



LST
COLLABORATION



CTA大口径望遠鏡初号機と MAGIC望遠鏡による研究成果

Seiya Nozaki (ICRR)

令和6年度東京大学宇宙線研共同利用研究成果発表会
Jan 29, 2025

共同利用研究課題(データ解析関連)

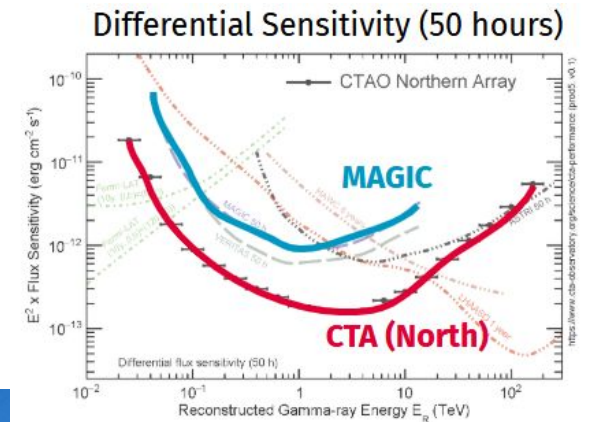
Funding supported data taking necessary for data analysis, software validation

In addition, it supported the software school for students
旅費

武石 隆治	CTA大口径望遠鏡のデータ解析手法の確立と初期観測	継続	500,000
大石 理子	CTA モンテカルロシミュレーション	継続	200,000
櫛田 淳子	大口径大気チェレンコフ望遠鏡を用いたニュートリノ放射源天体の探索	継続	600,000
窪 秀利	MAGIC望遠鏡を用いた高エネルギーガンマ線天体の研究	継続	500,000
Strzys Marcel	Development of a background reconstruction toolbox for the LST1 prototype and the upcoming CTA	継続	200,000

MAGIC & LST-1

- MAGIC (stereo, $\Phi 17$ m) and LST-1 (mono, $\Phi 23$ m)
- 3 more LSTs will be ready soon!

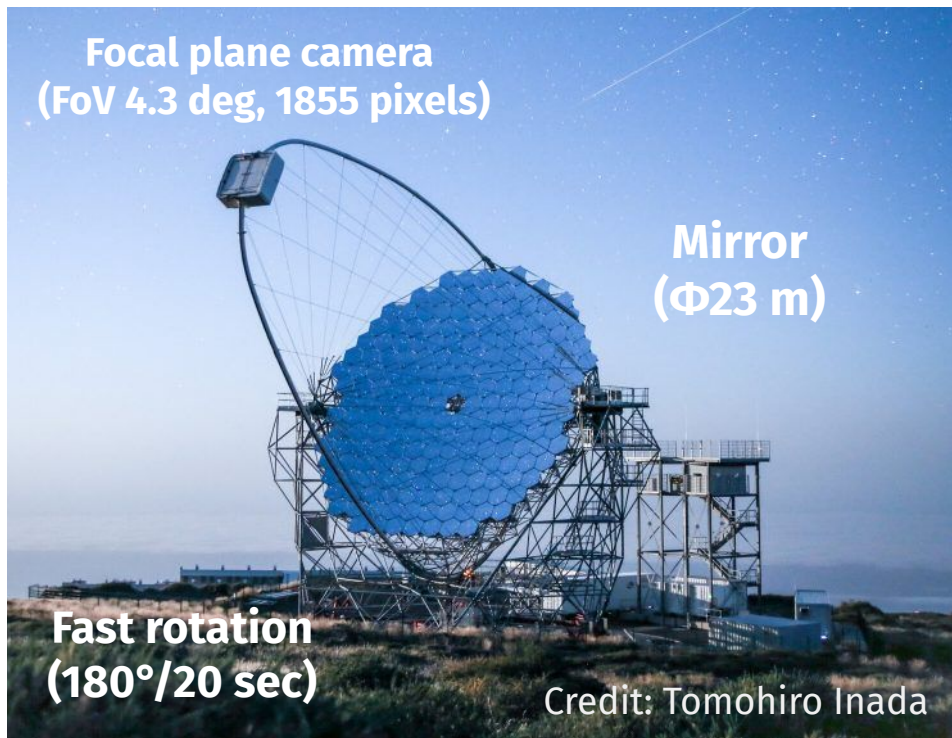


Roque de los Muchachos Observatory, La Palma (Spain)



Strong point of LST-1

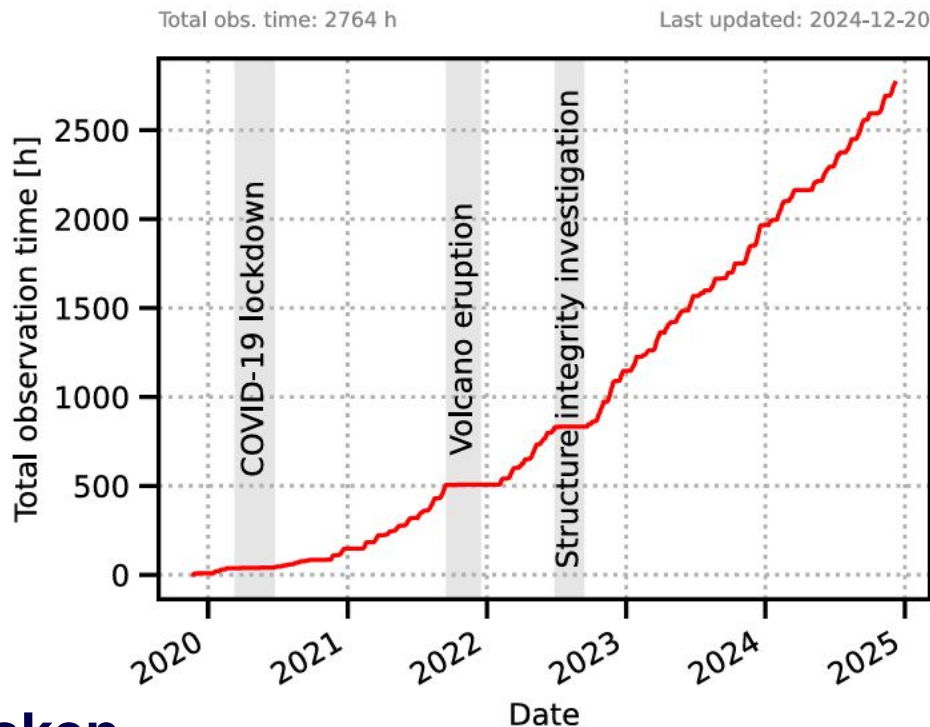
- **Energy threshold: 20–30 GeV**
 - Good for extragalactic observations because VHE gamma-ray photons (>100 GeV) are absorbed by extragalactic background (EBL) photons
- **Fast rotation (180°/20 sec)**
 - Good for GRB observations
- **Large FoV (4.3 deg)**
 - Good for extended sources



LST-1 observations

- 2018.10 Inauguration
- 2018.12 First light
- 2019.11 First Crab observation
- 2020-
Scientific observations
in parallel to commissioning tests

>2500 hours data were already taken



CTA-Japan Analysis activity

E11: M. Ohishi
→ S. Nozaki

- CTA-Japan analysis meeting@ICRR (2024 June 4-5)
 - Software/analysis school
 - Proposal discussion
 - Member contributions

Nice opportunity for beginners to learn analysis software and discuss ongoing/future projects

CTA-Japan AS&ODA extended (F2F+online) meeting

4-5 June 2024
ICRR Kashiwa
Asia/Tokyo timezone

25 (in person) + 4 (remote)

- Overview
- Timetable
- Contribution List
- My Conference
 - My Contributions
- Registration
- Participant List
- Accommodation 宿泊施設
予約

This meeting is an annual event mainly for young beginners and aiming for close communication between members. For this purpose, we recommend the in-person participation, we pay travel money for you.

