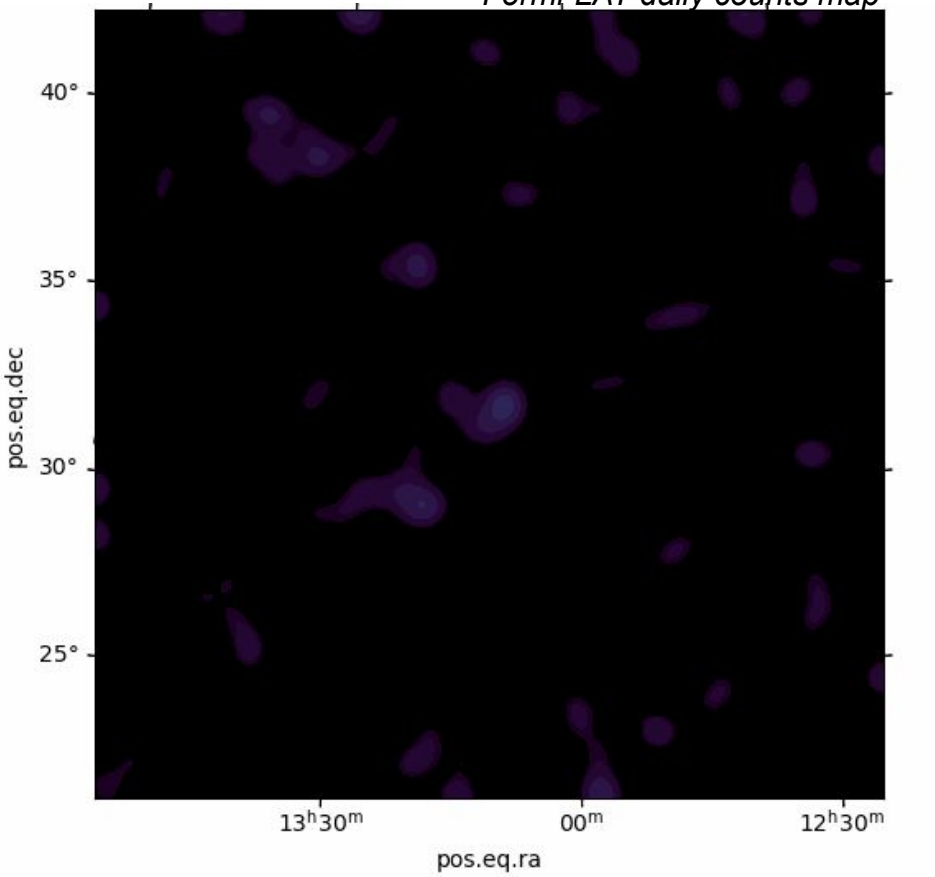
The Flat Spectrum Radio Quasar **OP313**

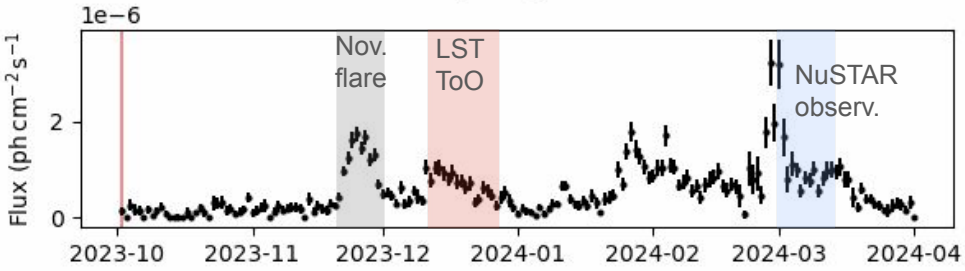
Very active in *Fermi*-LAT since November 2023 (during our ‘Moon break’).

LST-1 observations since December 9th, 2023.

Among the top **most luminous AGN** ever seen by LAT

Fermi-LAT daily counts map





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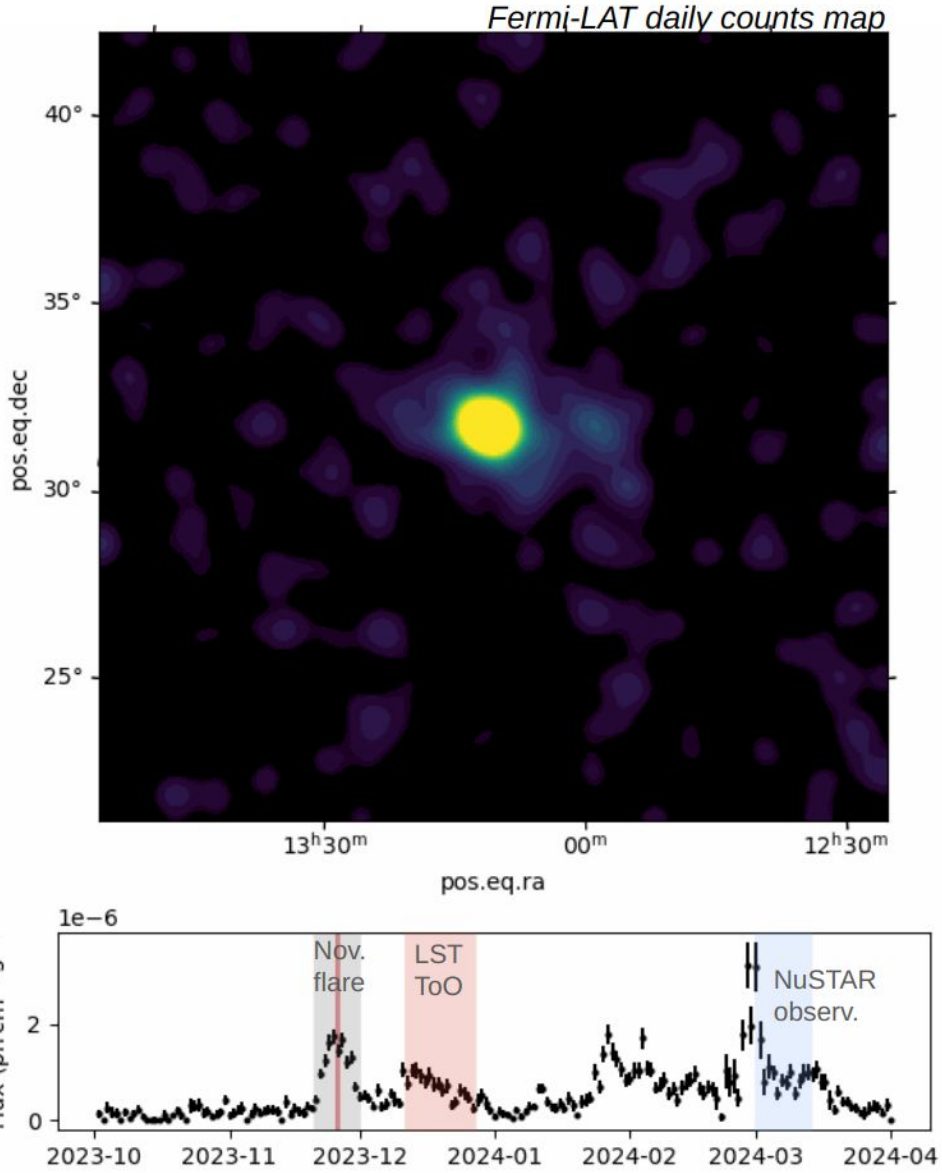
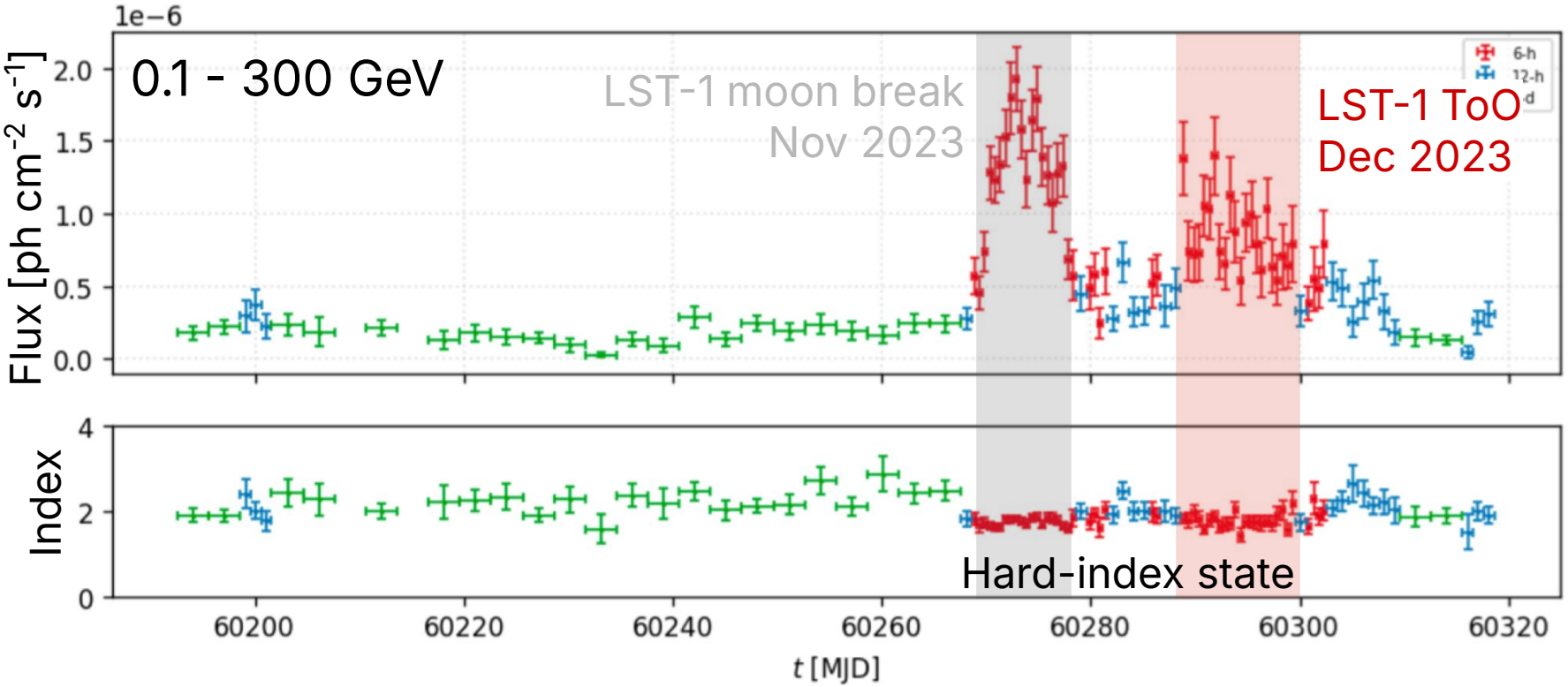


