

# The Extragalactic Sky at Very High Energies: Early Results from LST-1

**Jorge Otero Santos**

Istituto Nazionale di Fisica Nucleare - INFN Padova  
on behalf of the CTAO-LST Collaboration

LPNHE seminar - 22 June 2026

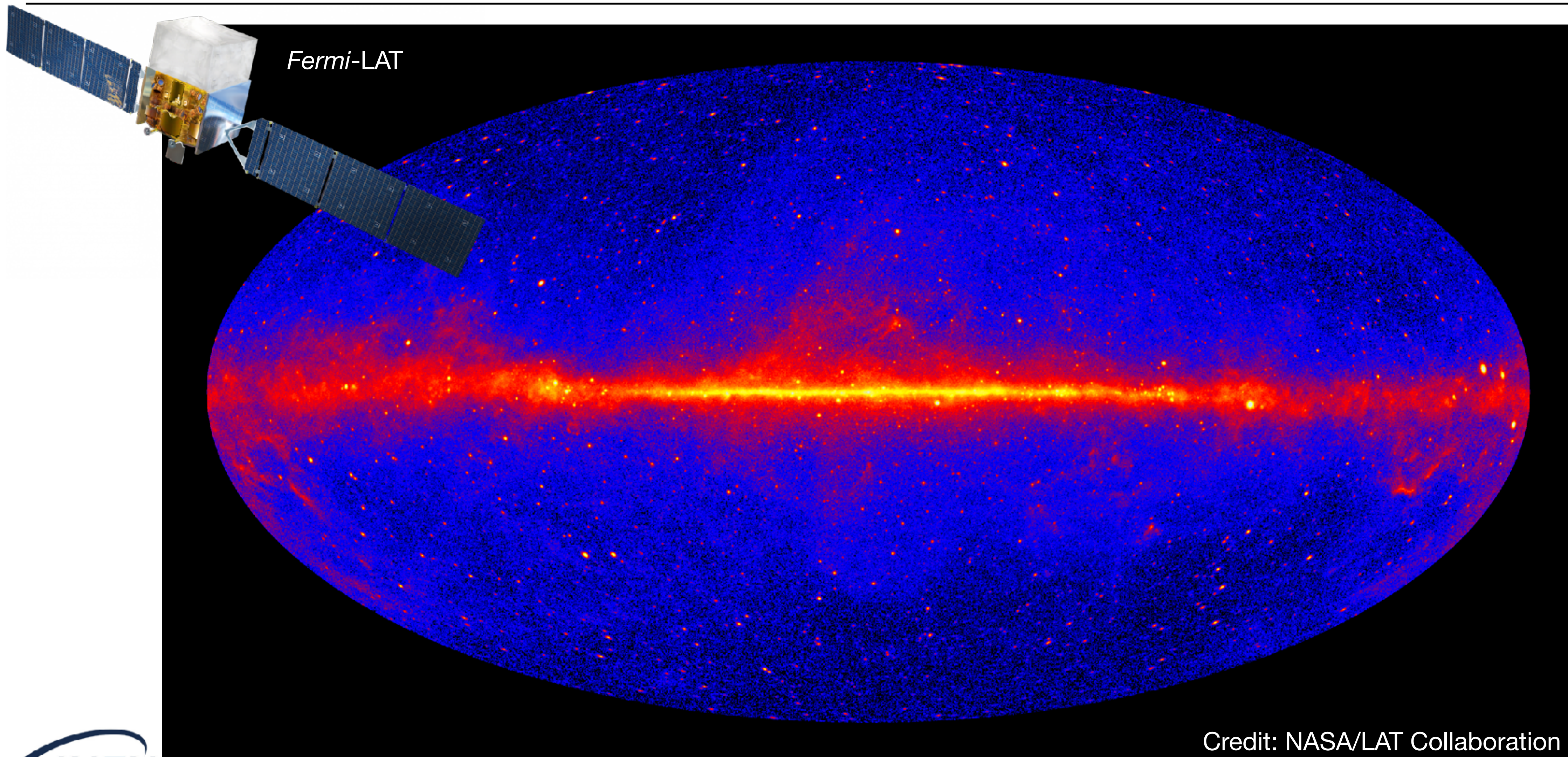


**CTAO**

LST  
COLLABORATION

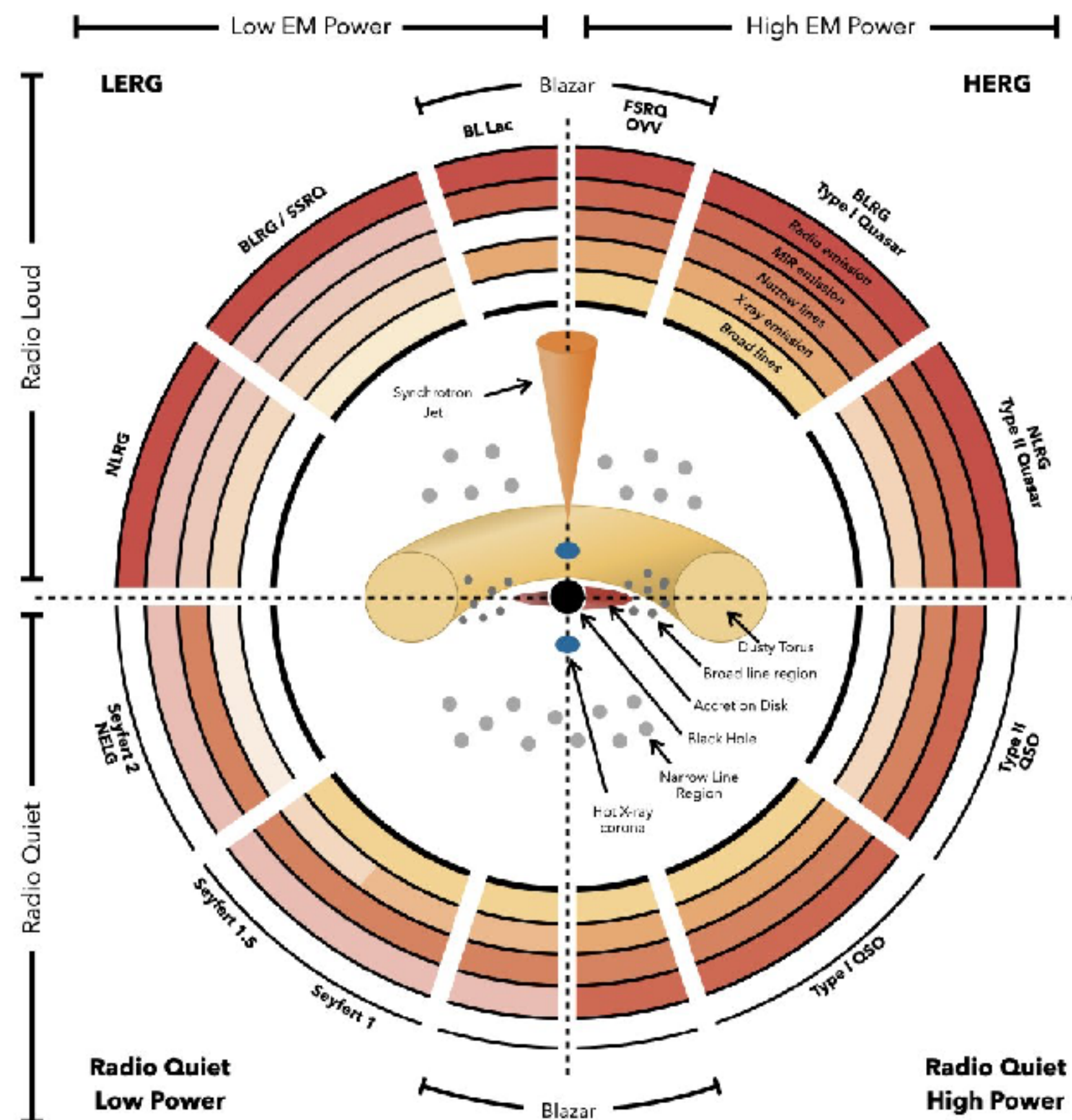
Image credit: Daniel López / IAC

