LST-1's Early Achievements in AGN Observations: Discovery of the Farthest Blazar OP 313 at VHE Gamma Rays

8th Heidelberg International Symposium on High-Energy Gamma-Ray Astronomy

Joshua R. Baxter*
Institute for Cosmic Ray Research, University of Tokyo
** joshua28@icrr.u-tokyo.ac.jp, joshuaicrr@gmail.com*

Axel Arbet-Engels (Max Planck Institute for Physics), Alessandra Briscioli (University of Padova), Federico Di Pierro (INFN Torino), David Green (Max Planck Institute for Physics), Lea Heckmann (Max Planck Institute for Physics), R. de Menezes (INFNC), Daniel Morcuende (IAA), Mireia Nievas Rosillo (IAC), Seiya Nozaki (Max Planck Institute for Physics, ICRR), Jorge Otero-Santos (IAA), V. Fallah Ramazani (University of Turku), David Sanchez (Laboratoire d'Annecy de Physique des Particules), Elisa Visentin (INFN, Torino) for the CTAO LST collaboration, MAGIC collaboration

Milano, Italy, Sep 2nd-6th 2024

東京大学 THE UNIVERSITY OF TOKYO

ICRR Institute for Cosmic Ray Research University of Tokyo

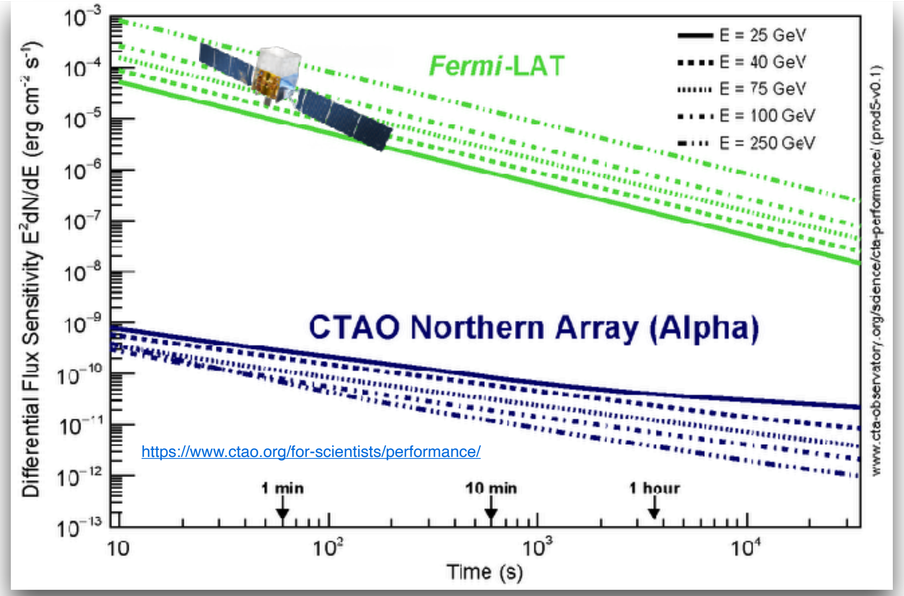
CTAO | LST COLLABORATION

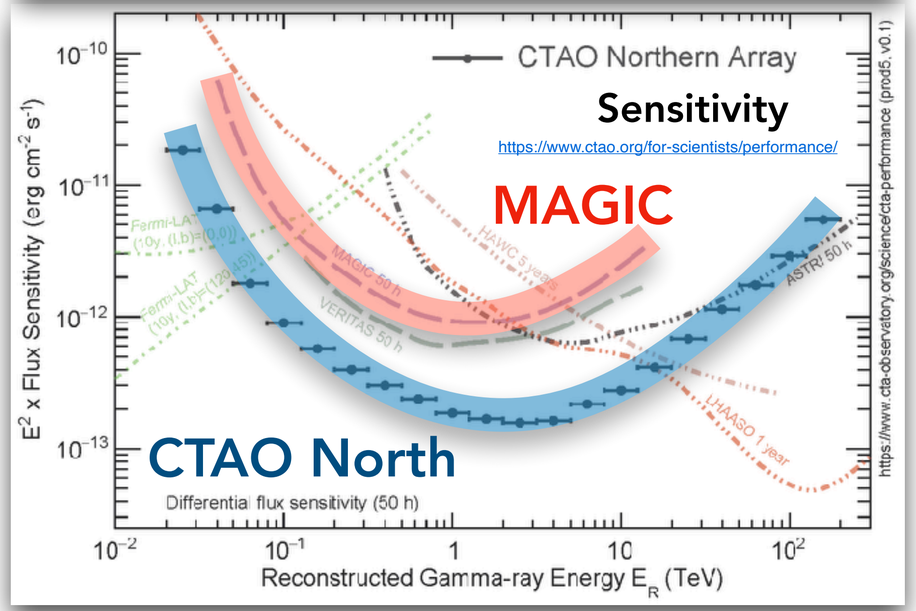
MAGIC

Cherenkov Telescope Array Observatory (CTAO)

Next generation ground-based telescopes for gamma-ray astronomy at very-high energies (VHE)

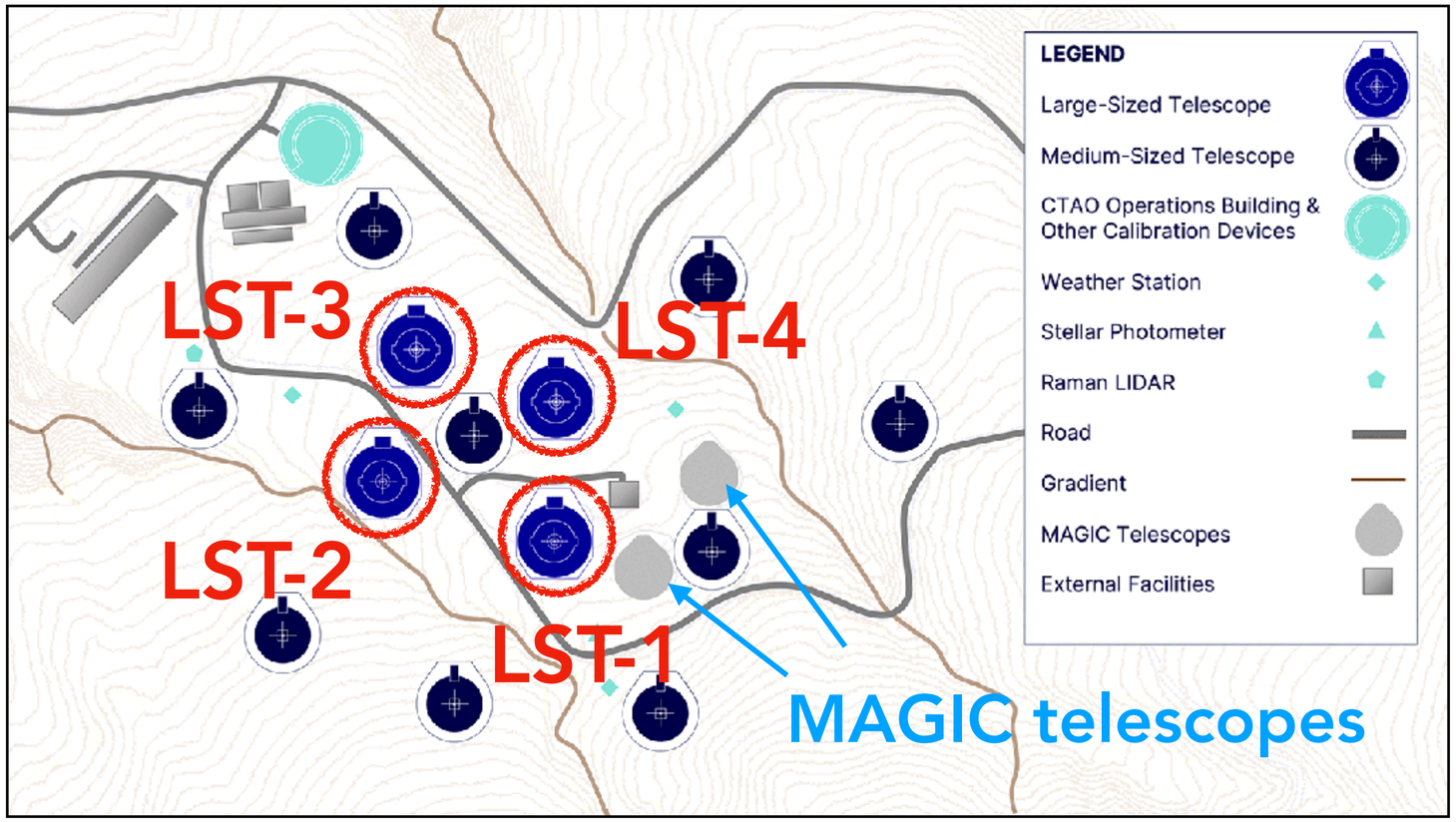
- Located in the **northern** and **southern** hemispheres with 64 telescopes
- Northern CTAO: 4 Large-Sized Telescopes + 9 Medium-Sized Telescopes, located in La Palma, Spain
- **x10 better sensitivity + wide energy coverage of 20 GeV-300 TeV**