The Flat Spectrum Radio Quasar **OP313**

Early observations (this work): daily observations from Dec 9 to 18, 2023 (15 h) [high state] + few days in Jan 2024 (5 h) [low state].

Telescope pointing zenith angle > 30 deg (energy threshold ≈40 GeV)



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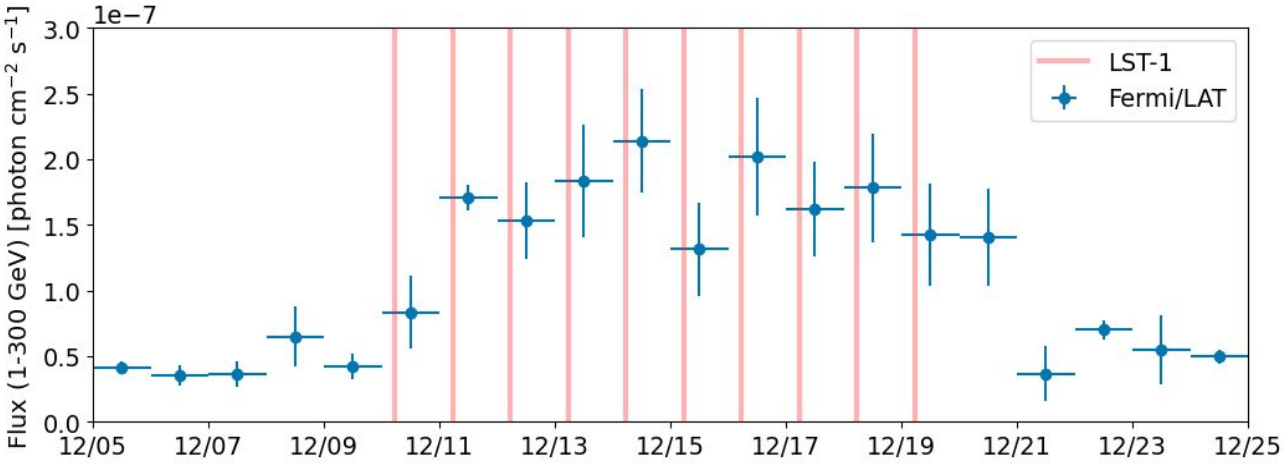
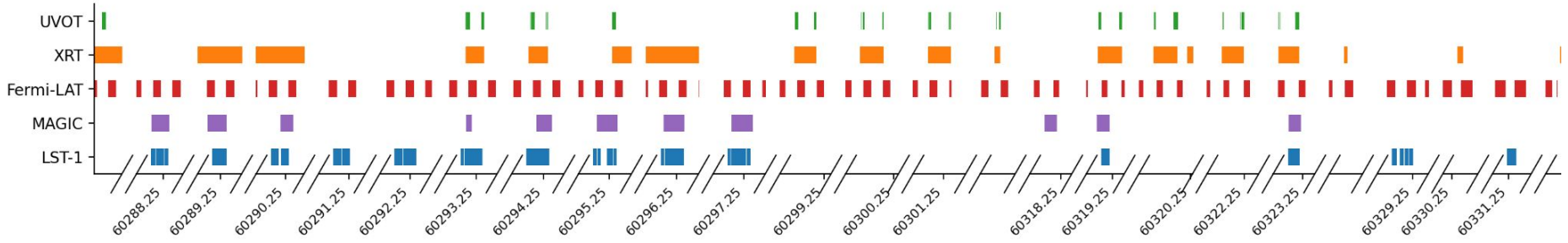


Fermi/LAT Monitored Source List Light Curves

(https://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/)

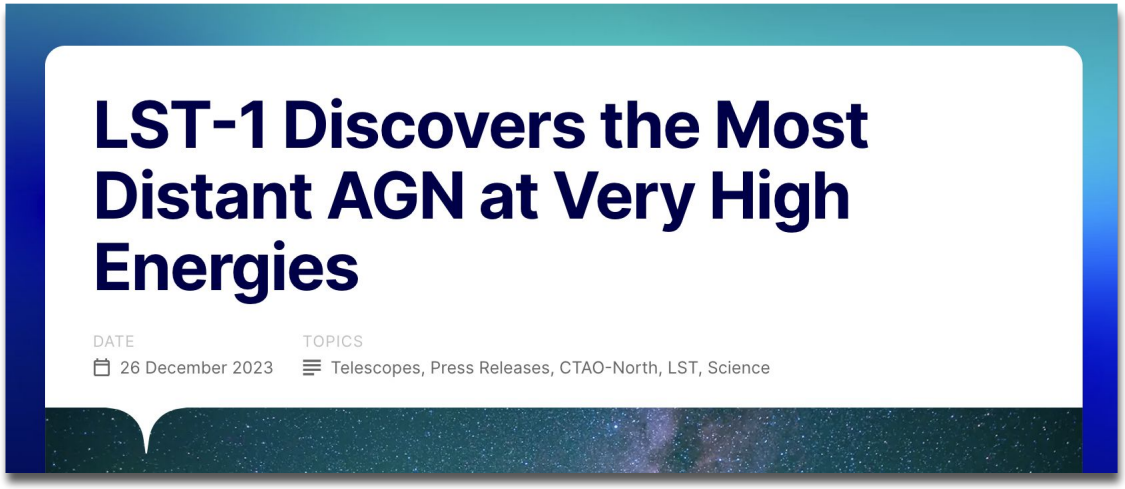


Detection of **OP313**, ATel and press releases

Detected with >5σ (Li&Ma) with data up to Dec 14th, 2023 (~6 h)

