Observation of NGC 1068 with the CTAO Large-Sized Telescope Prototype

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ABSTRACT

The IceCube Collaboration reported evidence at 4.2σ significance for 1–10 TeV neutrinos arriving from the direction of the nearby Seyfert/starburst galaxy **NGC 1068**. However, the MAGIC telescopes, in 125 h of observations over three years, did not detect gamma-ray emission from **NGC 1068** and instead set upper limits at high energies. As a follow-up, this study analyzes 17.7 hours of observational data obtained with the Large-Sized Telescope Prototype (**LST-1**). Although the **LST-1** is currently operated in monoscopic mode, it provides improved sensitivity at lower energies compared to MAGIC, allowing us to probe a complementary regime. We therefore analyzed the **LST-1** monoscopic data as a step toward future studies. In addition, we performed **1D simulations** using instrument response functions (**IRFs**) for a **4-LST** stereo configuration, to illustrate the expected detection prospects once **4LSTs** are fully operational.

Datasets

We analyzed the data of **NGC 1068** (z ≈ 0.0038) in the constellation Cetus, observed with the **LST-1** telescope during the periods **22 Sep 2023 – 10 Feb 2024 and 10 Sep 2024 – 07 Nov 2024**. After removing bad-weather runs and applying a zenith-angle cut of **50°**, we obtained a total of **17.7 hours** of good-quality data.

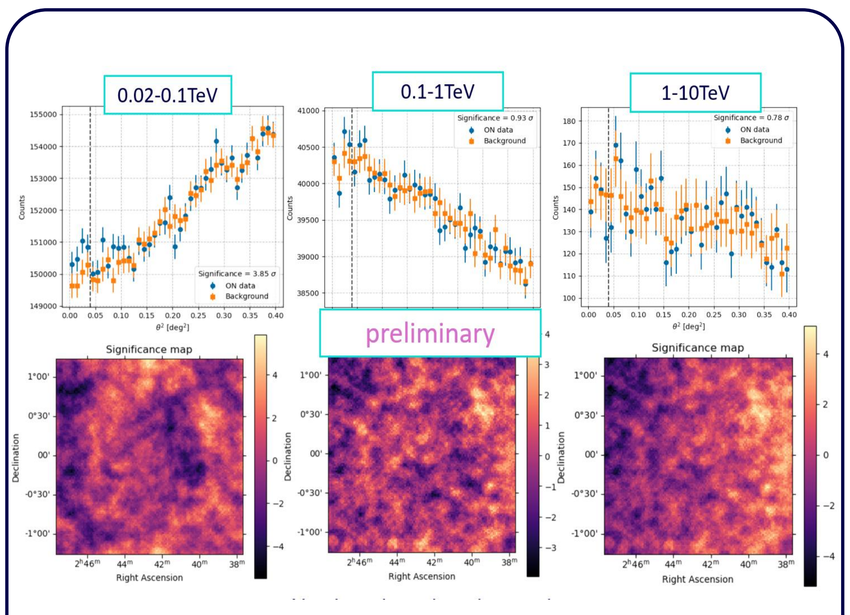

Fig. 1: θ² plot & TS map

Detection

The θ² plot and TS map show **no significant gamma-ray signal** likely due to the limited available data. Still, this result supports scenarios in which regions near the black hole—where high-energy ions interact with ambient gas and photons—are highly opaque to GeV–TeV gamma-rays. The obtained upper limits from our 17.7-hour dataset are approximately **an order of magnitude higher** than those reported by **MAGIC** telescopes (V. A. Acciari et al. 2019 [2]).