We also provide Zoom connection:

<https://u-tokyo-ac-jp.zoom.us/j/88338865797?pwd=unzOsbenMkaozeDtJThluvaqRoBRDo.1>

Starts 4 Jun 2024, 09:00

ICRR Kashiwa

CTA-Japan member contributions (FY2024)

- 7 presentations at international conferences

[COSPAR2024] S. Nozaki (OP313)

[TeVPa2024] R. Takeishi (AGN Zoo), K. Terauchi (GBR 221009A)

[GAMMA2024] J. Baxter (OP313), P. K. H. Yeung (Geminga)

[RICAP] S. Abe (Galactic Center)

[HEAC2024] R. Abhradeep (1ES1218+304)

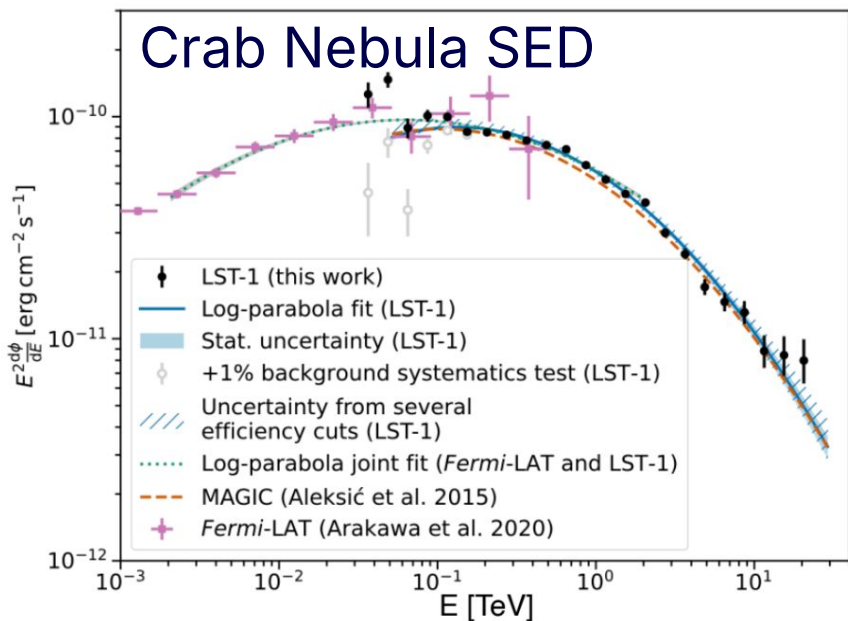
- 5 JPS talk + 2 ASJ talk (2024 Autumn)
- 5 JPS talk + 3 ASJ talk (2025 Spring)

Many young researchers are contributing to data analysis

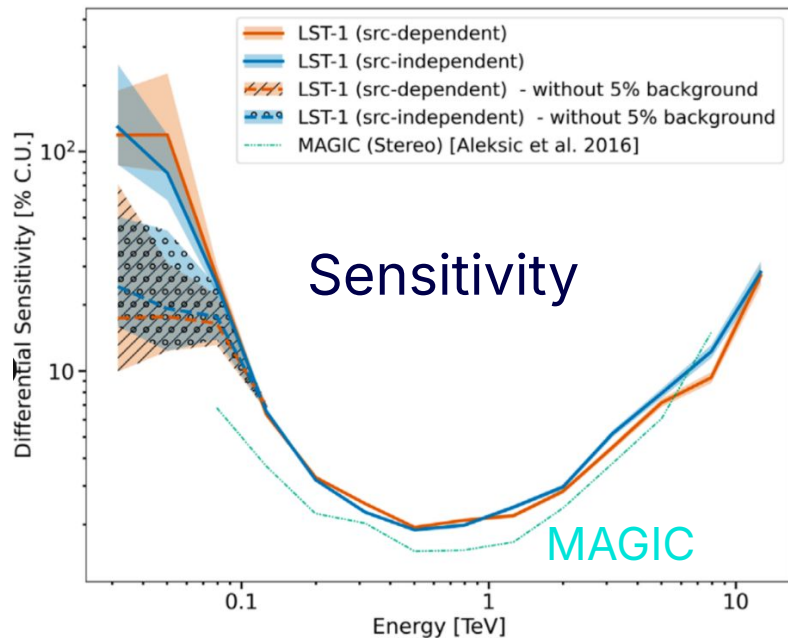
LST-1 analysis performance

[ApJ, 956, 80 \(2023\)](#)

Performance study with our standard candle Crab Nebula & MC(Zd<35)



Consistent with the results obtained by other experiments



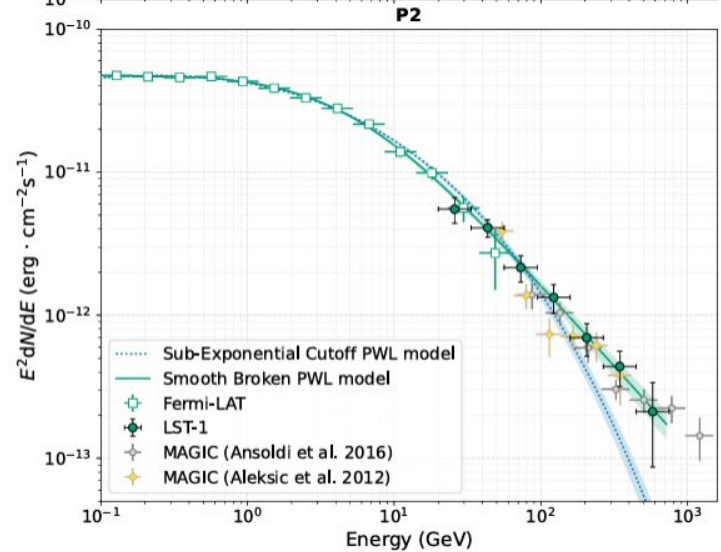
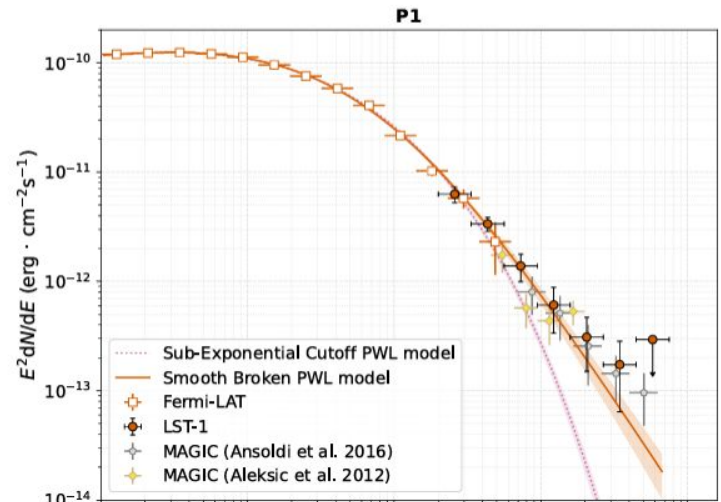
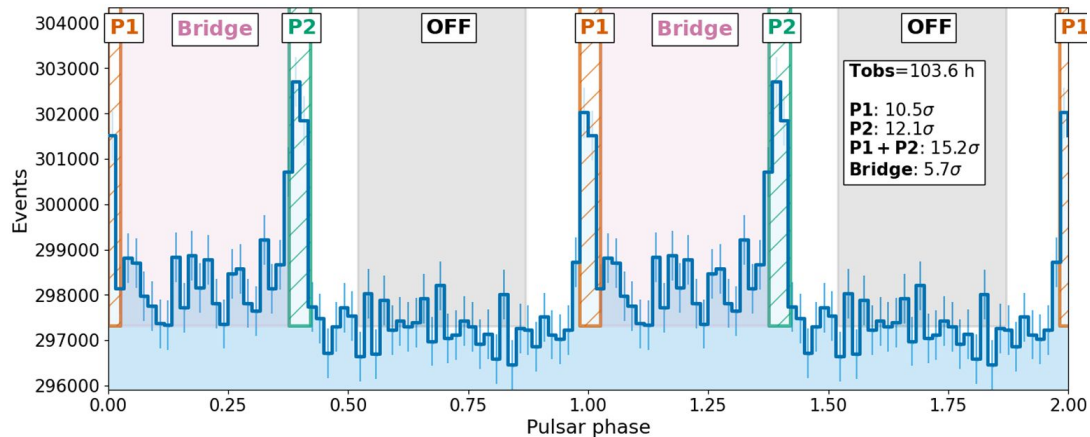
a bit worse than MAGIC stereo as expected, but almost comparable at higher energy