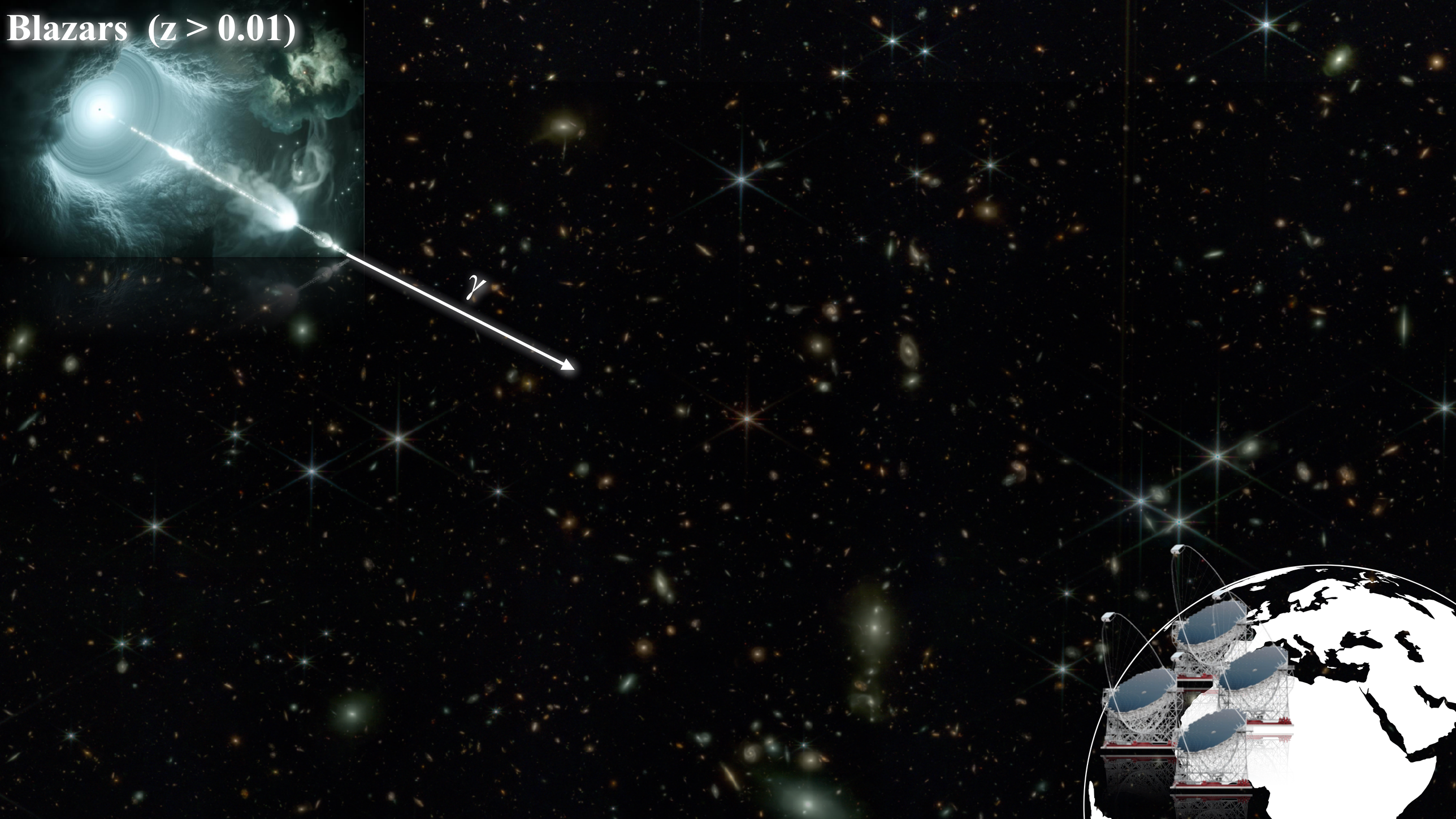


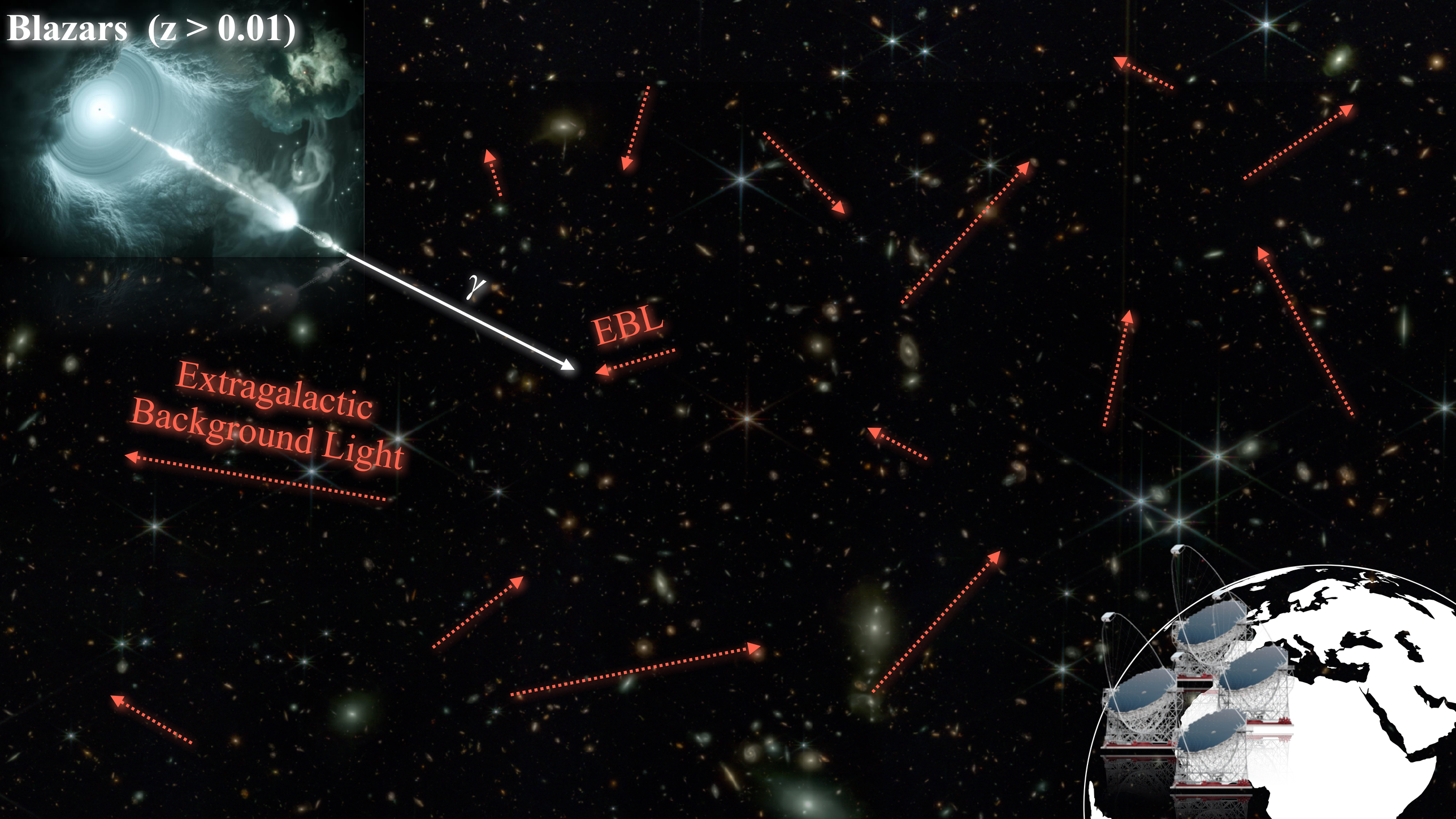


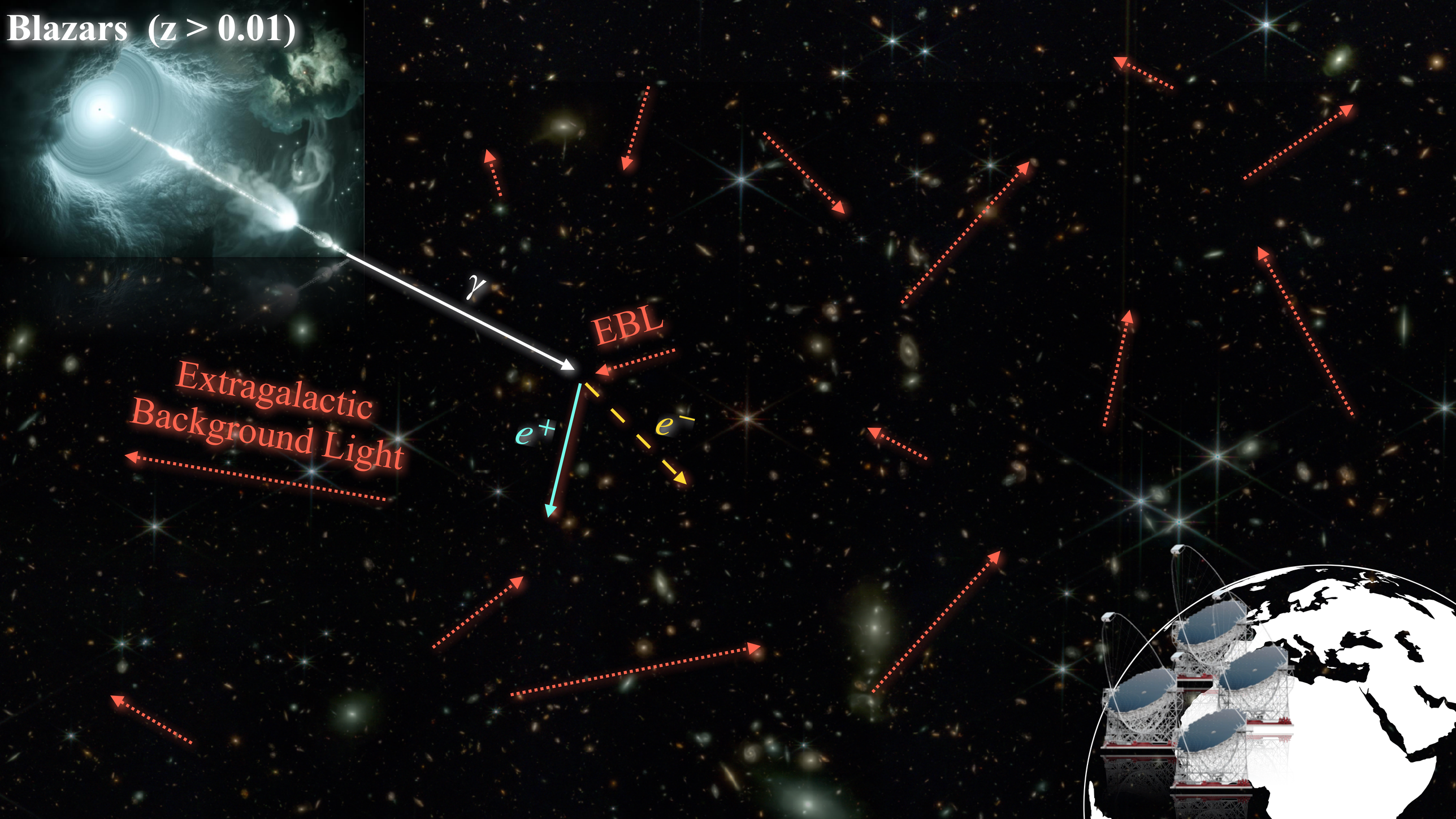
Large-Sized Telescope (LST)