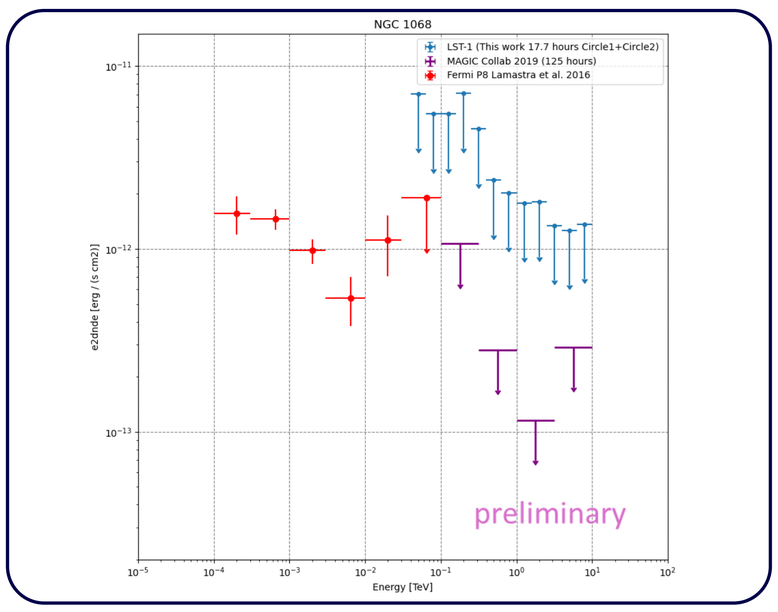

Fig. 2: SED of NGC 1068

Signal modeling

For the signal modeling, we adopted a simple power-law spectrum with an **index of 2.3**, motivated by the significant (**≈5σ**) gamma-ray emission detected at **10–30 GeV** in the Fermi-LAT 3FGL results (Lamastra et al. 2016 [1]), assuming that the entire gamma-ray flux originates from the inner **~100 pc region** of the galaxy.

Gammapy 1D simulation

Since no significant gamma-ray signal is detected, we performed a **1D simulation** using the official **4-LST** IRFs to evaluate the detectability of NGC 1068, assuming that all four LSTs are operational. In **Gammapy's 1D simulation** framework, the expected ON/OFF counts are computed by folding the source spectral model with the **instrument response functions** (Aeff, EDisp, and background). The simulation generates fake ON/OFF counts drawn from Poisson distributions to account for statistical fluctuations. For each assumed observation time, **100** pseudo-experiments were produced to estimate the expected excess and significance.

Results

The results of this study favors scenarios in which Its neutrino emission is likely produced in the immediate vicinity of the **supermassive blackhole** (SMBH) that powers the AGN, most plausibly within the AGN's corona (Murase K. 2022 [3]) and the **GeV** gamma-ray emission detected by Fermi-LAT from **NGC1068** is likely dominated by star-formation activity and its photon flux is lower than the observed neutrino flux. The 1D simulation further shows that, by extending the observation time to **100 hours** with **4 LSTs** fully operational, we may observe an average excess of approximately **1,450 events** from the simulation, corresponding to a Li & Ma significance of **≈ 5.60σ**. This result demonstrates a strong potential for detection with longer exposure. This highlights the strong potential of future observations to probe high-energy emission from this source more effectively. Since all **4 LSTs** are scheduled to become fully operational by late next year, our results suggest that a 5σ level of confidence per energy bin (five bins per decade) in the **20–100 GeV** range may be achievable.

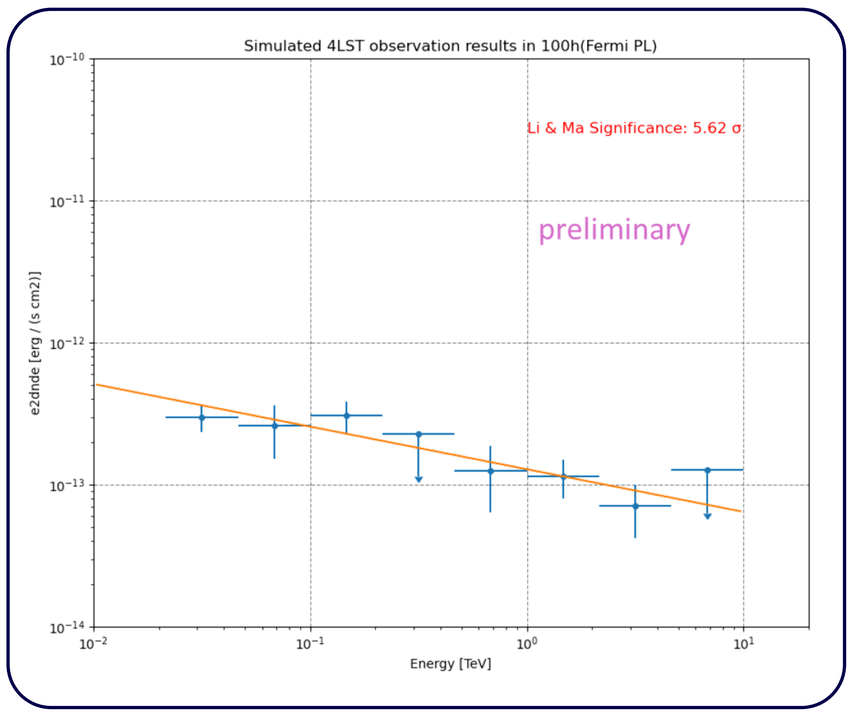

Fig. 3: 100h simulation result of 4 LSTs

References

[1] A.Lamastra et al. A&A 596 A68 (2016) DOI: 10.1051/0004-6361/201628667
[2] V. A. Acciari et al. 2019 ApJ 883 135 DOI: 10.3847/1538-4357/ab3a51
[3] Murase, K. 2022, ApJL, 941, L17, DOI: 10.3847/2041-8213/aca53c

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