ATel issued by LST-1 (#16381): 10th FSRQ detected in VHE gamma rays

Announced on CTAO, ATel, Newspaper, radio and TV



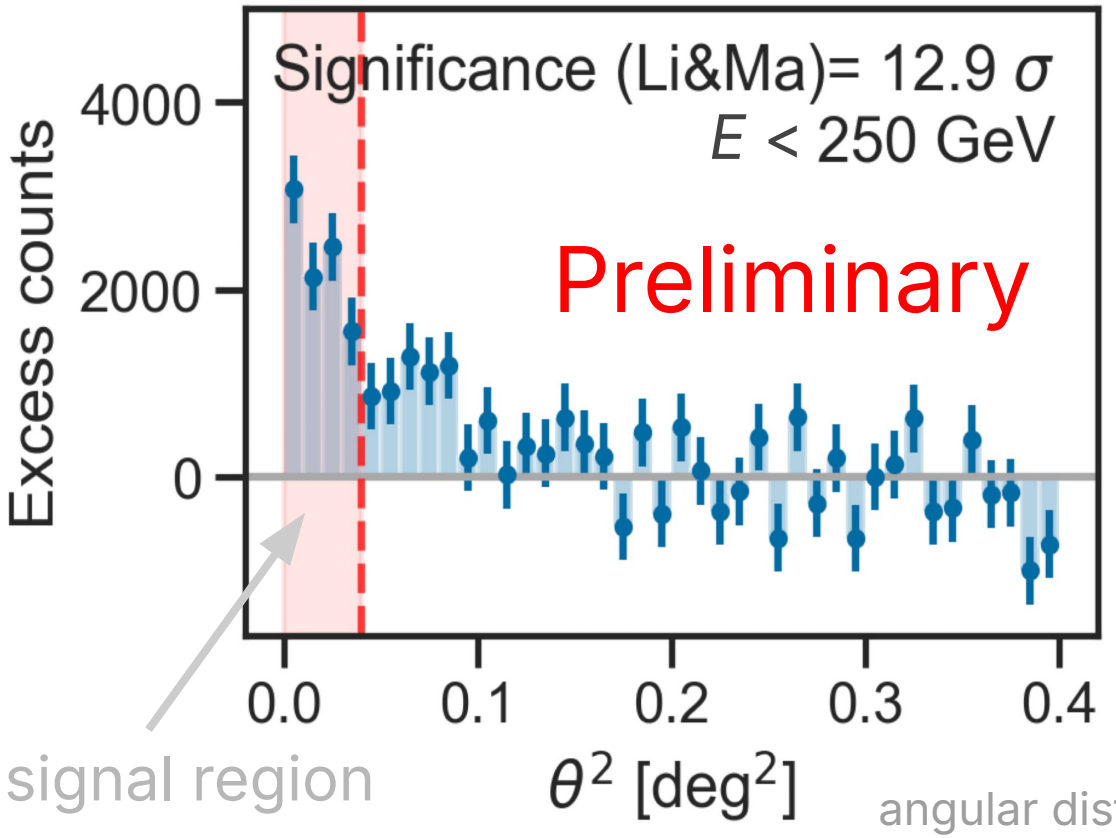
The Astronomer's Telegram

First detection of VHE gamma-ray emission from FSRQ OP 313 with LST-1

ATel #16381; *Juan Cortina (CIEMAT) for the CTAO LST collaboration*
*on **15 Dec 2023; 14:31 UT***
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, AGN, Blazar, Quasar

Detection of **OP313**: γ-ray excess



December dataset (15h):

Signif. (Li&Ma) ~13σ

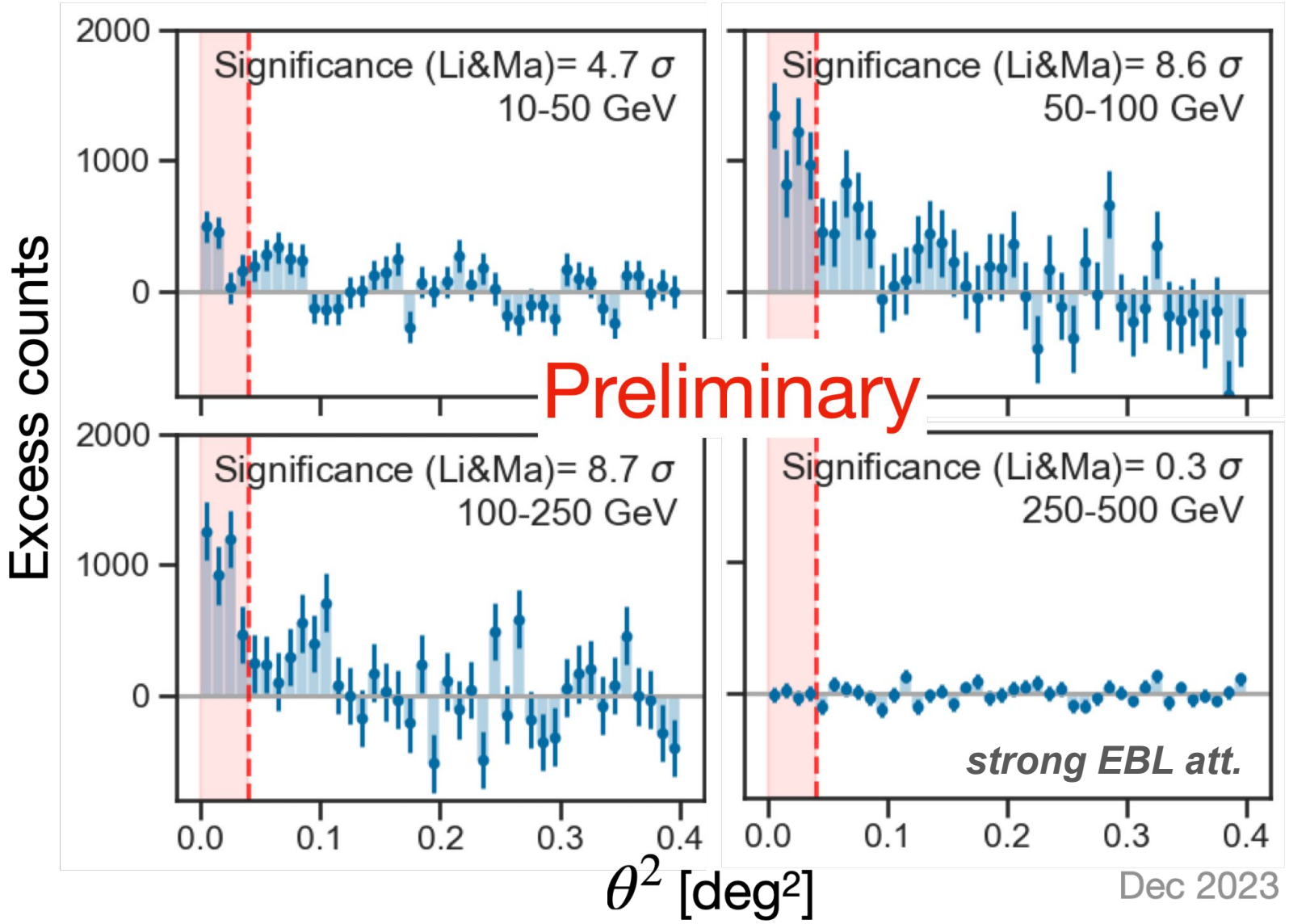
January dataset (5h):

No significant detection

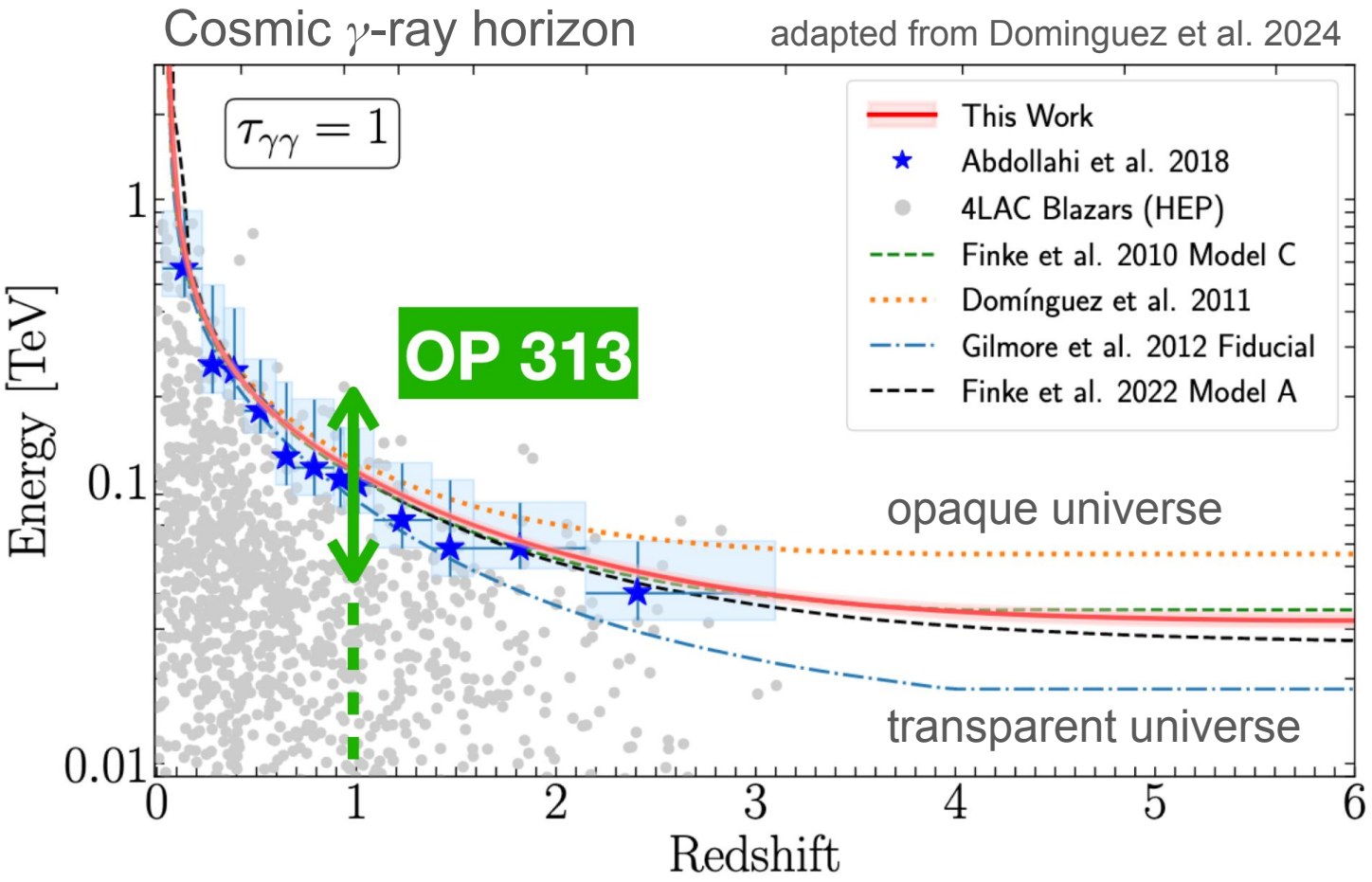
angular distance (squared) between γ-ray like events and source location