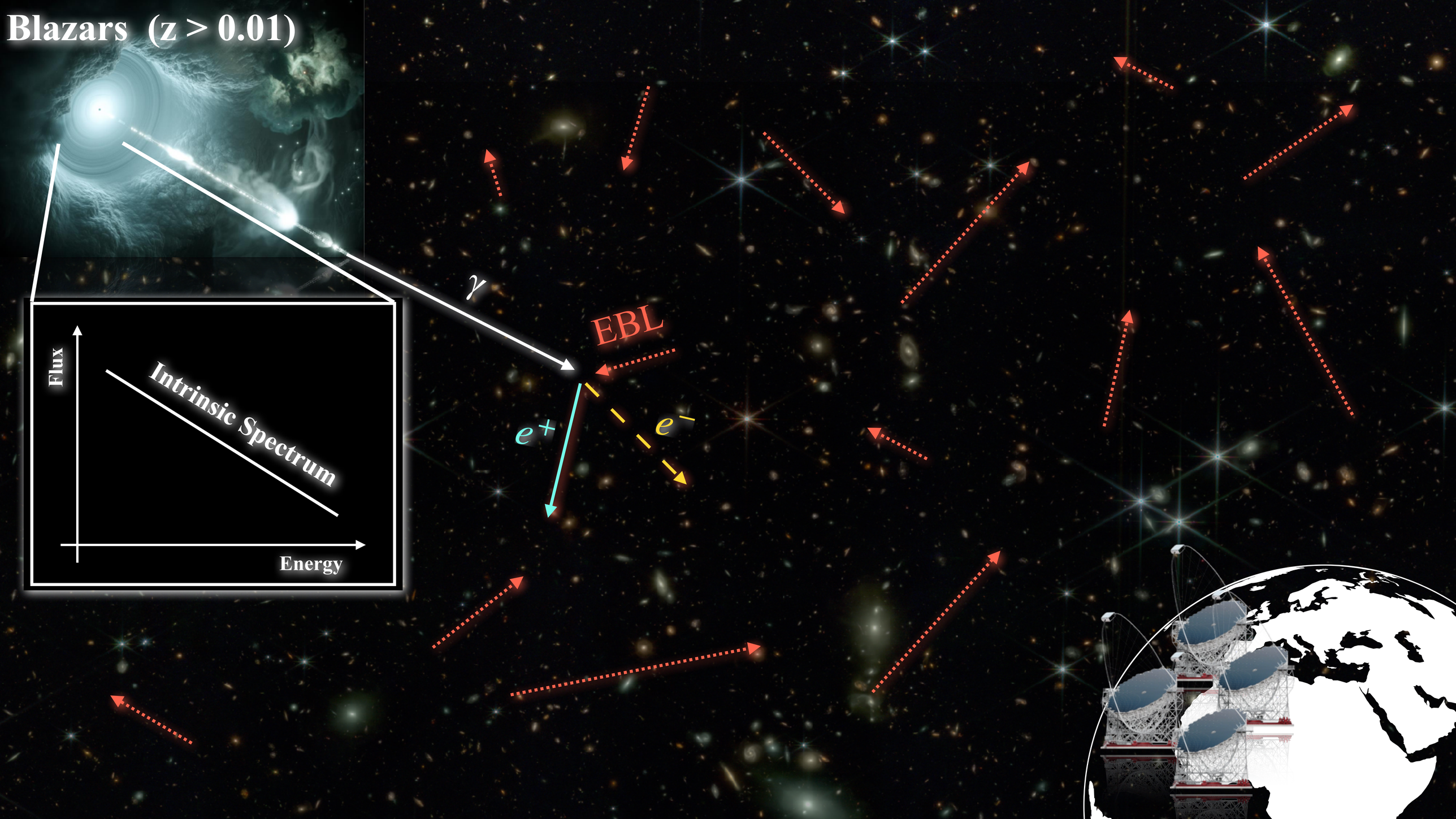
LSTs are designed to give optimal performance in the lowest region of the energy range covered by CTAO, down to ≃ 20 GeV