# The $\gamma$ -ray sky

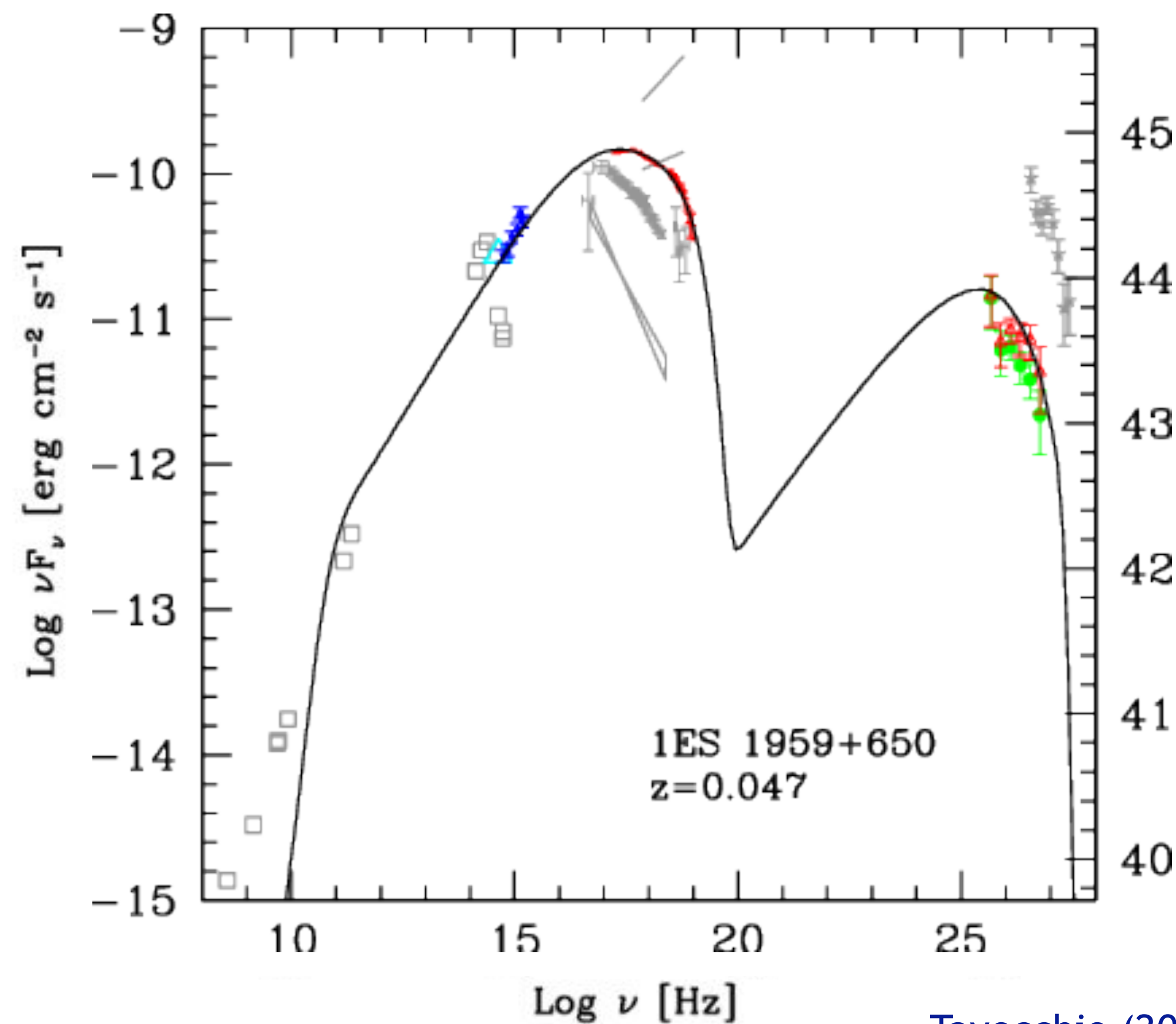


# Active galactic nuclei

Extragalactic  $\gamma$ -ray sky population dominated by active galactic nuclei (AGN), mostly blazars