Crab pulsar

- Clear detection of pulsar emissions
- Power-law extension at VHE

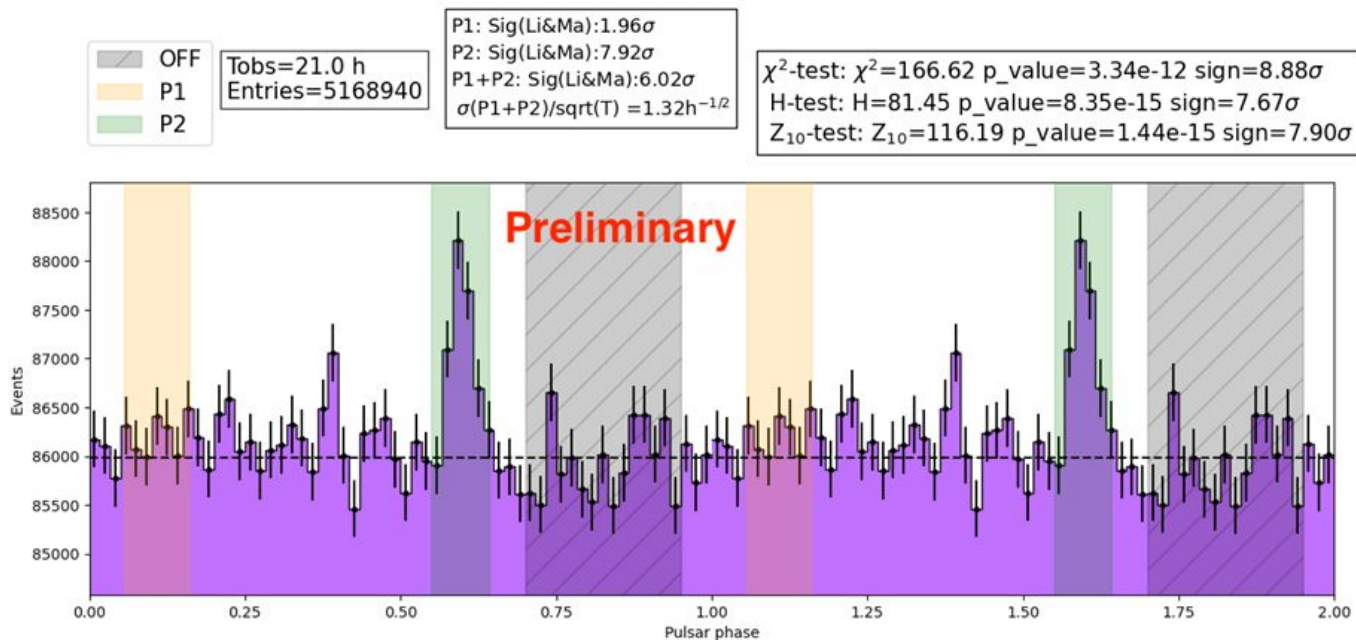
Paper published ([A&A, 690, 167](#))

"A detailed study of the very high-energy Crab pulsar emission with the LST-1" (2024 Oct)



Geminga pulsar

- Clear detection of P2 emission: $\sim 8\sigma$ in 21 hours
 - MAGIC: 6.3σ (P2) in ~ 80 hours



Excellent performance at a few tens of GeV!

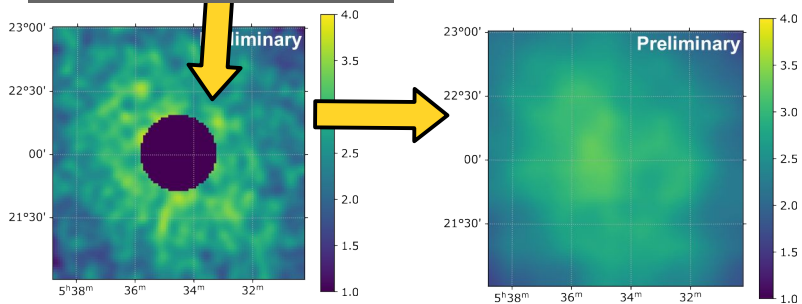
Pybkgmodel

- background modeling for CTAO

- Essential for the analysis of extended sources or sources with uncertain localisation (eg. GRBs, Neutrino follow ups)
- Tool finished development stage
- Already widely used within CTAO LST Collaboration (see Gal. Center results!)
- Currently final polishing for public release

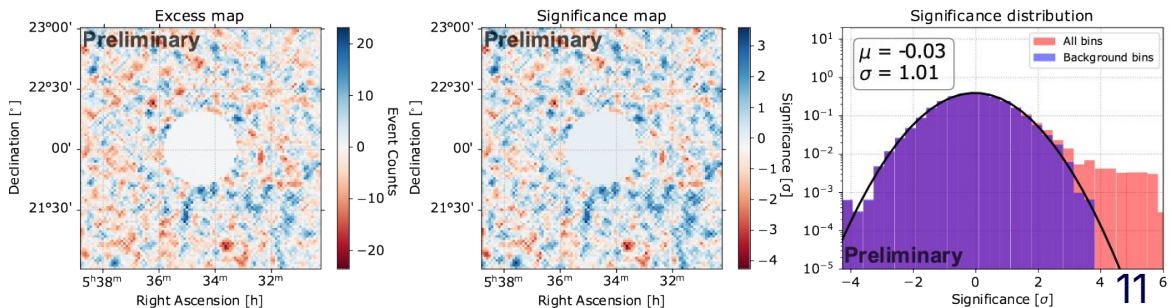
Aim: describe diffuse, irreducible background across FoV

Our tool can reconstruct this background



We can accurately model the background emission and run 3D (energy+spatial) analysis in gammapy

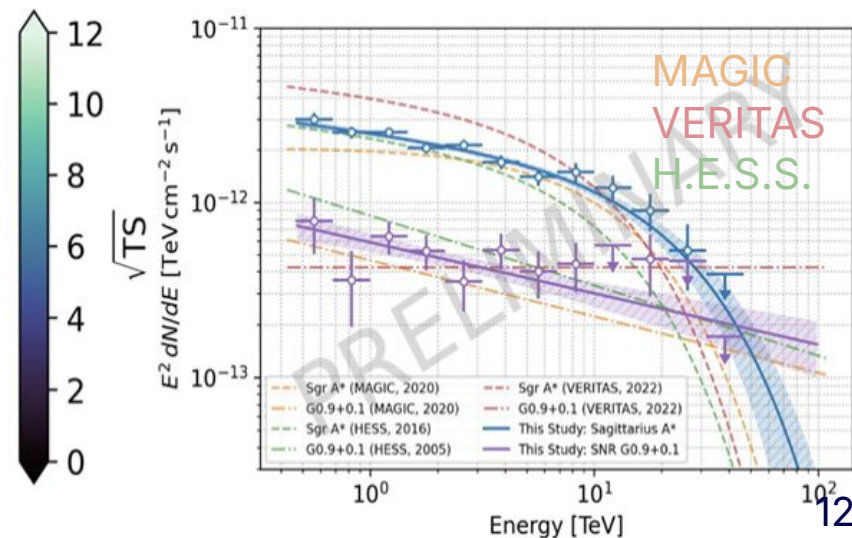
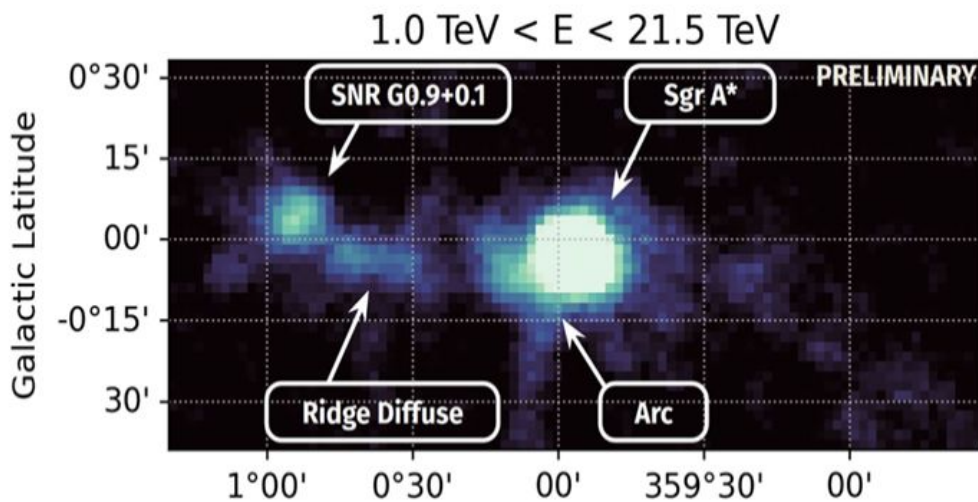
- Publication under consideration; presented at ICRC2023 incl. Proceeding and JPS meetings