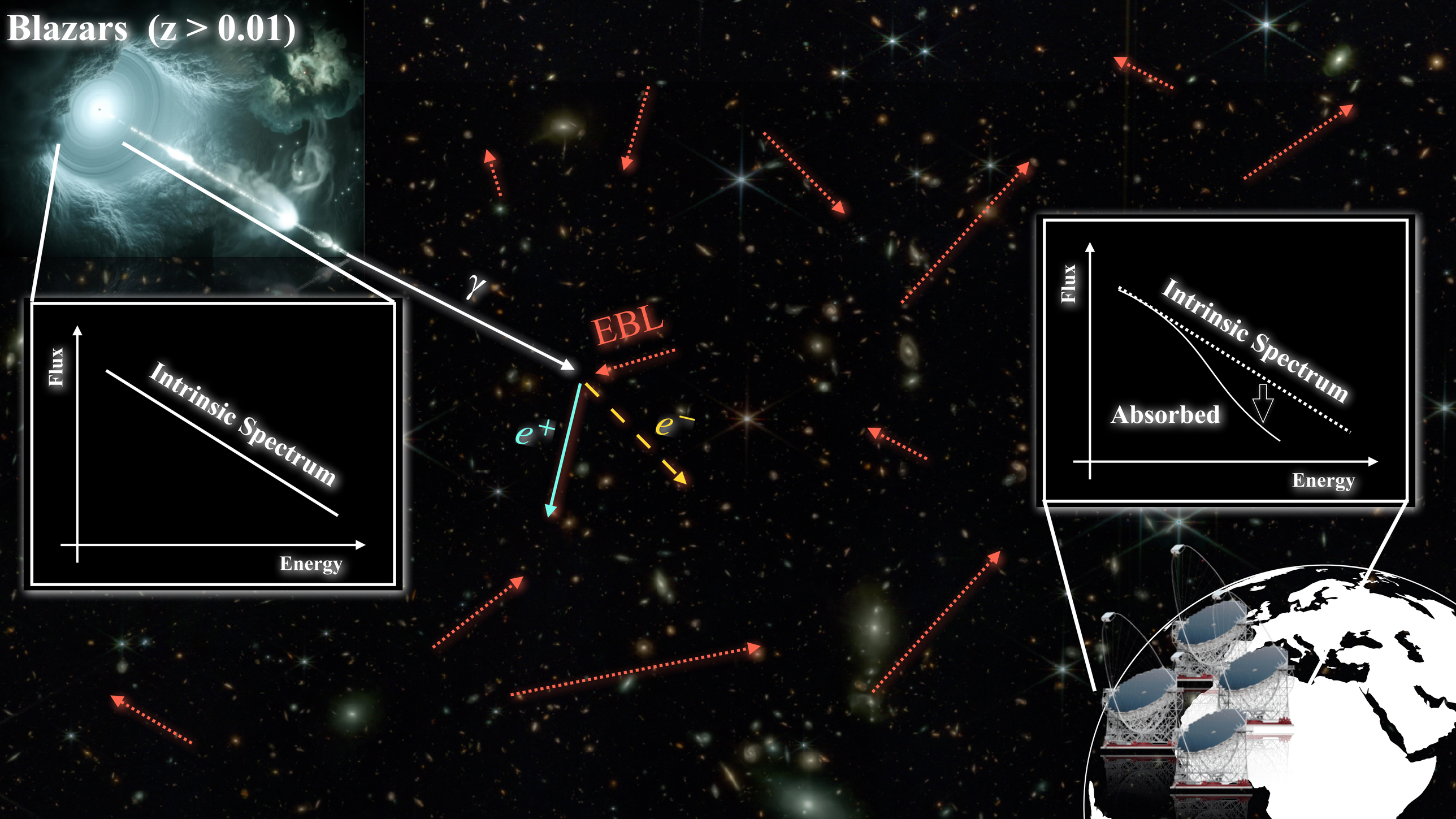


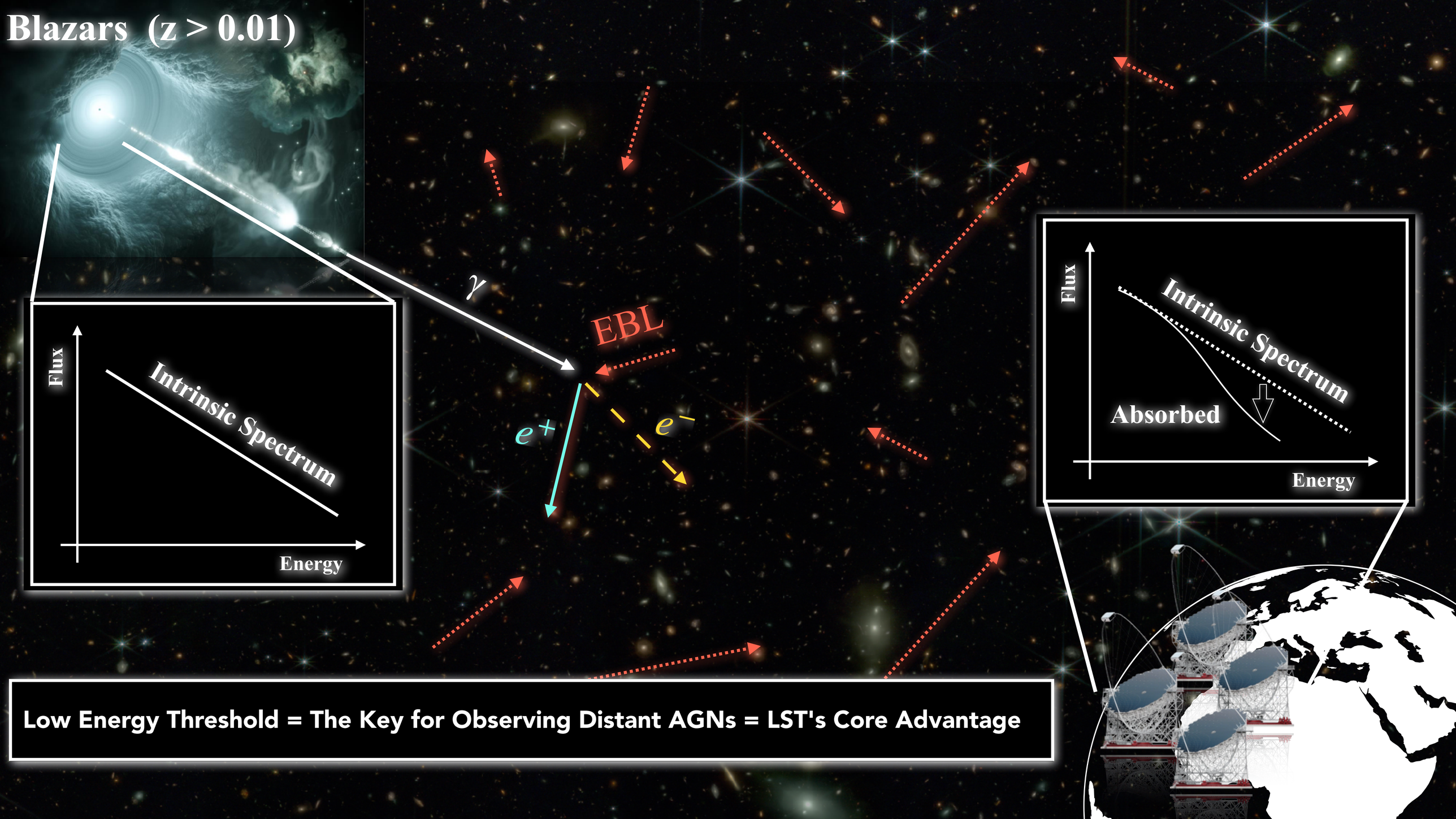

Blazars (z > 0.01)
γ


Blazars (z > 0.01)
γ
EBL
Extragalactic
Background Light


Blazars (z > 0.01)
γ
EBL
Extragalactic
Background Light
e+
e-


Blazars (z > 0.01)
γ
EBL
e+
e−
Flux
Intrinsic Spectrum
Energy

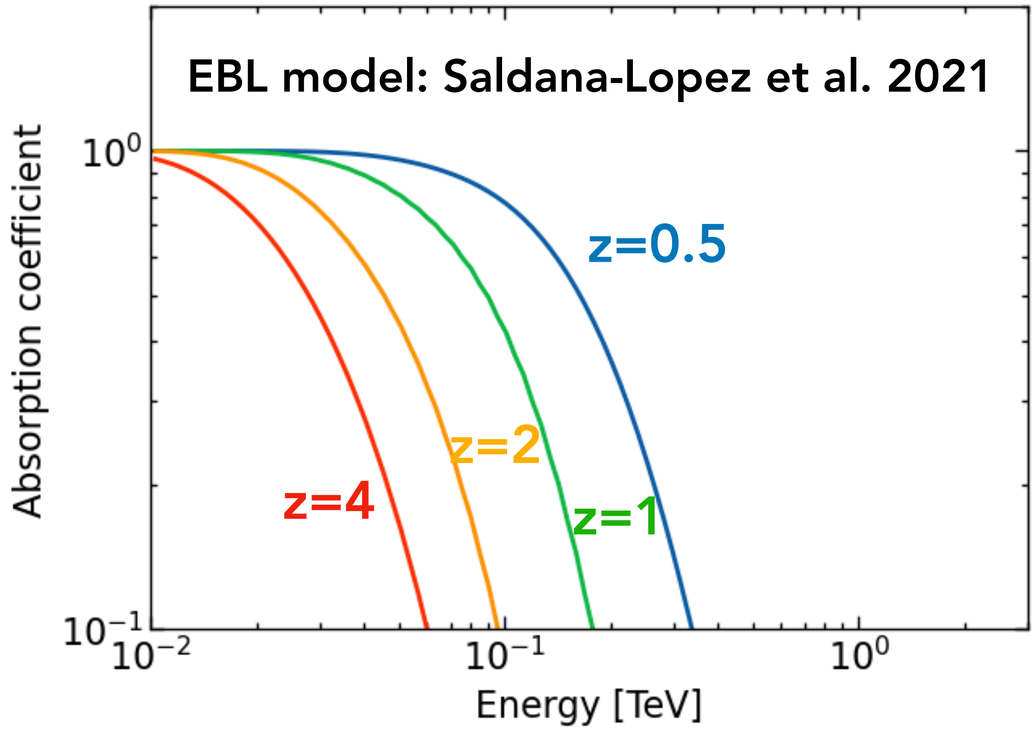

Blazars (z > 0.01)
γ
EBL
e+
e−
Flux
Intrinsic Spectrum
Energy
Flux
Intrinsic Spectrum
Absorbed
Energy