Average VHE flux (>100 GeV): 28% Crab (December 2023)

Detection of **OP313**: in energy bands

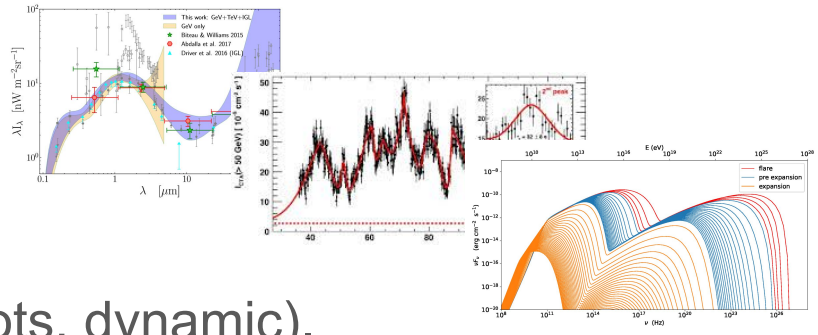


Prospects: EBL constraints

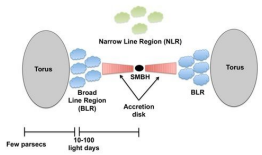


Prospects: Ongoing work and publication plans

Likely among the most intense observation campaigns on a distant FSRQ to date. Large project, with a large team, and many ramifications, including:



- VHE emission & EBL constraints.
- Variability: long-term, short-term.
- Broadband SED modeling (snapshots, dynamic).
- Broad-line-region studies (optical & gamma-ray effects).



- Very deep exposure nights: optical, X-rays & gamma-rays, polarimetry
- Technical papers (new analysis methods, data formats).

$\gamma\pi$ A **Python** package for **gamma-ray** astronomy

Summary

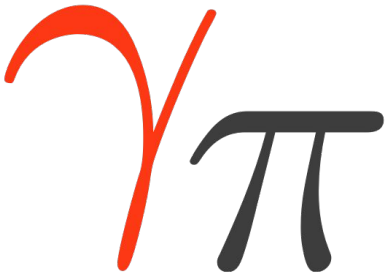
- Major flare from OP313 detected with *Fermi*-LAT in November 2023 (Moon break) and once again December 2023 (LST-1 begins observations)
- First detection of VHE emission from quasar OP 313 (z=0.997) by LST-1 + more detections in the next months (very structured flare)
  - Prompt reaction of LST Collaboration (observations and analysis)
  - First VHE source discovered by LST-1 (important milestone)

    … and the most distant VHE AGN.

    … and among the most luminous ones.
- Very fruitful observation campaign. Many projects started.
- First publication from LST-1 coming soon, stay tuned.

Bonus

A new multi-wavelength analysis and data management workflow based on …



A **Python** package for **gamma-ray** astronomy

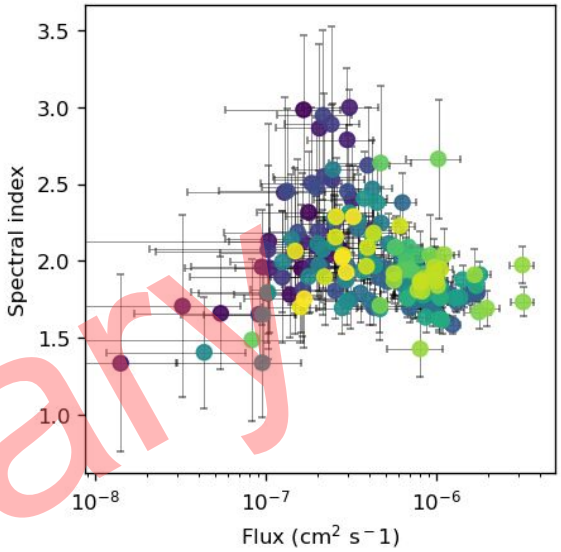
A method to store (*binned) event data* from optical to gamma-rays (>11 orders of magnitude)

A method to analyse (full forward folding with events + IRFs): no more flux points !

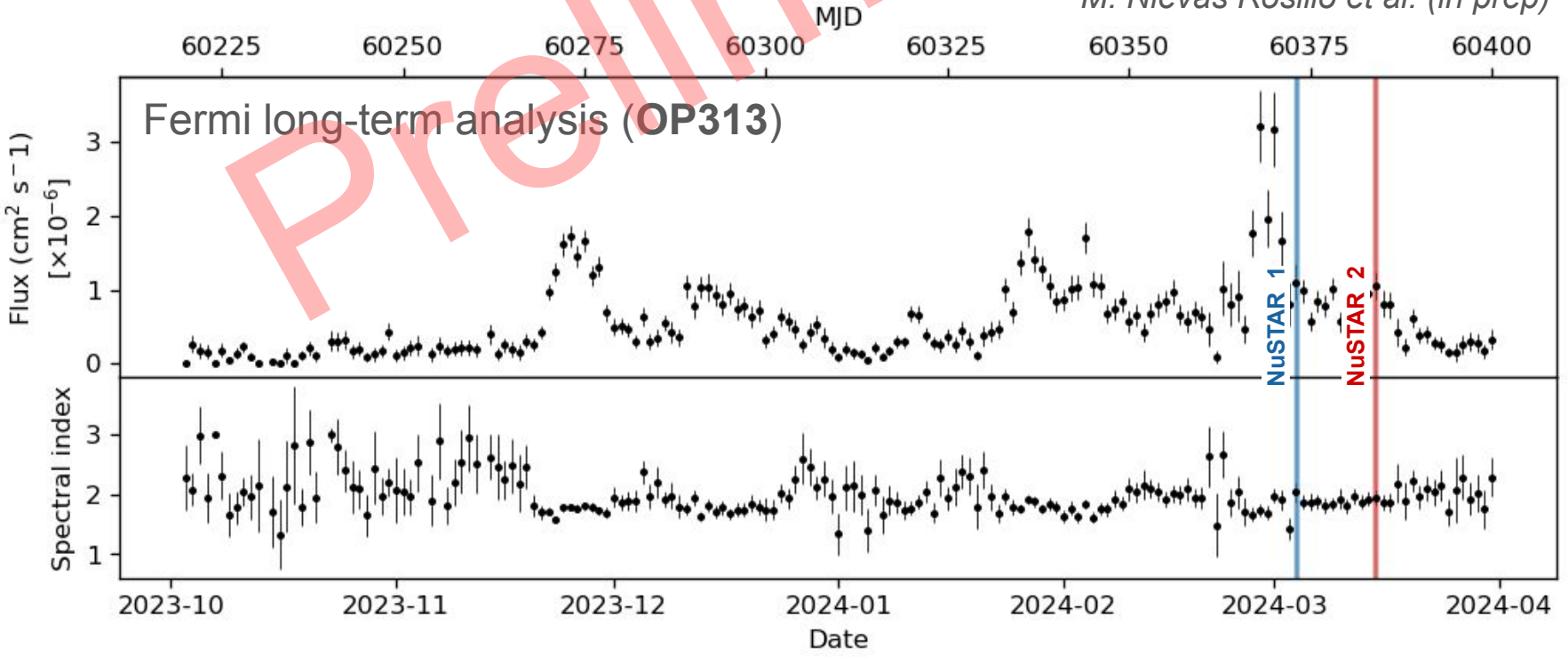
MWL *gammapy* workflow

1st Goal: publish ***binned event data*** from optical to gamma-rays (11 orders of magnitude)