Galactic center

S. Abe (ICRR)

- 39 hours observation (very large zenith angle) in 2021/2022
- Detection of Sgr A* & SNR G0.9+0.1 and verification of extended source analysis with *pybackground* software
- SED result is in line with one obtained by other experiments



AGN observations

E9: R. Takeishi

- Blazar monitoring observations at the beginning of commissioning phase
- Known TeV blazars
 - Mrk 421, Mrk 501, 1ES 1959+650, 1ES 0647+250, PG 1553+113

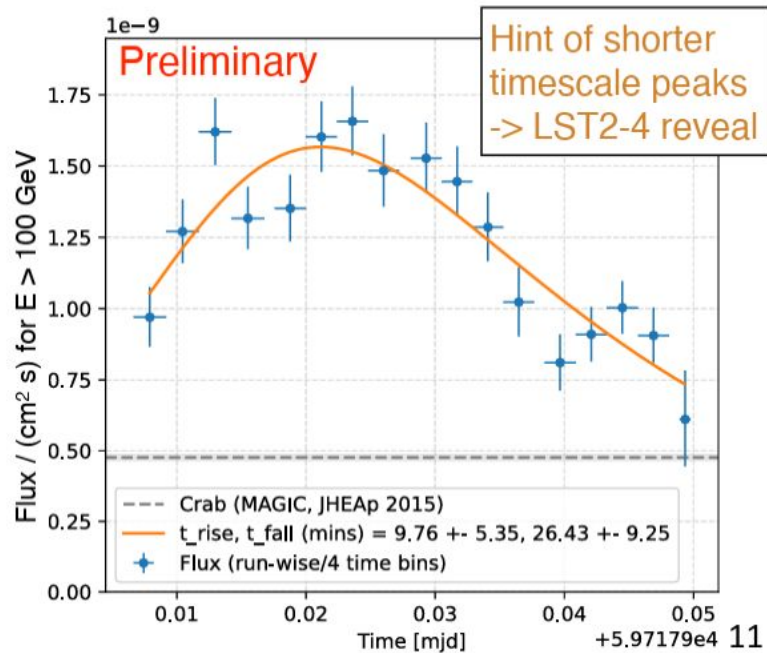
Source	Observation date	Redshift	Observation time before/after cut (h)	Detection significance (σ)
Mrk 421	2020 Dec. 12 - 2022 May 23	0.031	68.5 / 31.9	53
Mrk 501	2020 July 10 - 2022 May 22	0.034	67.2 / 39.7	21
1ES 1959+650	2020 July 11 - 2022 May 5	0.048	21.3 / 11.8	13
1ES 0647+250	2020 Dec. 16 - 2020 Dec. 21	0.45±0.05	8.8 / 8.2	7
PG 1553+113	2021 Apr. 8 - 2022 May 23	0.433	12.2 / 9.9	16

~178 hours observations (2020 July - 2022 May)

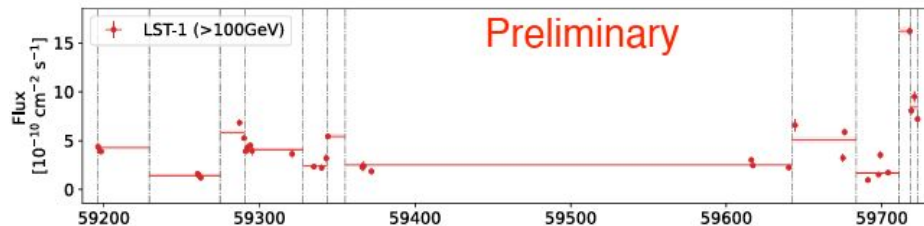
AGN observations (Mrk 421)

R. Takeishi (ICRR)

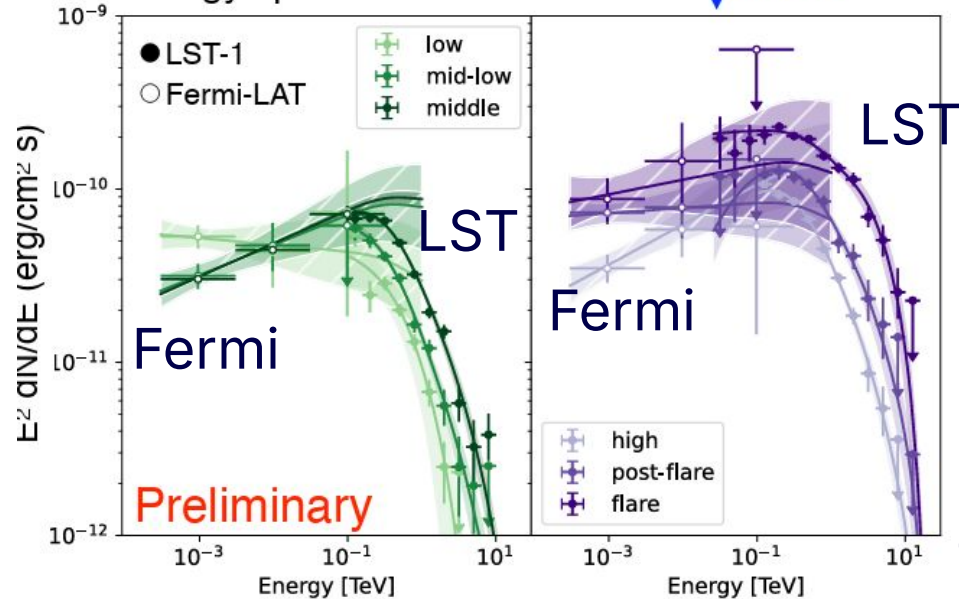
- Consistent with Fermi flux
- Intra-night variability



Night-wise light curve



Energy spectra in each state



AGN ToO program

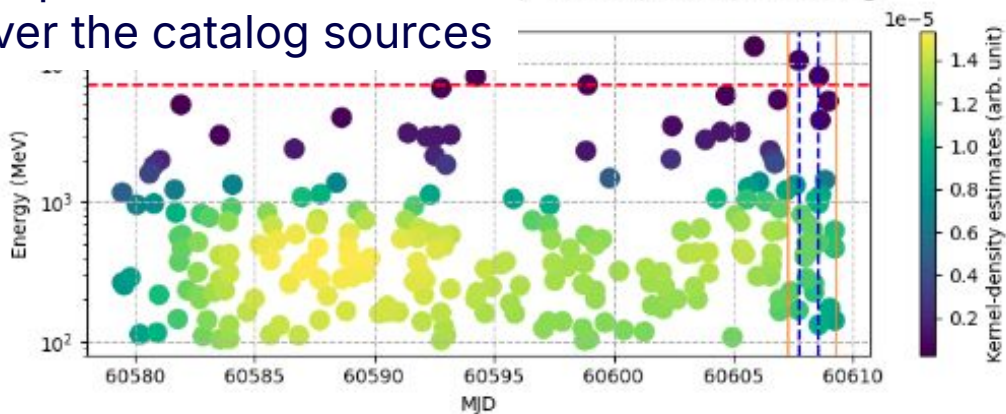
Several pipeline to detect AGN flares

- Fermi aperture photometry light curve
- Fermi high-energy photon search
- ZTF optical monitoring