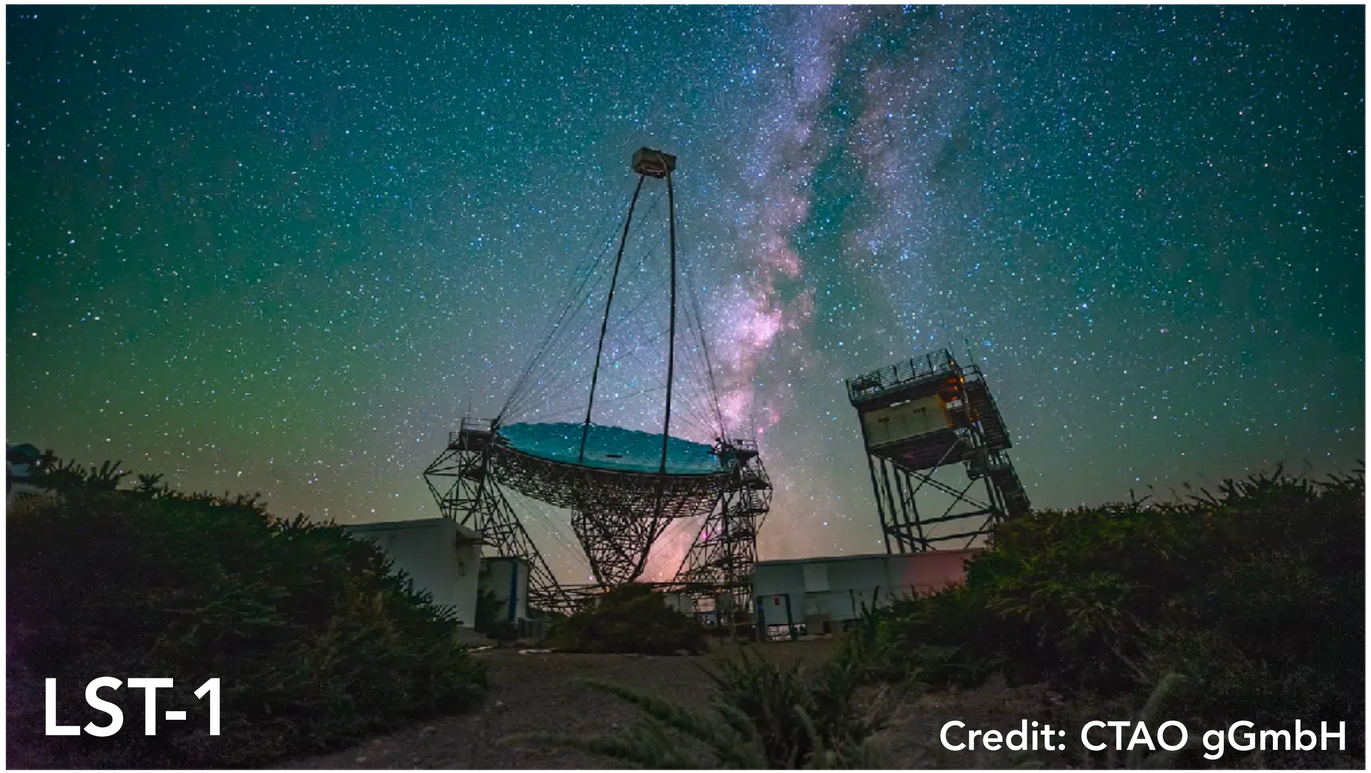

Blazars (z > 0.01)
γ
EBL
e+
e−
Flux
Intrinsic Spectrum
Energy
Flux
Intrinsic Spectrum
Absorbed
Energy
Low Energy Threshold = The Key for Observing Distant AGNs = LST's Core Advantage

The Prototype Large-Sized Telescope: LST-1

Operated since 2020,
already dedicated over 1000 hours to AGN observations

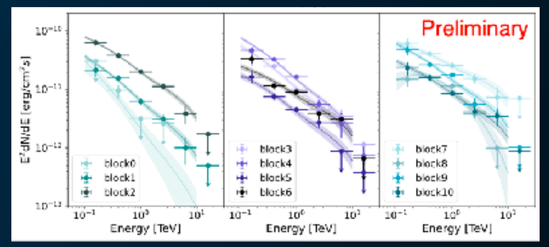
- Suitable for **transient** / **soft** / **distant** sources

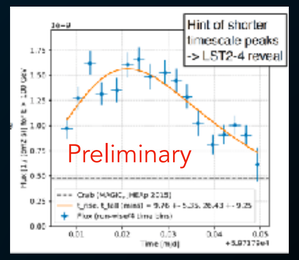




Ongoing main AGN projects within LST-1's EGal Group

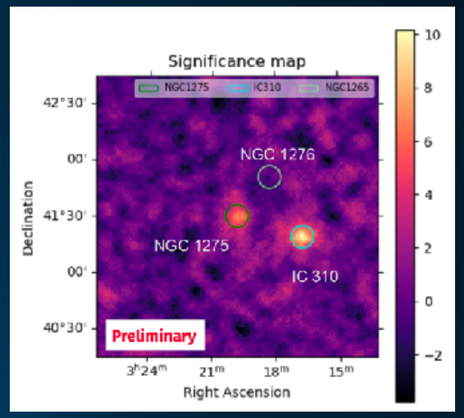
❶ AGN Zoo Project





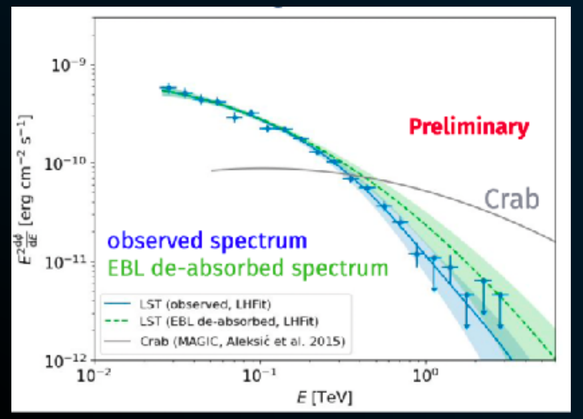
- SEDs of known sources: Mrk 421, Mrk 501, 1ES1959+650, PG1553+113, 1ES0647+250
- BB block analysis, min-time scale variability confirmed for Mrk 421

❷ Radio Galaxy Observation



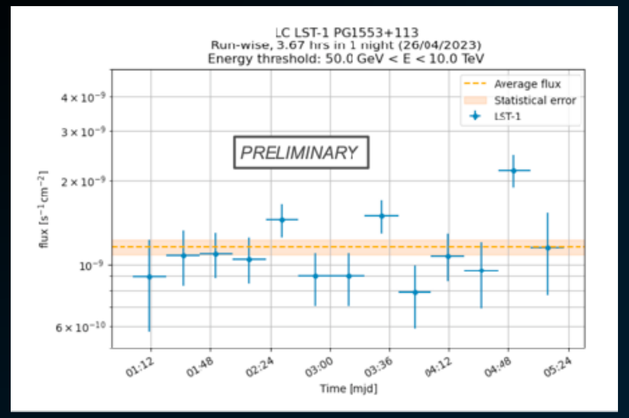
- NGC 1275 and IC 310 detected by LST-1
- NGC 1275: Clear spectral variability over the whole period
- IC 310: Mostly ULs, but detected on 2023-12-08 (~0.2 C.U.)

❸ BL Lac Flares



- ISP BL Lac Object (z = 0.069)
- LST-1 observed major flares in 2021, and 2022
- Fast and large intra-night variability (up to 3~4 C.U.)

❹ Variability Search in PG1553+113

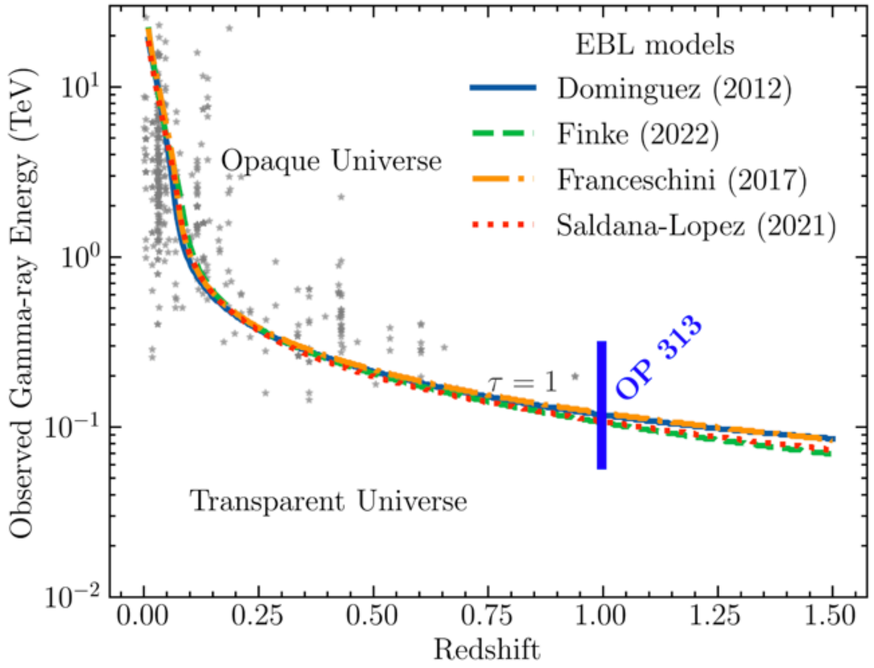


- Variability known for GeV (Ackermann et al 2015), but what about in VHE?
- Poster contribution: https://indico.ict.inaf.it/event/2661/contributions/19127/

OP 313: The New Kid on the VHE Cosmic Block!