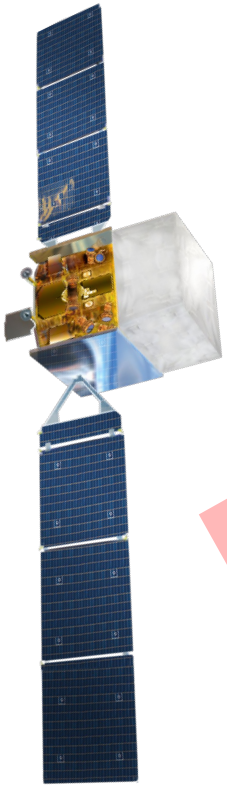
2nd Goal: forward folding fit of models (no more flux point fitting)

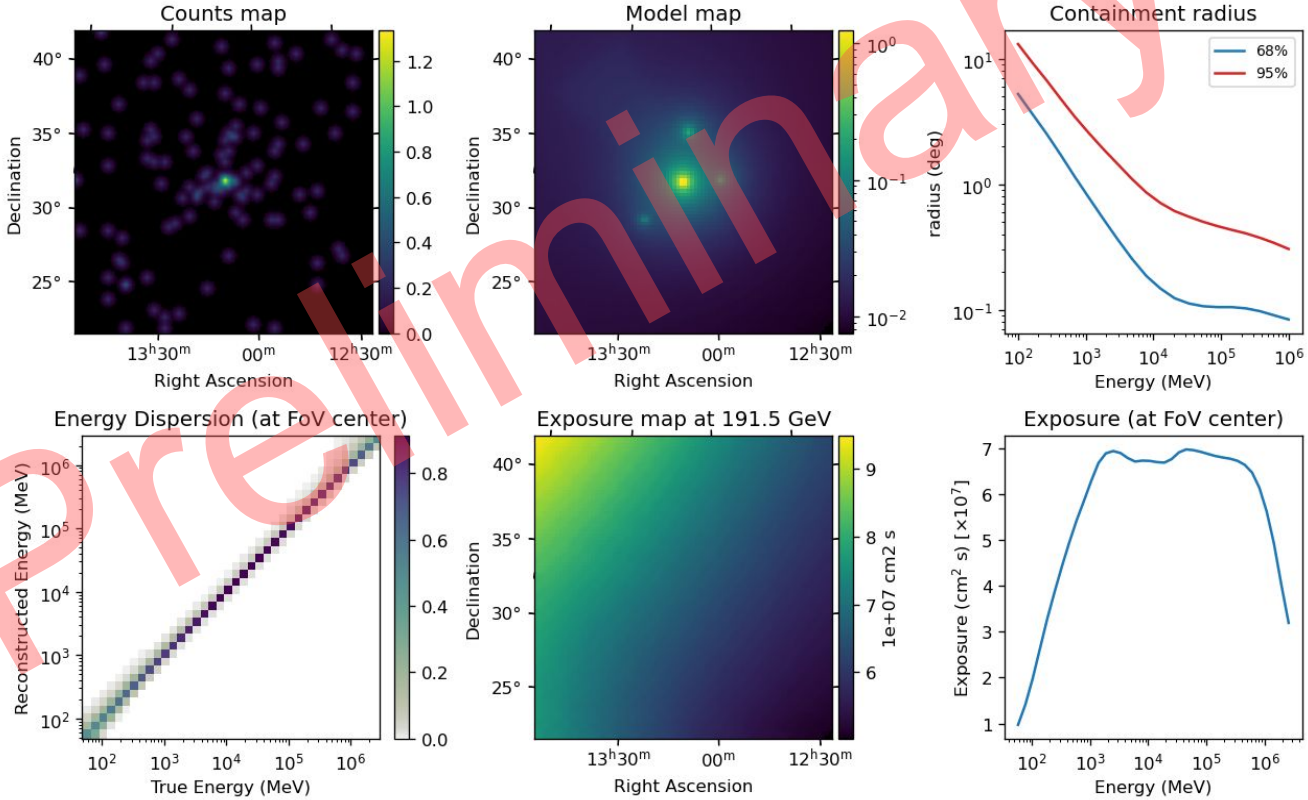


M. Nievas Rosillo et al. (in prep)



MWL *gammapy* workflow

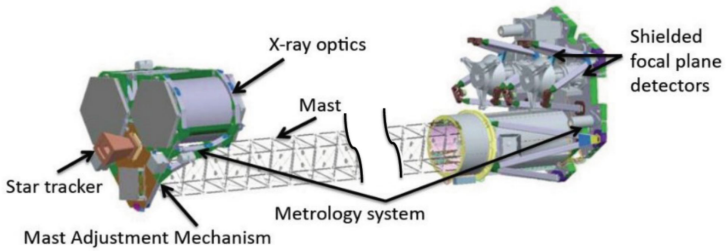


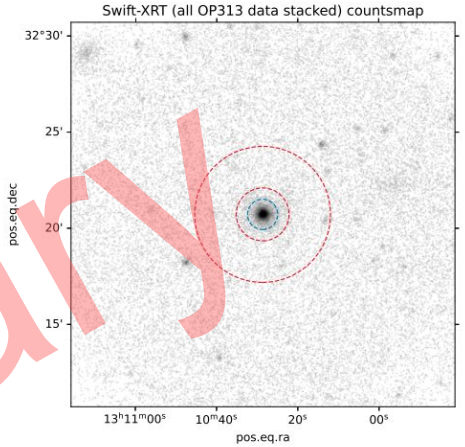


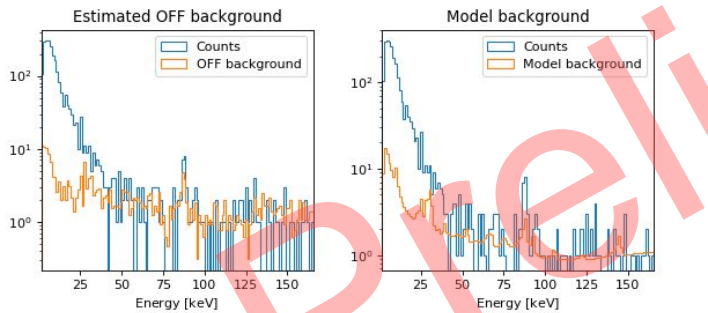
Fermi-LAT

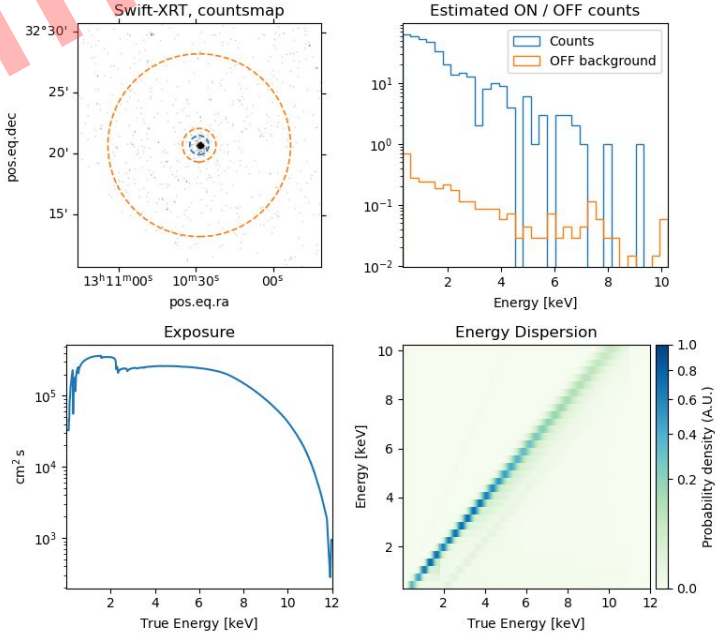
(space-based, HE gamma rays, 3D)

MWL *gammapy* workflow









NuSTAR

(space-based, hard X-rays, 1D)