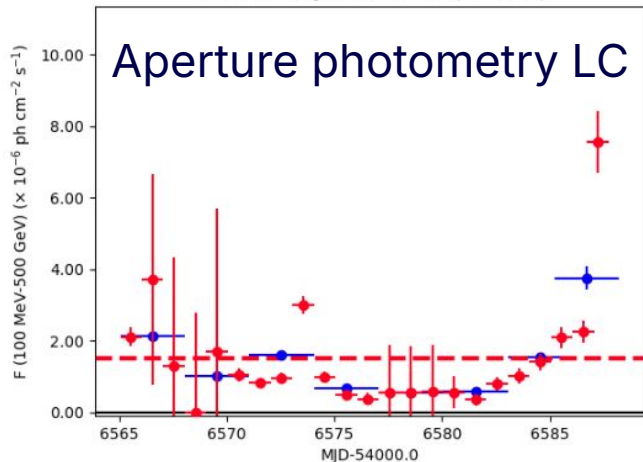
4FGL_J0521.2+1637 (3C 138) [CSS, LSP], $z=0.76$

HE photon search
over the catalog sources

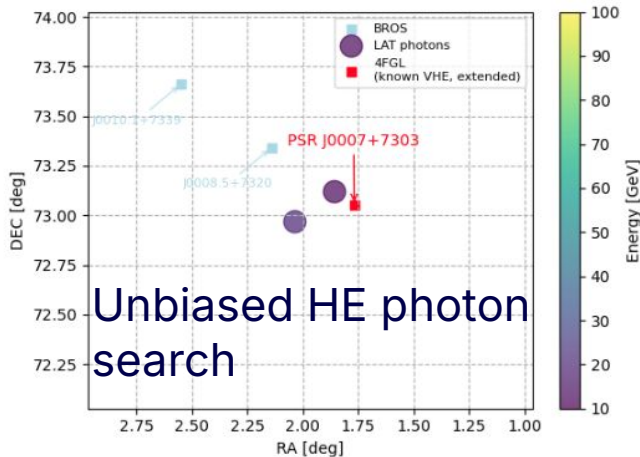
/10/26 06:48:56, [E>7 GeV]
10.4 GeV, BACK, at 0.13 deg
8.0 GeV, FRONT, at 0.18 deg



BLLAC, 4FGL J2202.7+4216 ($z=0.069$)

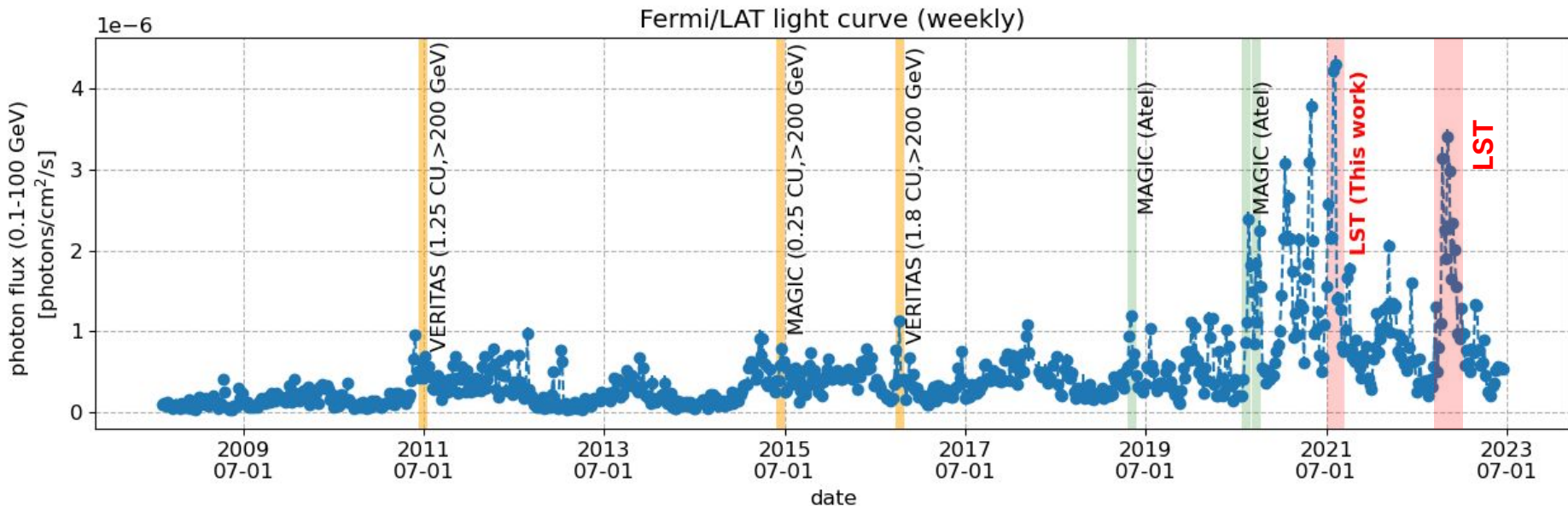


from 2024/10/03 06:57:30 to 2024/10/05 06:57:30, [E>10 GeV]
MJD=60586.43 (2024/10/03 10:24:44), 12.4 GeV, FRONT
MJD=60586.58 (2024/10/03 13:51:39), 19.7 GeV, BACK



BL Lac flare (2021 & 2022)

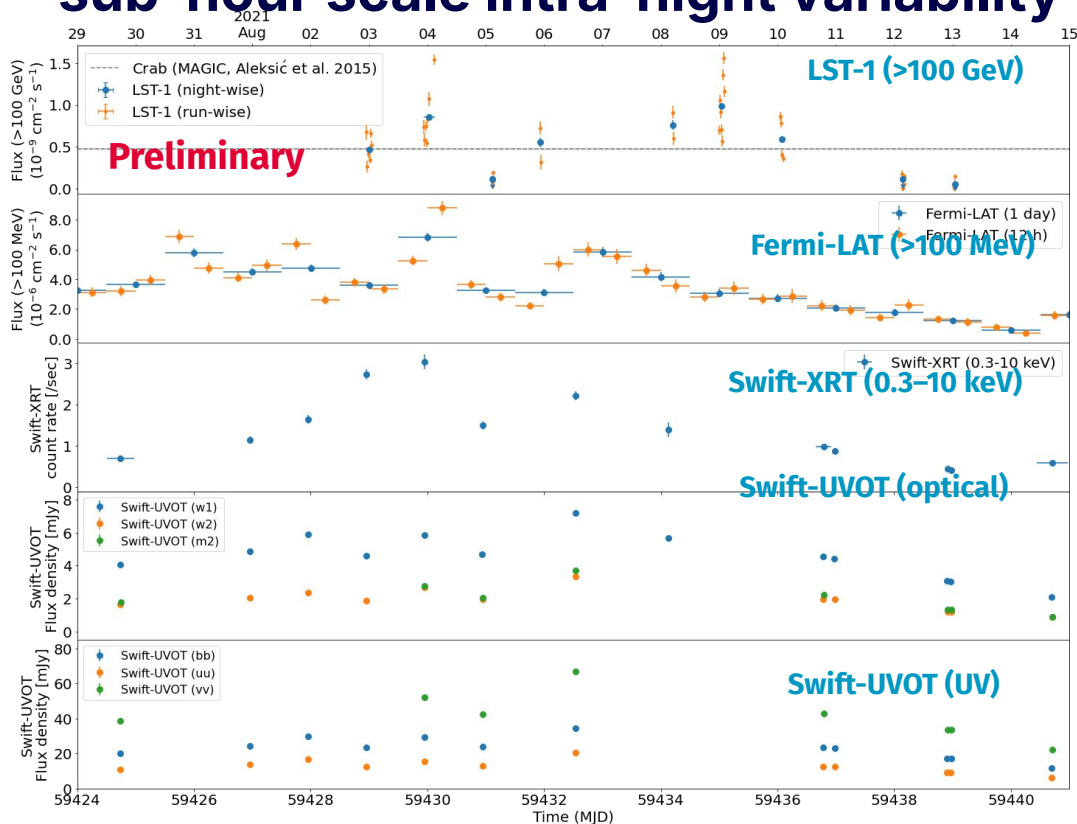
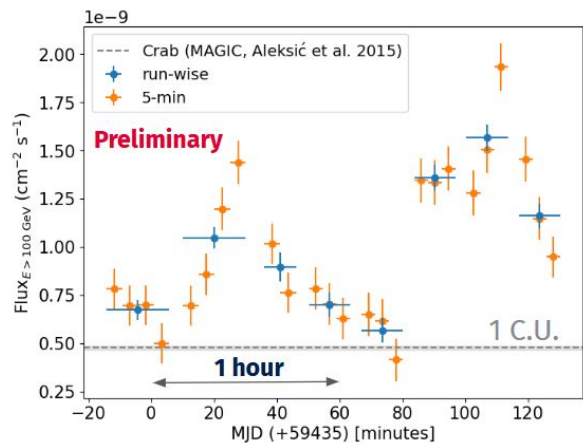
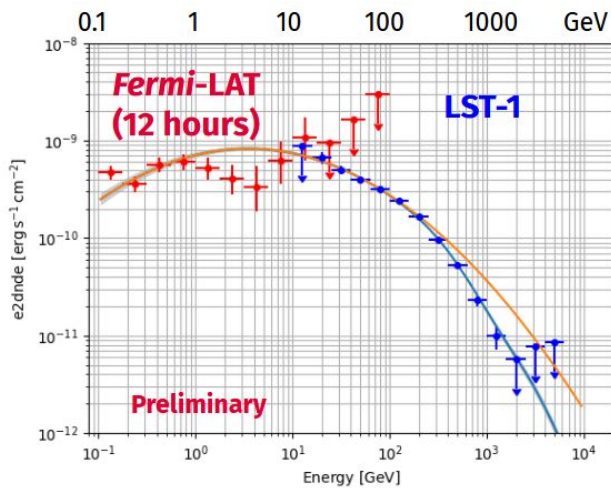
- Multiple gamma-ray flares especially after 2020
- VHE emission from BL Lacertae was only detected during the flare
 - LST-1 observed BL Lac flares in 2021 and 2022