Thanks to the low energy threshold of LST-1,
we detected the first VHE emission from OP 313 during its flare state in December 2023

- First scientific discovery of the LST-1: ATel #16381
- Furthest FSRQ (z = 0.997) ever detected in VHE by IACTs Schneider et al., 2010
  - The **10th** VHE FSRQ



The Astronomer's Telegram

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

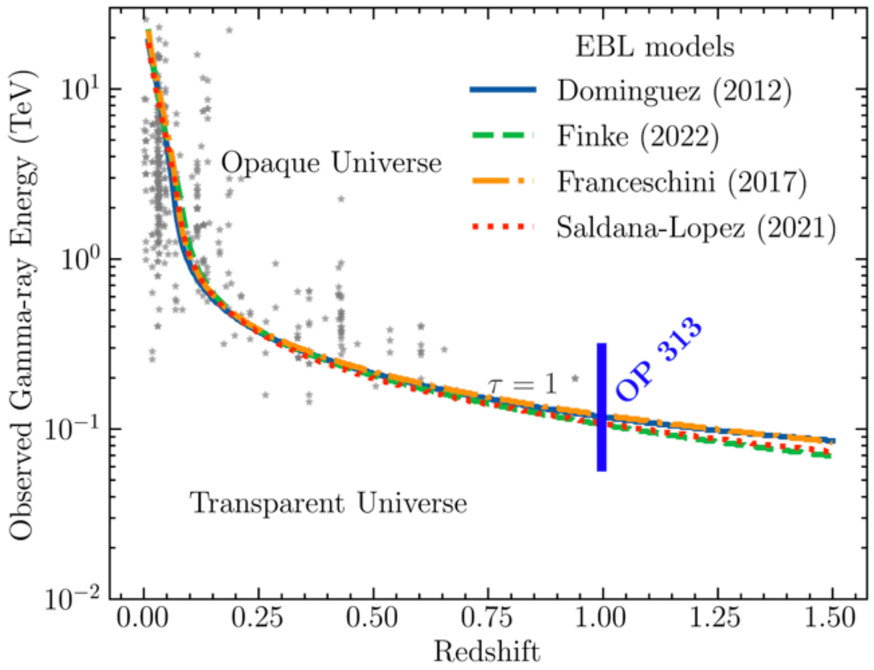
ATel #16381; *Juan Cortina (CIEMAT) for the CTAO LST collaboration*
*on **15 Dec 2023; 14:31 UT***
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

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

OP 313: The New Kid on the VHE Cosmic Block!

Thanks to the low energy threshold of LST-1,
we detected the first VHE emission from OP 313 during its flare state in December 2023

- First scientific discovery of the LST-1: ATel #16381
- Furthest FSRQ (z = 0.997) ever detected in VHE by IACTs [Schneider et al., 2010]
  - The **10th** VHE FSRQ



LST-1 is pushing the limit of the observable VHE universe!

The Astronomer's Telegram

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

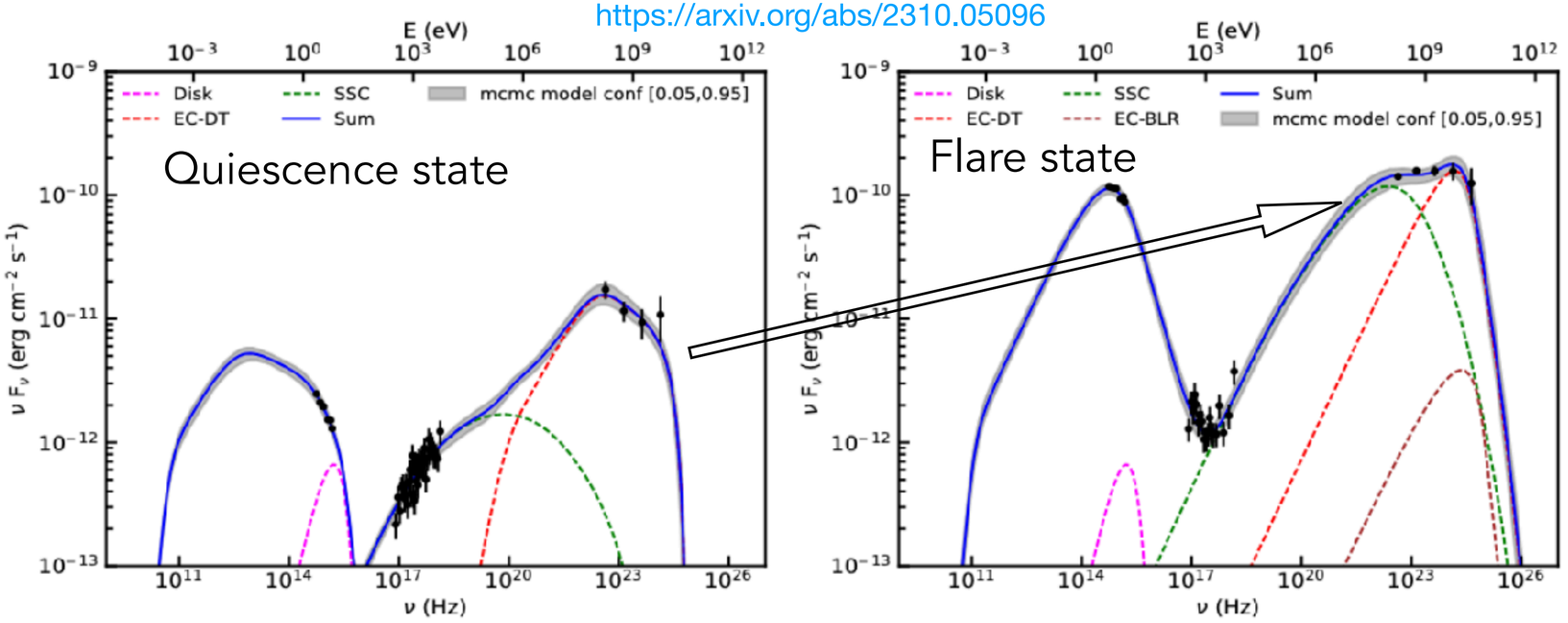
ATel #16381; *Juan Cortina (CIEMAT) for the CTAO LST collaboration*
*on **15 Dec 2023; 14:31 UT***
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

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

Flat-spectrum radio quasar OP313

- The source had already been detected at lower energies:
  - HE γ-ray, X-ray, UV, optical bands...
- A notable flare occurred in **June-July 2022**: Known as a **<u>transition</u> blazar**
  - The synchrotron peak frequency shifted from ~8×10^{12} Hz in quiescence to ~6×10^{14} Hz during the flare, with a Compton dominance decreased, suggesting a transition from an **LSP** to an **ISP** blazar