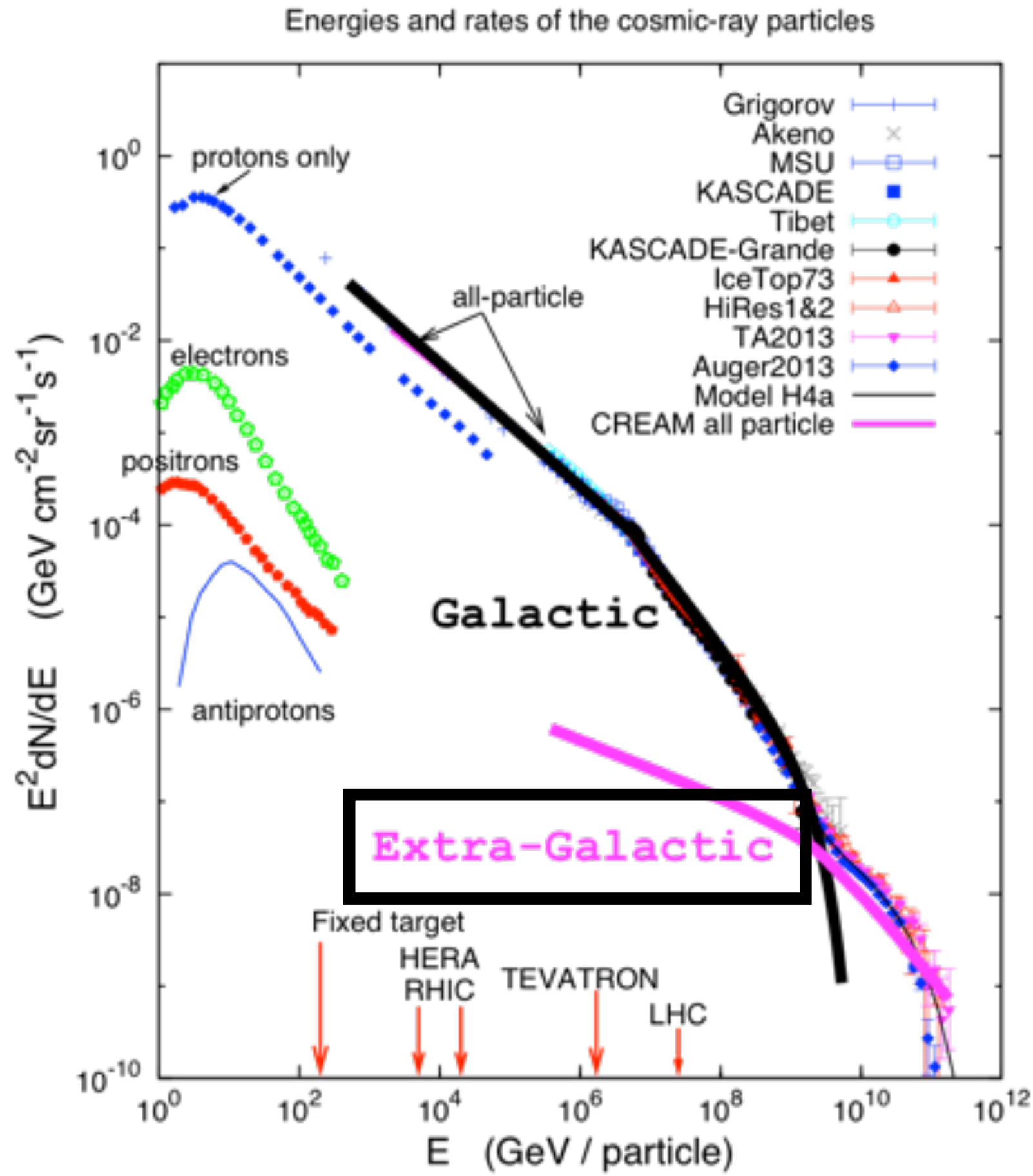


J. E. Thorne