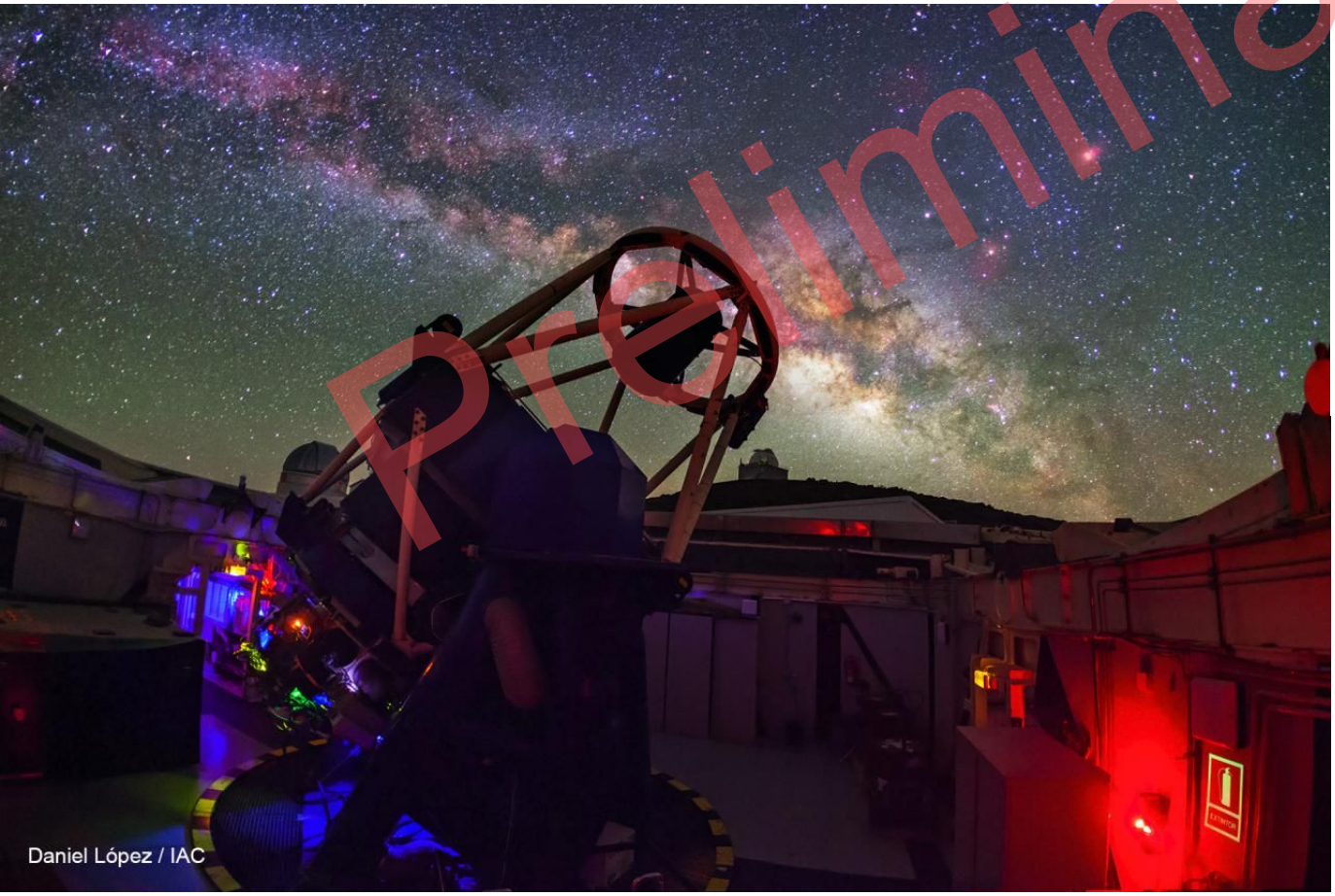
Swift (XRT & UVOT)

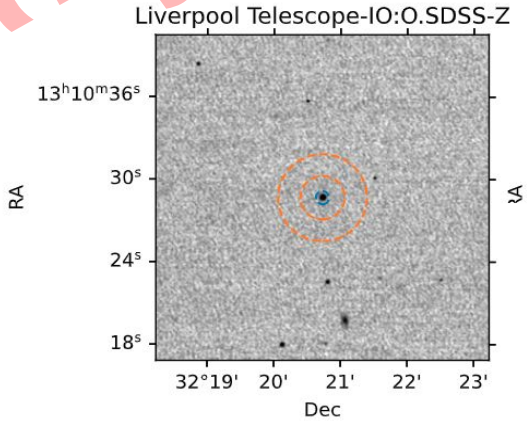
(space-based, X-ray and optical-UV, 1D)

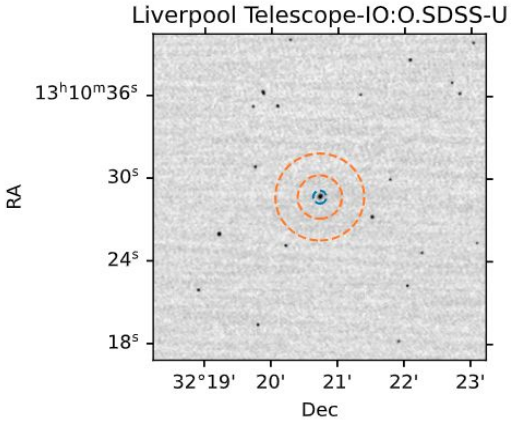
MWL *gammapy* workflow

Liverpool Telescope

(ground based, optical-IR photometry, 1D)







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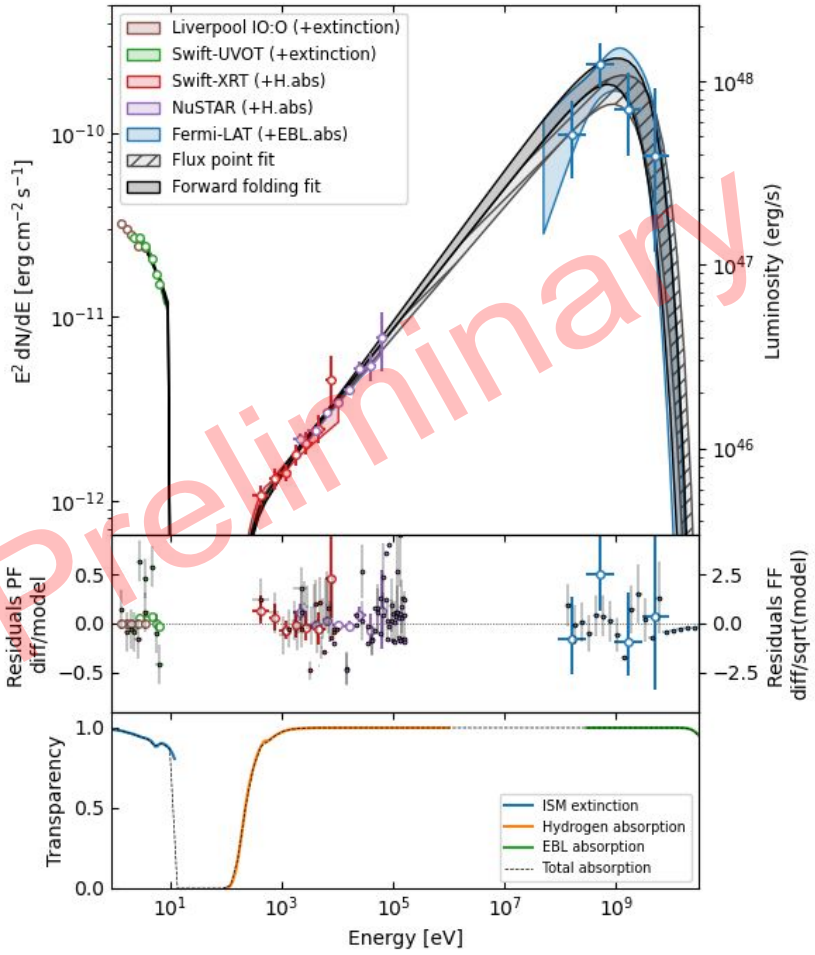