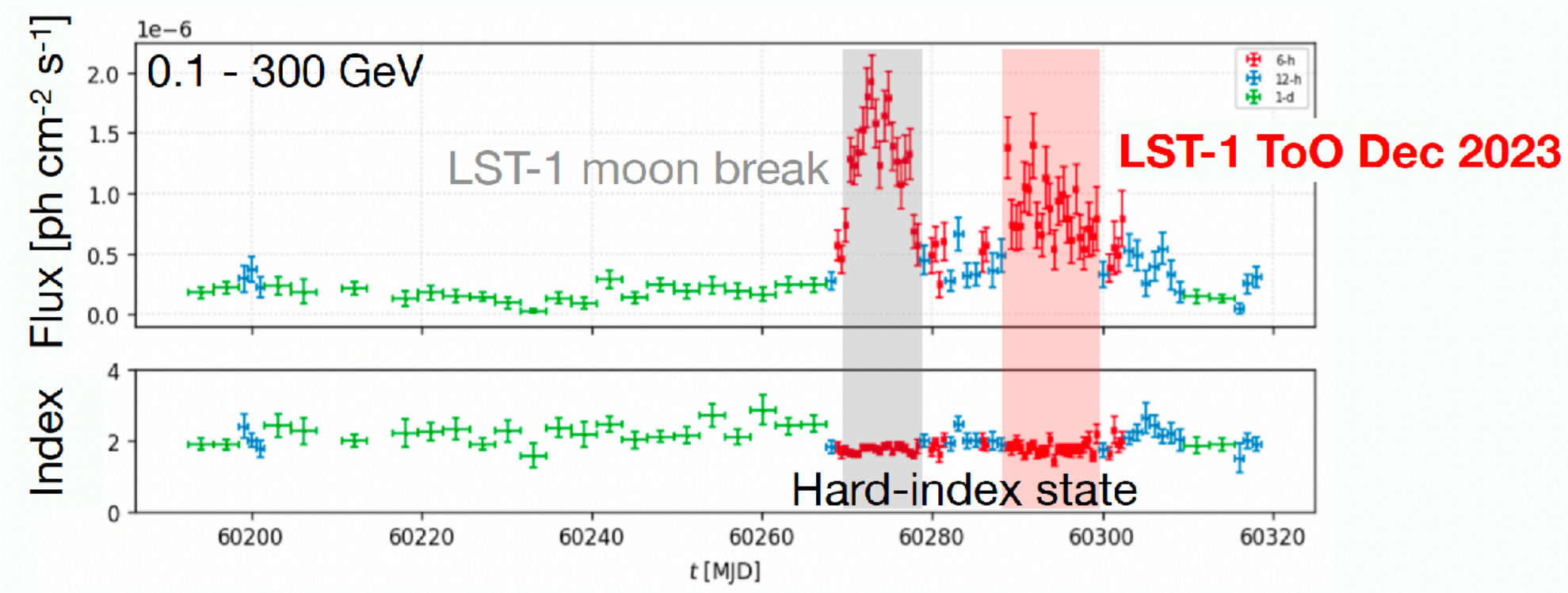
https://arxiv.org/abs/2310.05096



Fermi-LAT monitoring of OP 313

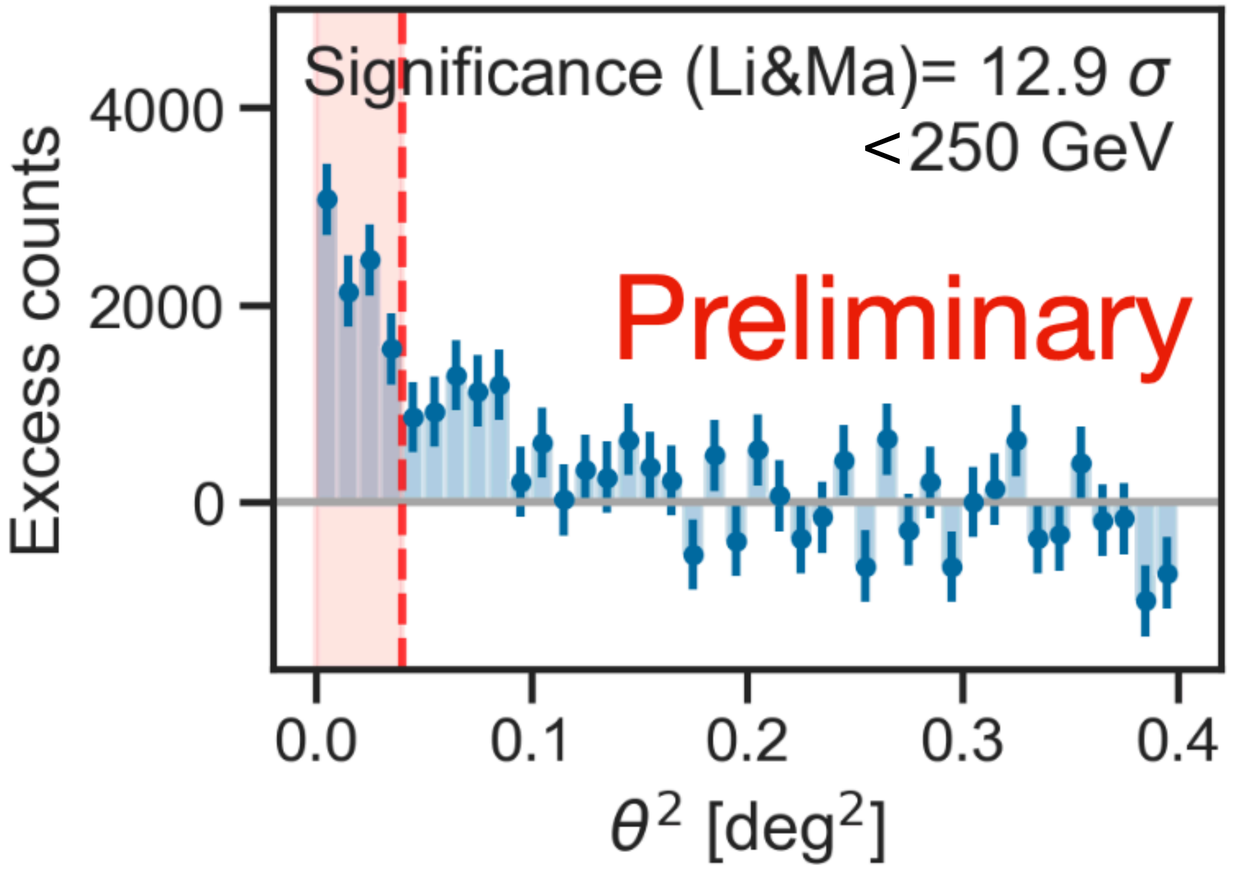
Our pipeline based on FlaapLUC sends email notifications when the LCs exceed the threshold. This alerted us to the flare state of OP 313, prompting us to direct the telescope towards it.

- FlaapLUC (J. P. Lenain, 2018) alerted us in November 2023, but LST-1 was on a moon break
- LST-1 ToO observations started on December 9th, 2023



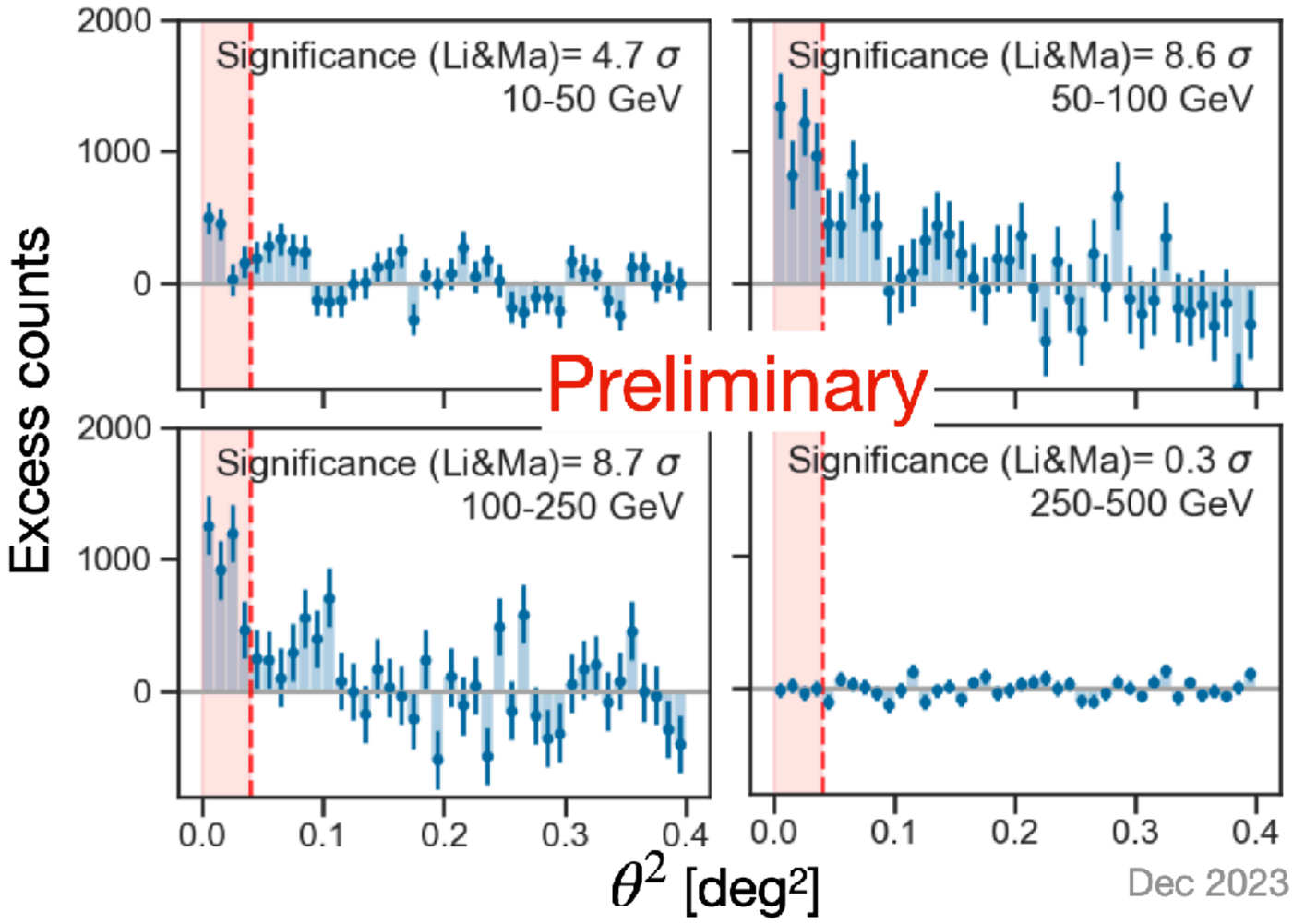
VHE detection of OP 313 by LST-1

- December 2023 data: ~14.6 h
  Significance (Li&Ma) ≈**13 σ**
  below **250 GeV**
- No detection at higher energies
- No significant detection in
  January 2024 dataset: ~5 h