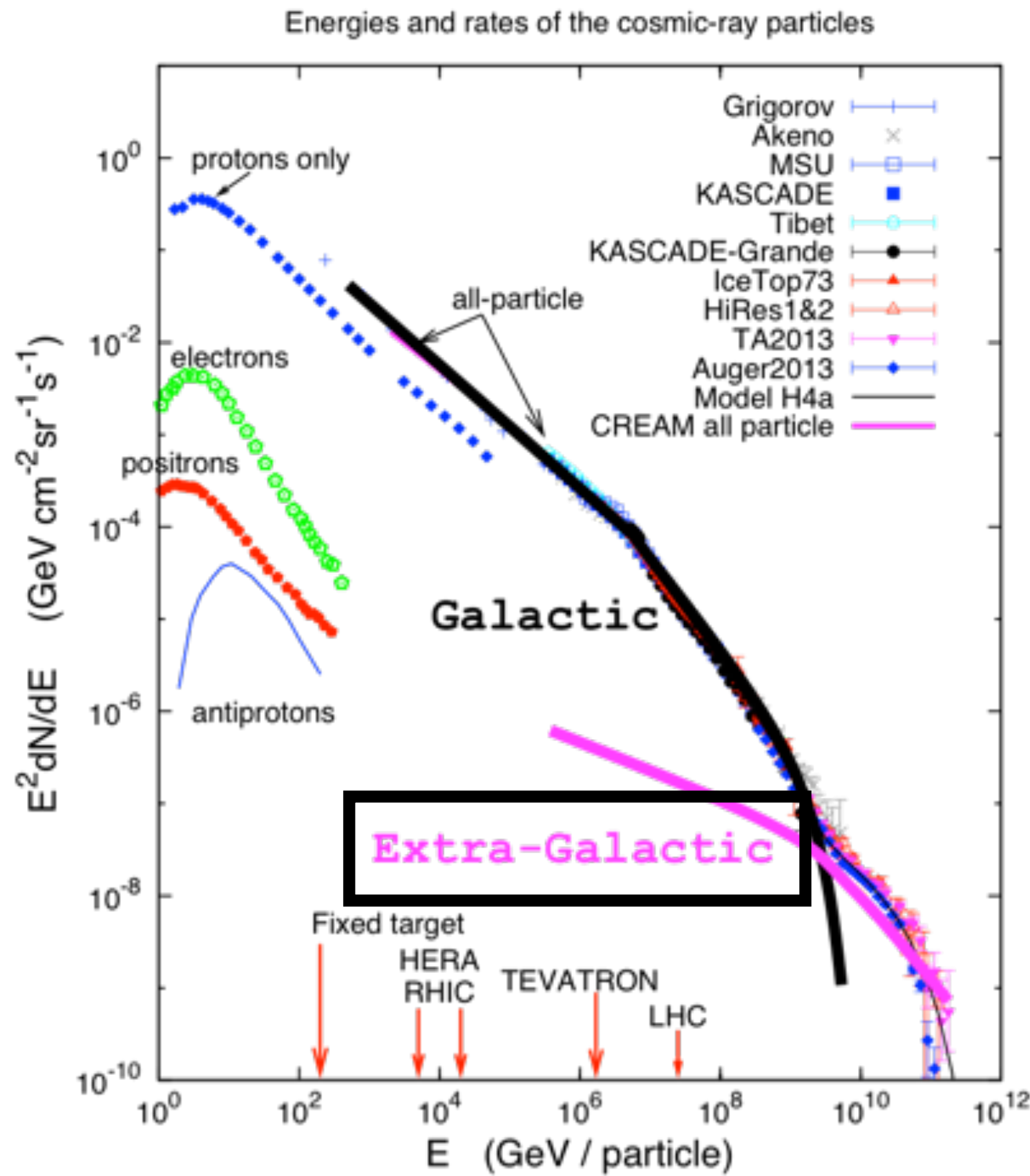


Tavecchio (2008)