BL Lac 2021 flare (2021.07-08)

S. Nozaki (ICRR)

SED down to 20–30 GeV sub-hour scale intra-night variability



OP 313 flare

- **First discovery by LST-1!**
- Furthest blazar ($z=0.997$) & 10th FSRQ detected by IACT
- Data set is also used for EBL study

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

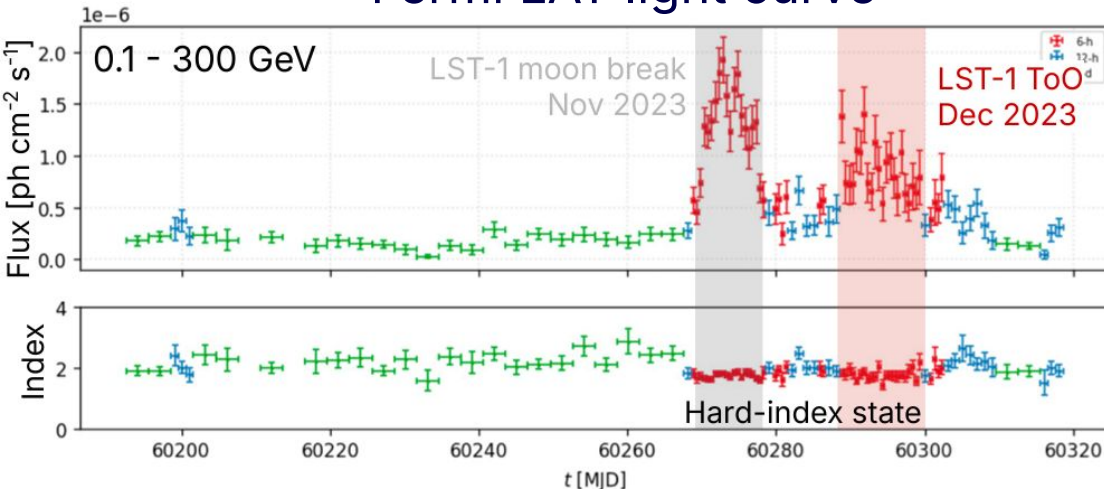
Credential Certification: *Juan Cortina (Juan.Cortina@ciemat.es)*

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

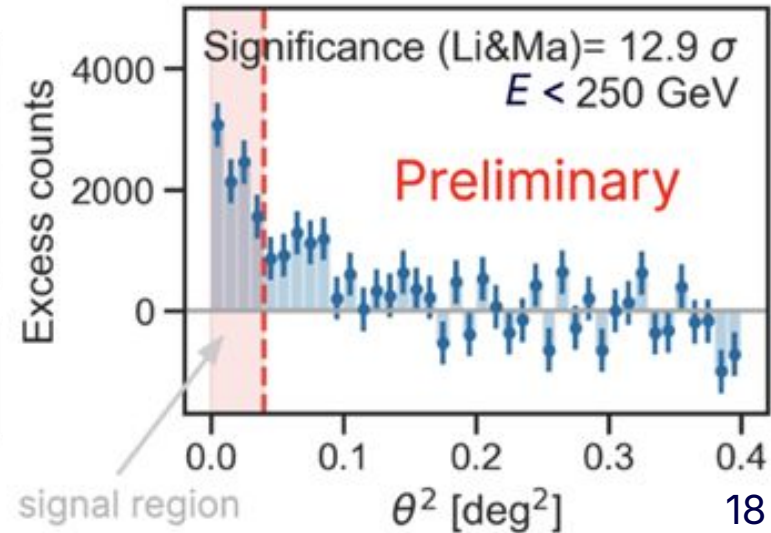
✕ Post

The Large-Sized Telescope (LST-1) on La Palma has been monitoring the very distant Flat Spectrum Radio Quasar (FSRQ) OP 313 ($z=0.997$, Schneider et al. 2010, AJ, 139, 2360) since November 2023. Following the announcement of enhanced gamma-ray emission by

Fermi LAT light curve



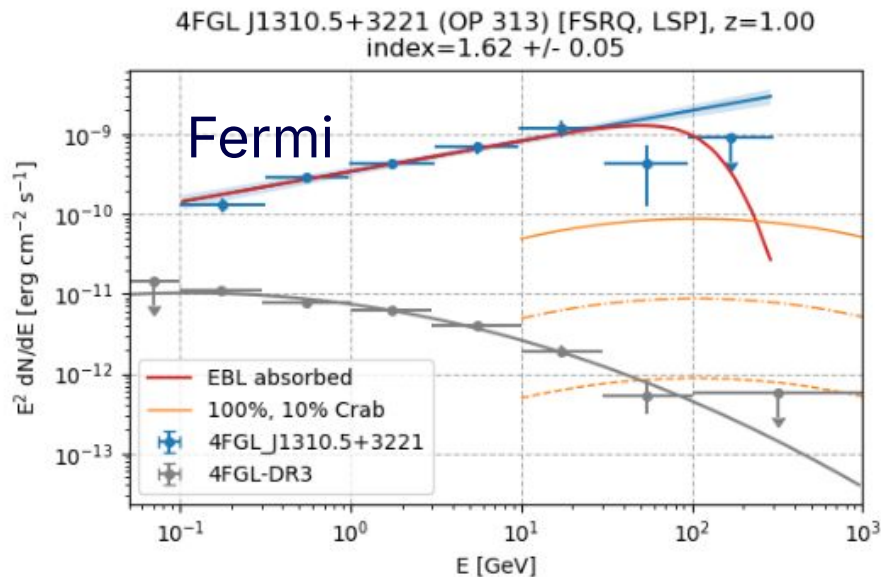
2023 Dec



OP313 is flaring now!

- Very bright flare of OP313
 - a magnitude brighter than one of Crab at 10 GeV
- LST-1 is also observing this source, stay tuned!