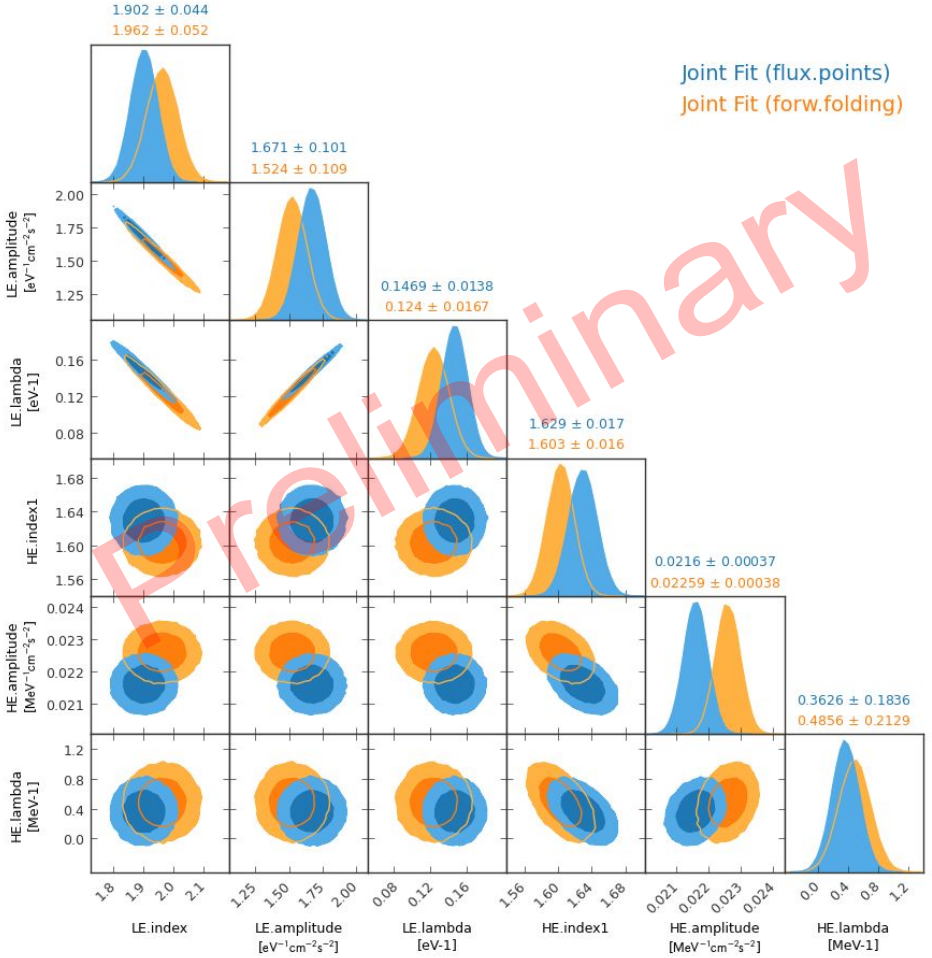

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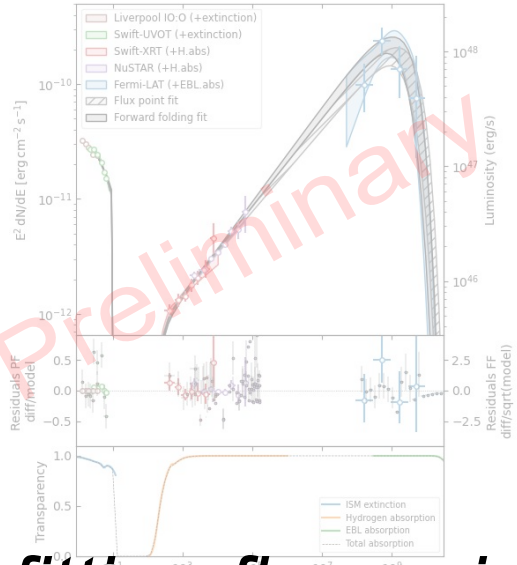
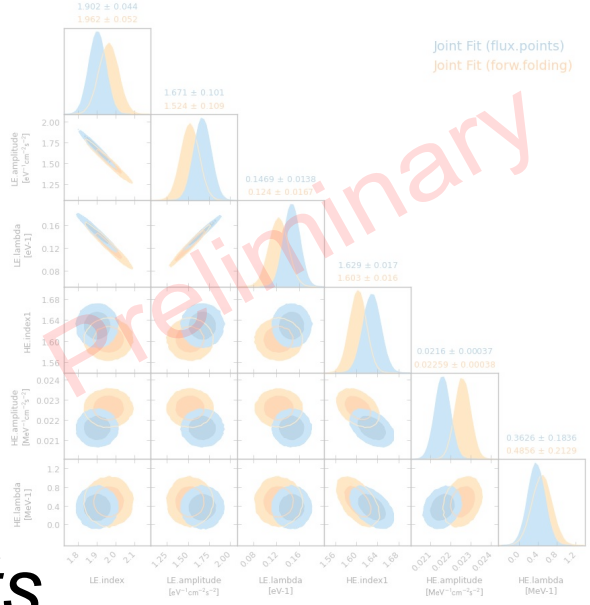
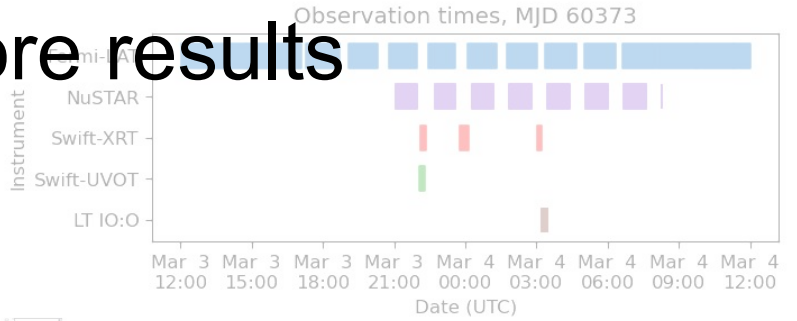