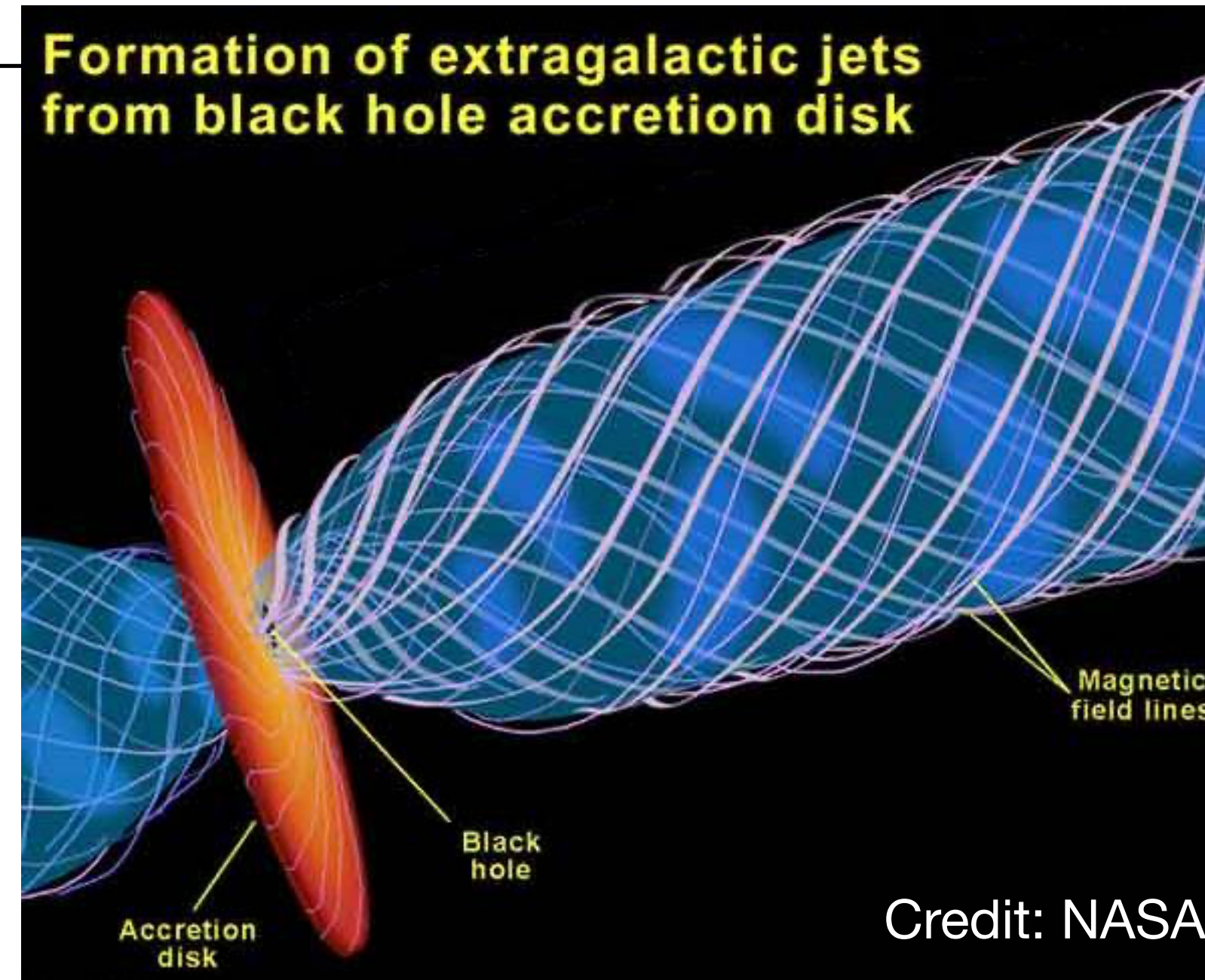
# Extragalactic $\gamma$ -ray observations