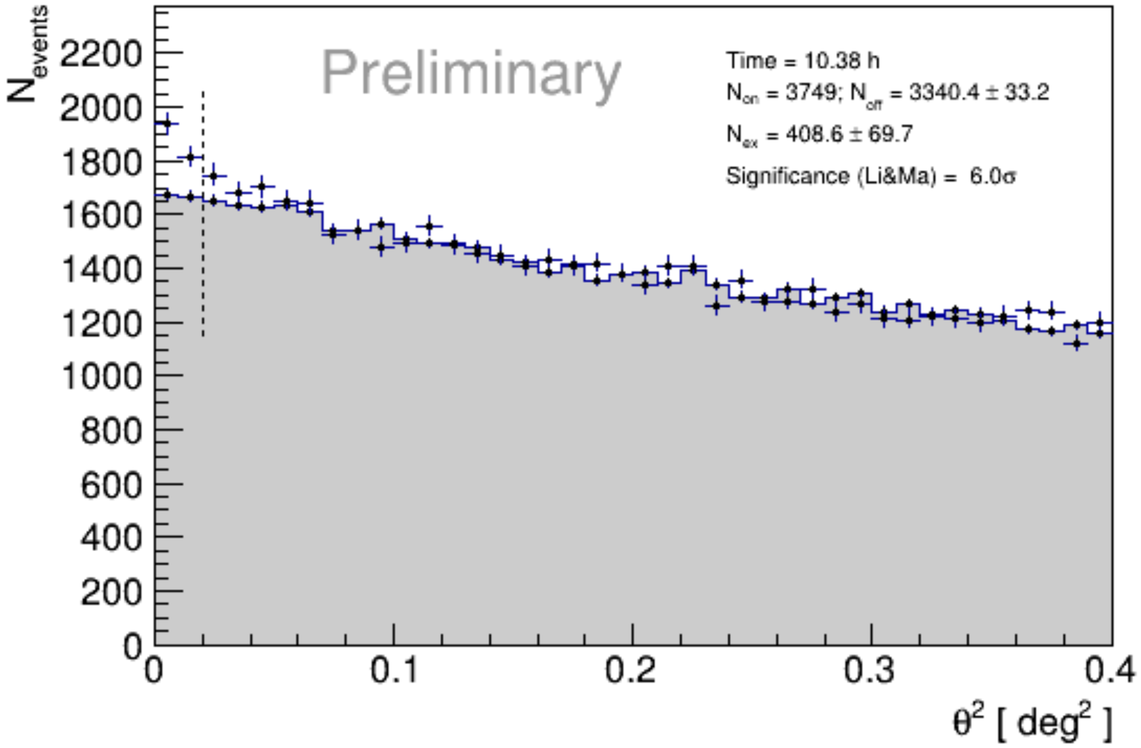
VHE detection of OP 313 by LST-1

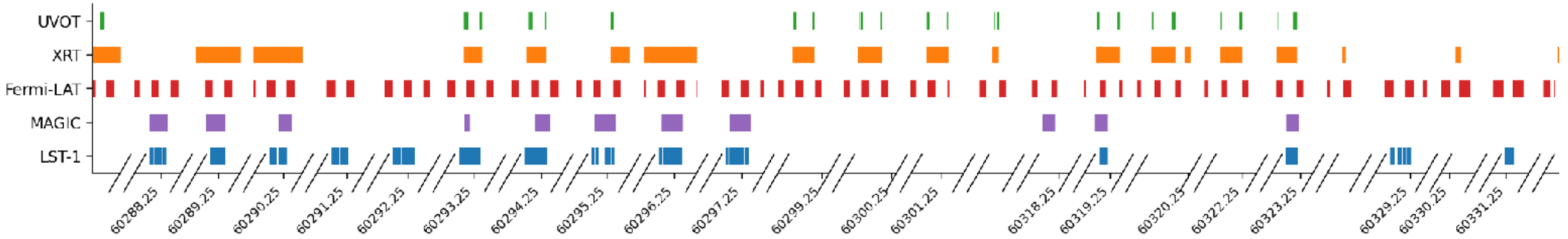
- December 2023 data: ~14.6 h
  Significance (Li&Ma) ≈**13 σ**
  below **250 GeV**
- No detection at higher energies
- No significant detection in
  January 2024 dataset: ~5 h



VHE detection of OP 313 by MAGIC

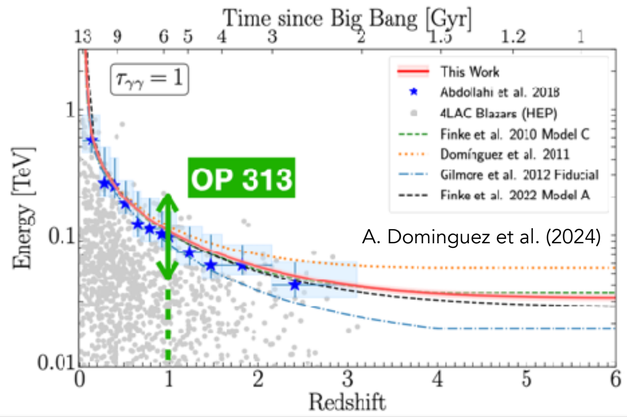
- MAGIC also detected the source with **6σ** (Li & Ma) after **10 hours** of observation during Dec. 2023
- A joint paper with the MAGIC collaboration reporting these results is in preparation — **stay tuned!**





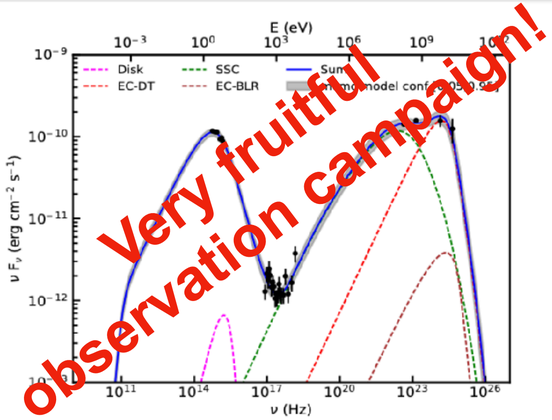
Prospects: Ongoing / Potential Projects

EBL Constraint



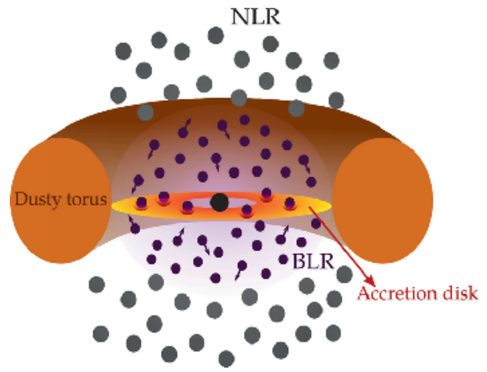
A. Dominguez et al. (2024)

Broadband SED Modeling



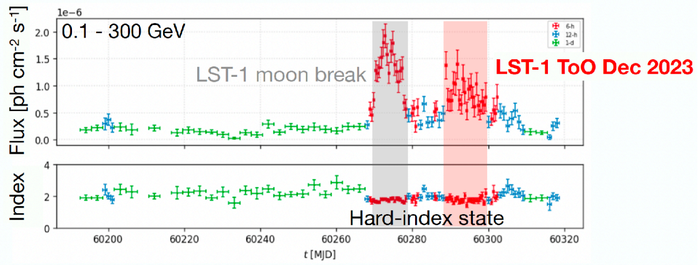
Very fruitful observation campaign!

Broad-line Region Studies

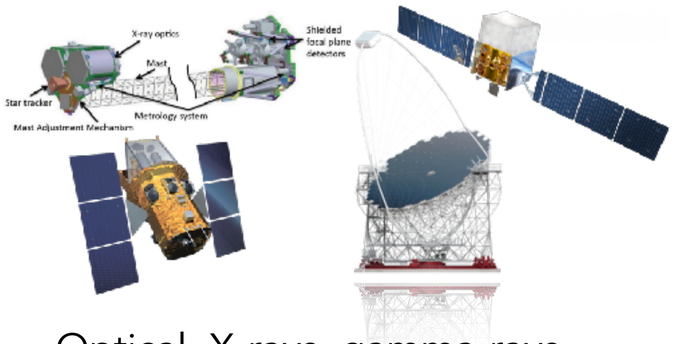


https://link.springer.com/chapter/10.1007/978-3-031-10306-3_6

Variability Studies



Deep-Exposure Nights



- Optical, X-rays, gamma-rays

Technical Papers

- New MWL Gammapy workflow

- Binned event data from Optical to gamma-rays
- Full forward folding

Summary

- CTAO is the next generation ground-based telescopes for gamma-ray astronomy at VHE
  - LST-1 already dedicated over 2000 hours to AGN observations
    - Several projects are underway, including well-known VHE blazars, radio galaxy observations, variability studies of PG 1553+113, and flare monitoring of BL Lac
- Detected the first VHE emission from OP 313 during its flare state in December 2023
  - LST-1: ~13 σ (~15 h), MAGIC: ~6 σ (~10 h)
  - Furthest FSRQ (z = 0.997) ever detected in VHE by IACTs
  - Many results expected from this source
    - EBL constraint, MWL SED modeling, Variability studies, etc.

Backup

Fermi-LAT Light Curves of OP 313

Fermi LAT Light Curve Repository (LCR)