stop fitting flux points

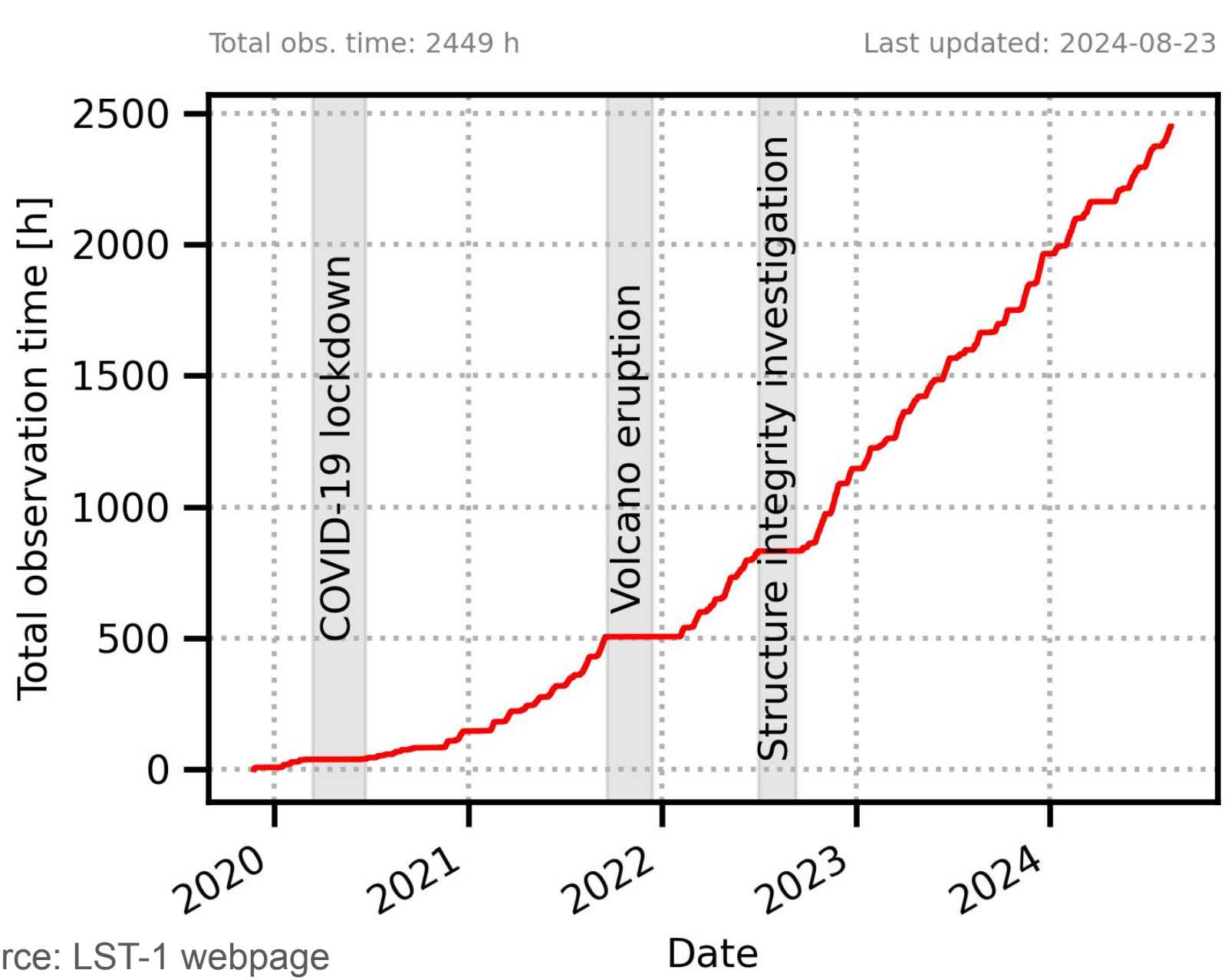
&

keep tuned for more results



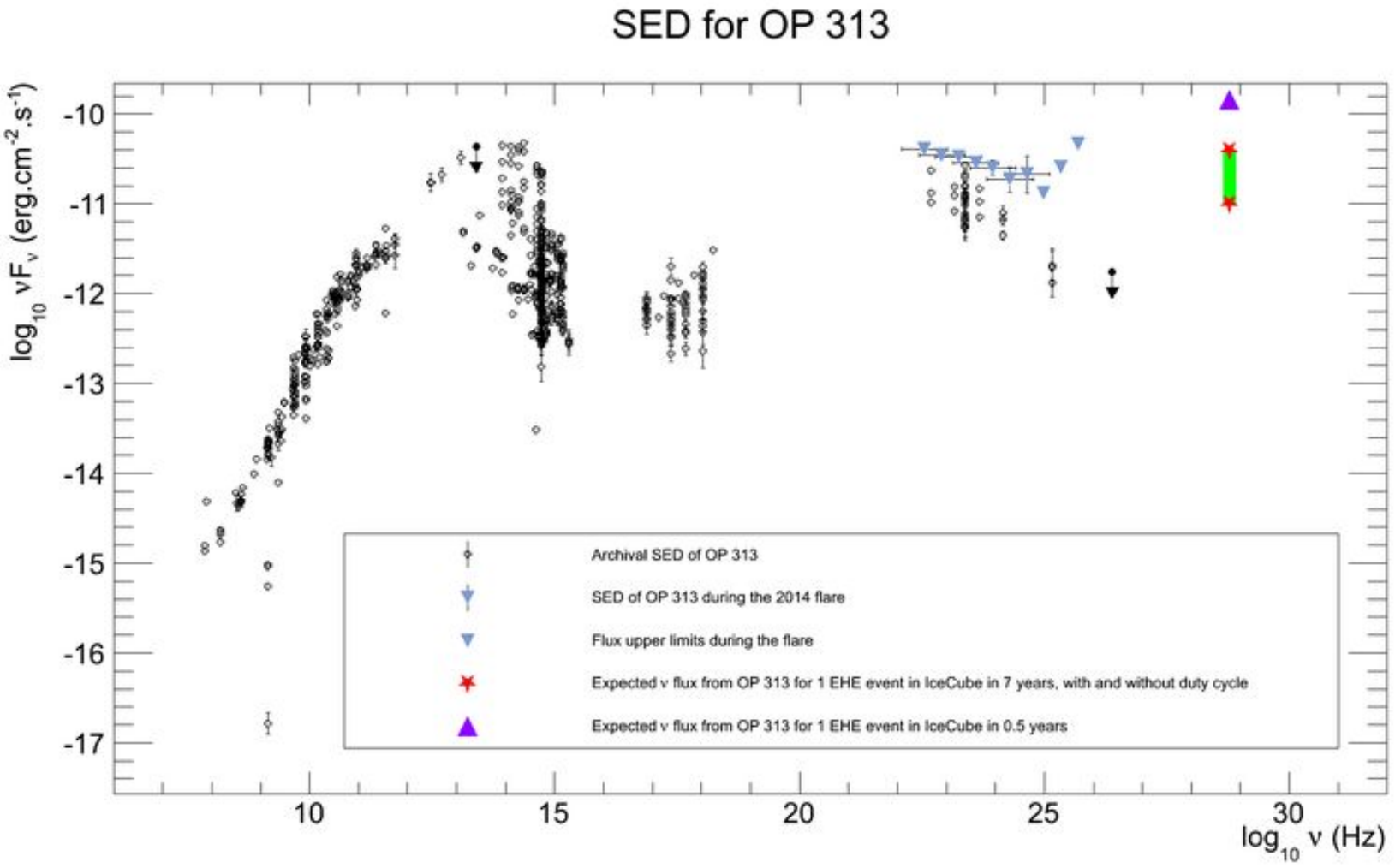
M. Nievas Rosillo et al. (in prep)

Backup



source: LST-1 webpage

2014 flare



Marinelli+ 21 MNRAS 506, 3, pp.3760-3772

2014 & 2019 flares

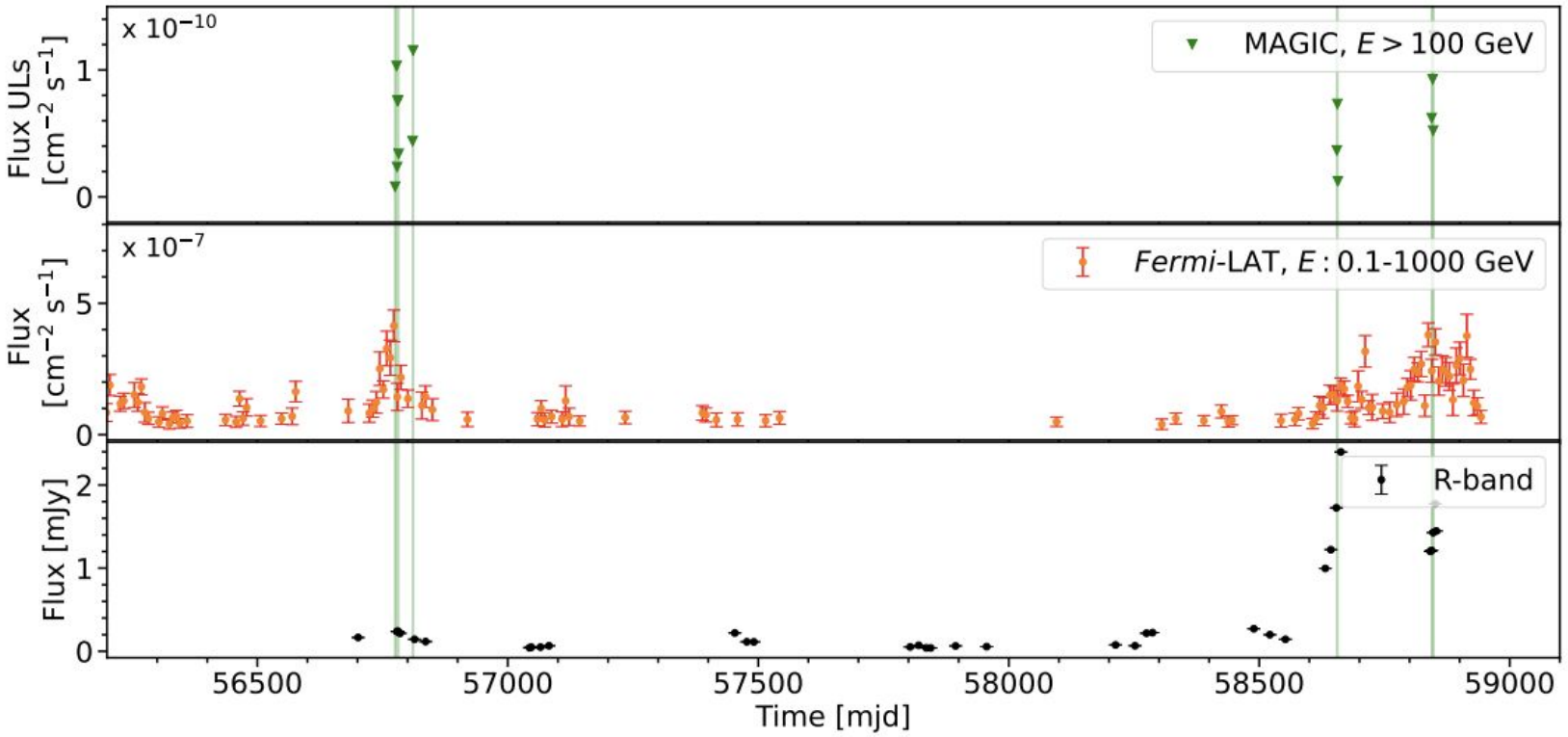


Figure A3. MWL light curve of OP 313. The labels are the same as Fig. A2.

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