Atel issued by MAGIC



Strong very-high-energy gamma-ray flaring activity from FSRQ OP313 detected with the MAGIC telescopes

ATel #17000; *David Paneque (Max Planck Institute for Physics), Chitranshi Bakshi (Saha Institute of Nuclear Physics), Axel Arbet-Engels (Max Planck Institute for Physics), Mireia Nieves Rosillo (IAC), Giacomo Bonnoli (INAF), Jorge Otero Santos (INFN Padova) on behalf of the MAGIC collaboration*

on 28 Jan 2025; 15:36 UT

Credential Certification: *David Paneque (dpaneque@mppmu.mpg.de)*

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

✕ Post

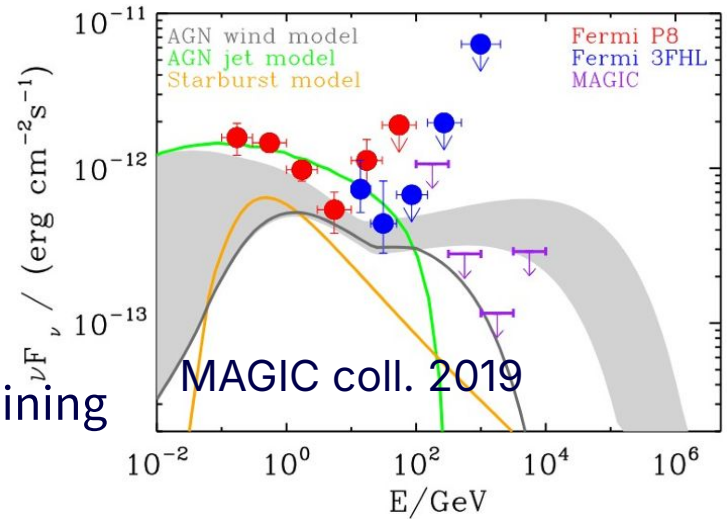
30 σ (3 hours)

The MAGIC Collaboration reports the detection of a strong activity in very-high-energy (VHE; $E > 100$ GeV) gamma rays from the flat spectrum radio quasar (FSRQ) OP 313 (R.A. = 197.61943 deg, Dec. = +32.34549 deg, J2000.0, redshift $z = 0.997$). The preliminary analysis of the 3-hour long MAGIC observation from 2025/01/27 (MJD 60702) yielded a detection of OP 313 with a statistical significance above 30 standard deviations. The estimated flux above 80 GeV reached a level comparable to that of the Crab Nebula.

NGC 1068

Y. Yao (Tokai U)

- Neutrino candidate starburst galaxy
 - Try to constrain the emission model by obtaining more strict upper limit around 100 GeV
- 9 hours LST-1 observations (2023/09–2024/02)
 - Obtained upper limits
- Simulation with 4 LSTs is ongoing
- To be presented at the next JPS meeting



GRB 221009A: Brightest-of-all-times GRB

$z=0.15$

- $\sim 4 \sigma$ excess on Oct. 10 (1.3 d after the burst onset, strong moon)
- Filling the time gap between HAWC (day before) and H.E.S.S. (day after)

theta2 plot

light curve

Fundamental physics

- Dark Matter Line Search
 - S. Abe (ICRR), T. Inada (Kyushu U)
- ALPs (Axion-like Particles)
 - Y. Sato (Tokai) [1ES 1959+650]
- PBH (Primordial black hole)
 - M. Takahashi (ISEE), M. Teshima (MPI & ICRR), A. Okumura (ISEE & KMI), H. Katagiri (Ibaraki), T. Inada (Kyushu U)
- Iron spectrum using Direct Cherenkov lights
 - S. Nozaki (ICRR), Y. Suda (Hiroshima)

Many members are also involved in fundamental physics projects

MAGIC Publications (FY2024)

E14: Kubo

- [“Cosmic-ray acceleration and escape from supernova remnant W44 as probed by Fermi-LAT and MAGIC”](#), accepted for publication by A&A
- [“Characterization of Markarian 421 during its most violent year: Multiwavelength variability and correlations”](#), accepted for publication by A&A
- [“Time-dependent modelling of short-term variability in the TeV-blazar VER J0521+211 during the major flare in 2020”](#), , accepted for publication by A&A
- [“Broadband multi-wavelength properties of M87 during the 2018 EHT campaign including a very high energy flaring episode”](#), **A&A, 692, A140 (2024 Dec)**
- [“Constraints on Lorentz invariance violation from the extraordinary Mrk 421 flare of 2014 using a novel analysis method”](#), JCAP, 2024, 07, 044 (2024 July)
- [“Insights into the broad-band emission of the TeV blazar Mrk 501 during the first X-ray polarization measurements”](#), A&A, 685, A117 (2024 May)
- [“Constraints on axion-like particles with the Perseus Galaxy Cluster with MAGIC”](#), Physics of the Dark Universe, 44, 101425 (2024 May)
- [“Performance and first measurements of the MAGIC stellar intensity interferometer”](#), MNRAS, 529, 4, 4387–4404 (2024 April)
- [“First characterization of the emission behavior of Mrk 421 from radio to very high-energy gamma rays with simultaneous X-ray polarization measurements”](#), A&A, 684, A127 (2024 April)

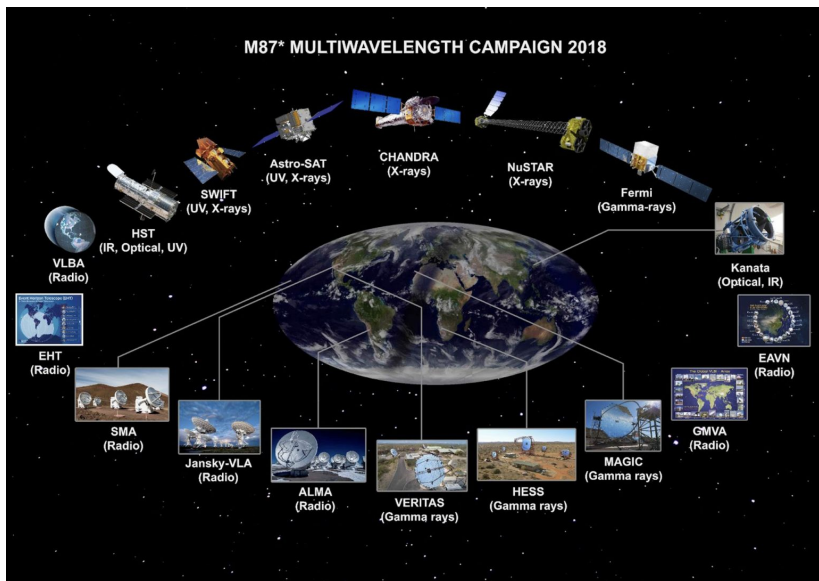
MAGIC highlight results (M87)

ICRR
Latest News



【Press Release】 M87's Powerful Jet Unleashes Rare Gamma-Ray Outburst

Press Releases 2024.12.13



The University of Tokyo

Nagoya City University

Mizusawa VLBI Observatory, National Astronomical Observatory of Japan

Kogakuin University

Institute of Science Tokyo

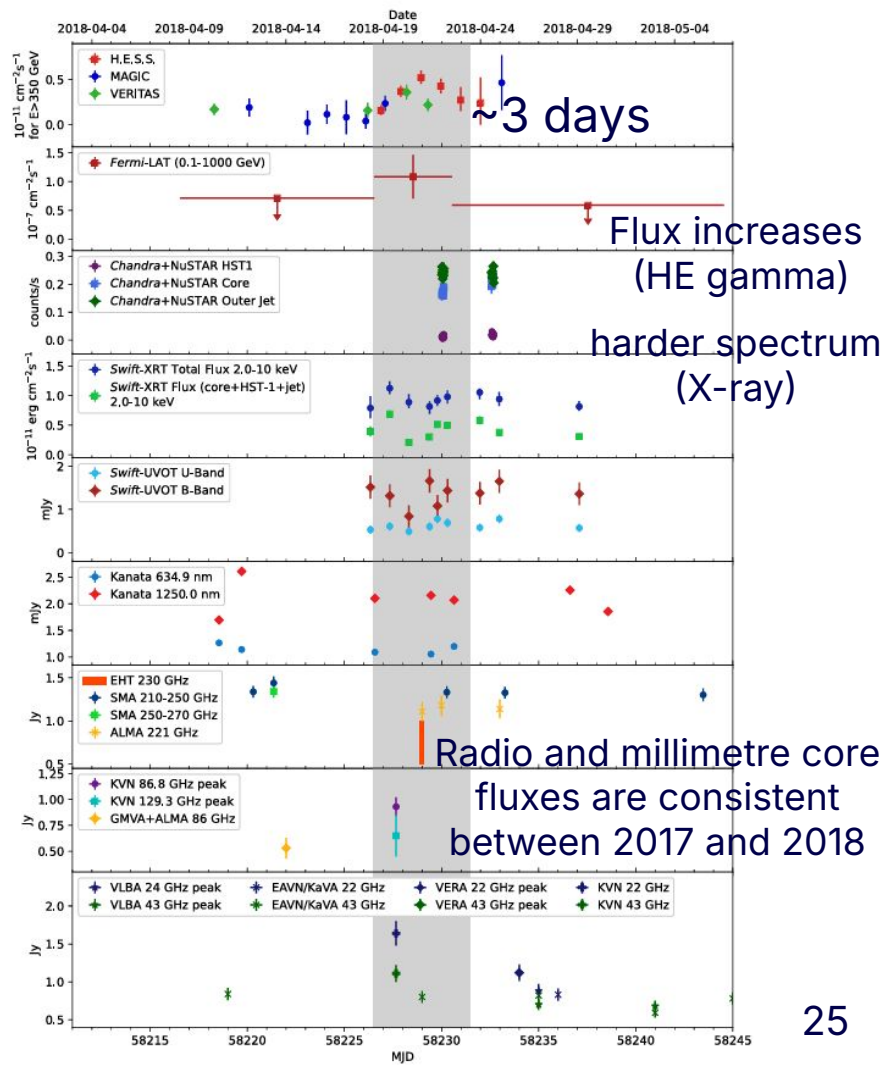
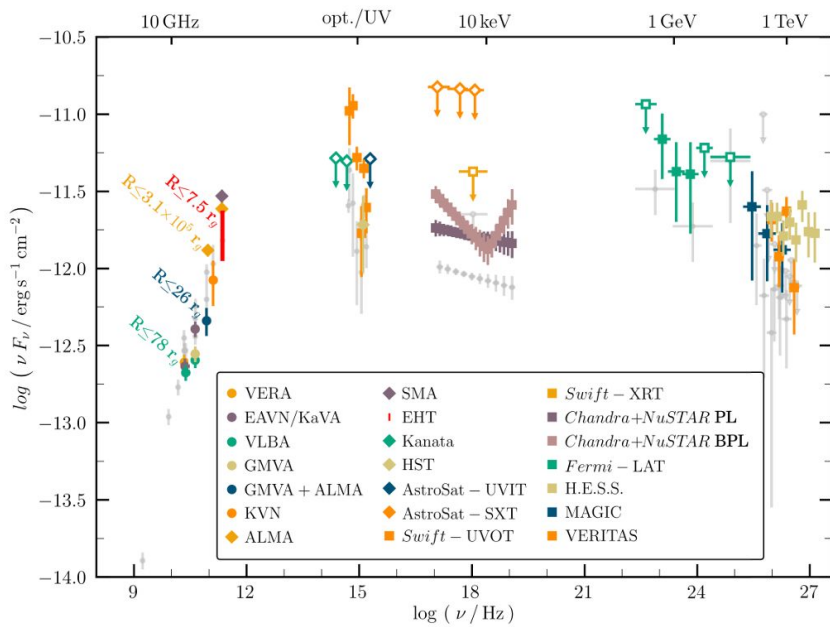
Center for Computational Astrophysics, National Astronomical Observatory of Japan

Ibaraki University

Osaka Metropolitan University

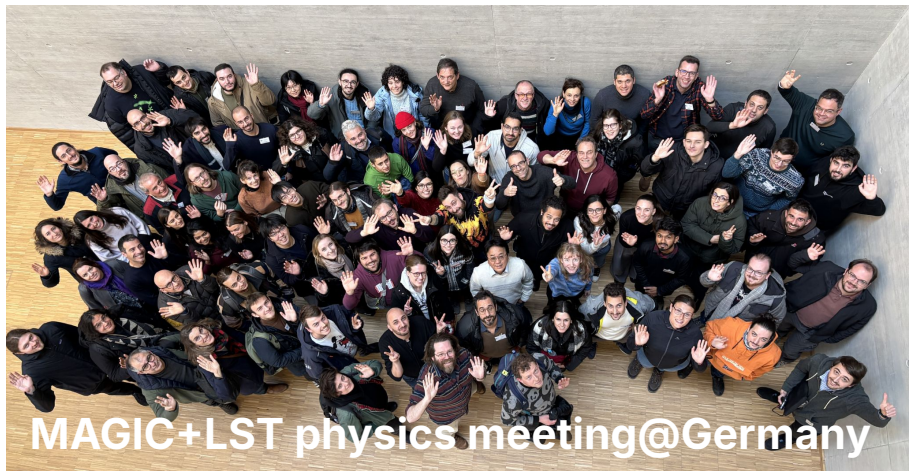
M87 EHT campaign

- EHT campaign in April 2018
- First VHE flare since 2010
- challenge to simple one-zone leptonic emission model

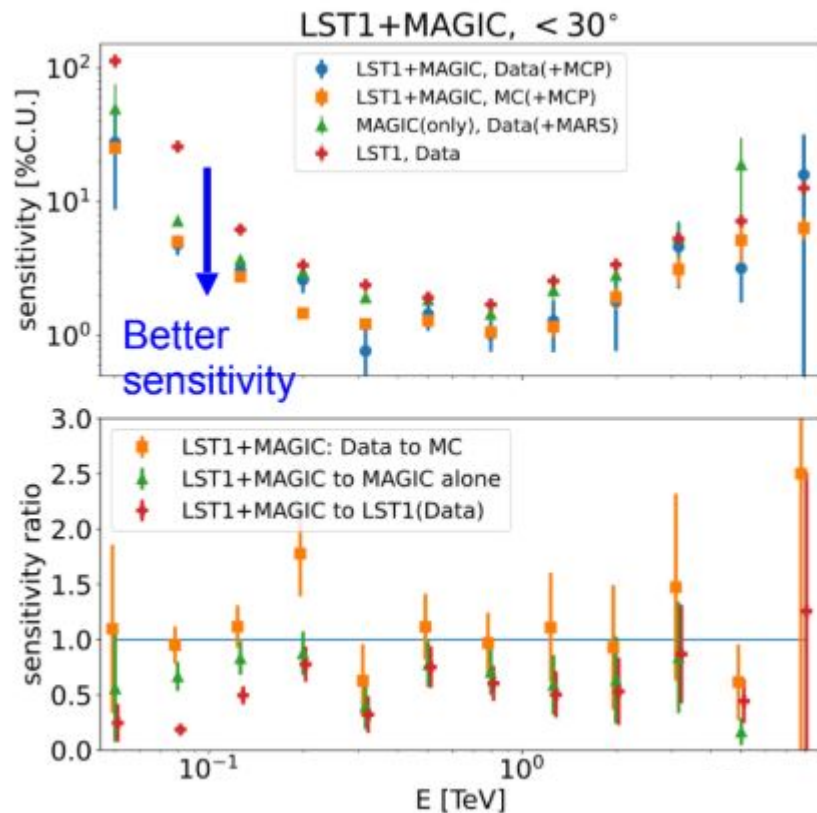


MAGIC + LST

- This year MAGIC & LST proposals will be evaluated at the same place
 - Proposal deadline: Jan 31
 - External members can also join proposals!



30–40% better than MAGIC



Summary

- LST-1 collected more than 2500 hours of scientific data in parallel to commissioning tests
- Performance study with Crab Nebula confirmed our expected LST-1 mono performance
- Pulsar data revealed the excellent performance in a few tens of GeV
- Galactic Center analysis is the successful case of extended observation and analysis method. Large FoV helps to analyze extended sources.
- We are eager to hunt AGN flares with several pipelines and the detection of OP 313 flare confirmed our potential to detect high-z sources
- 4 sigma hint of GRB 221009A. 4LSTs are expected to detect more GRBs thanks to the fast rotation
- MAGIC+LST are cooperating together for better performance