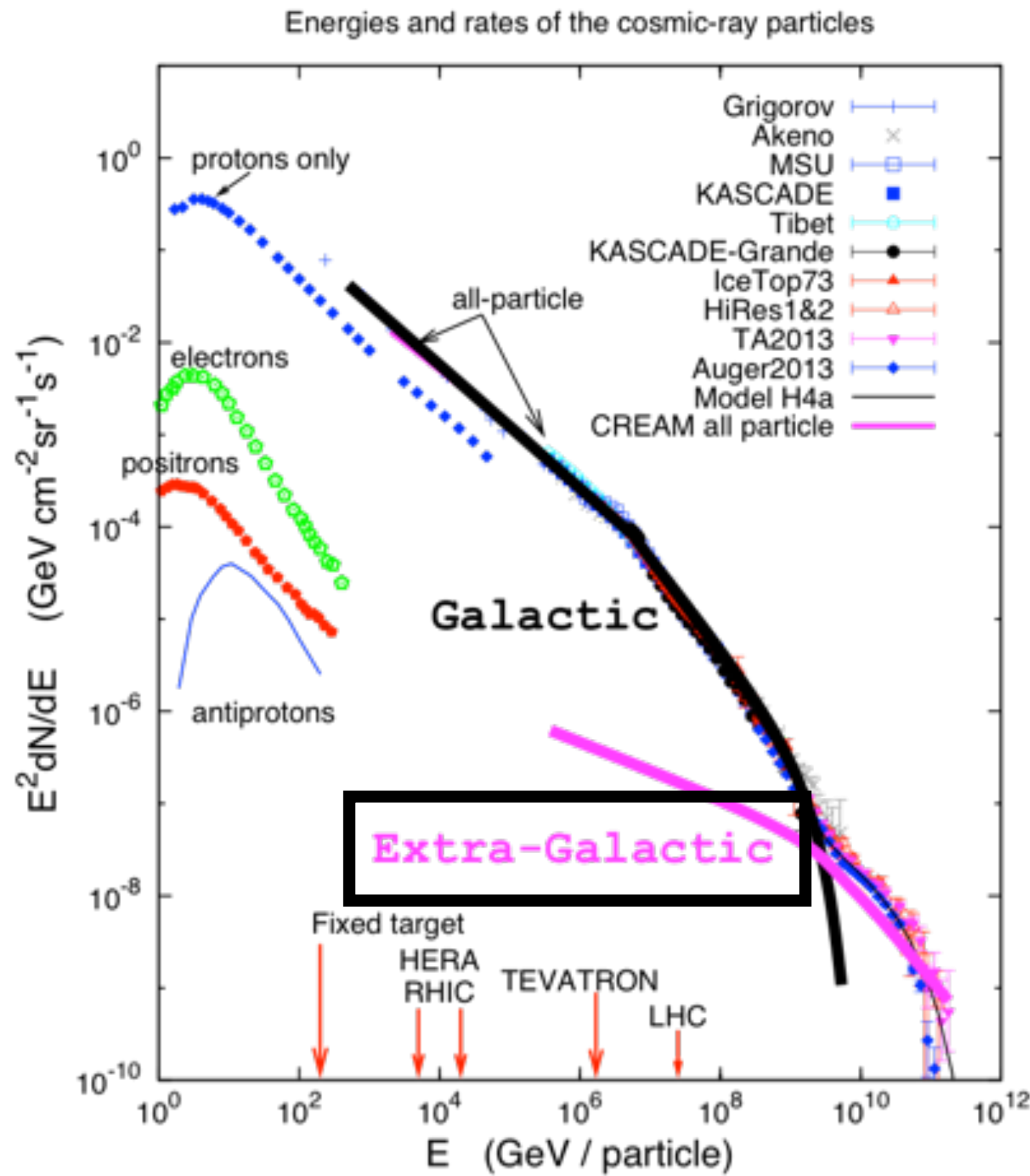
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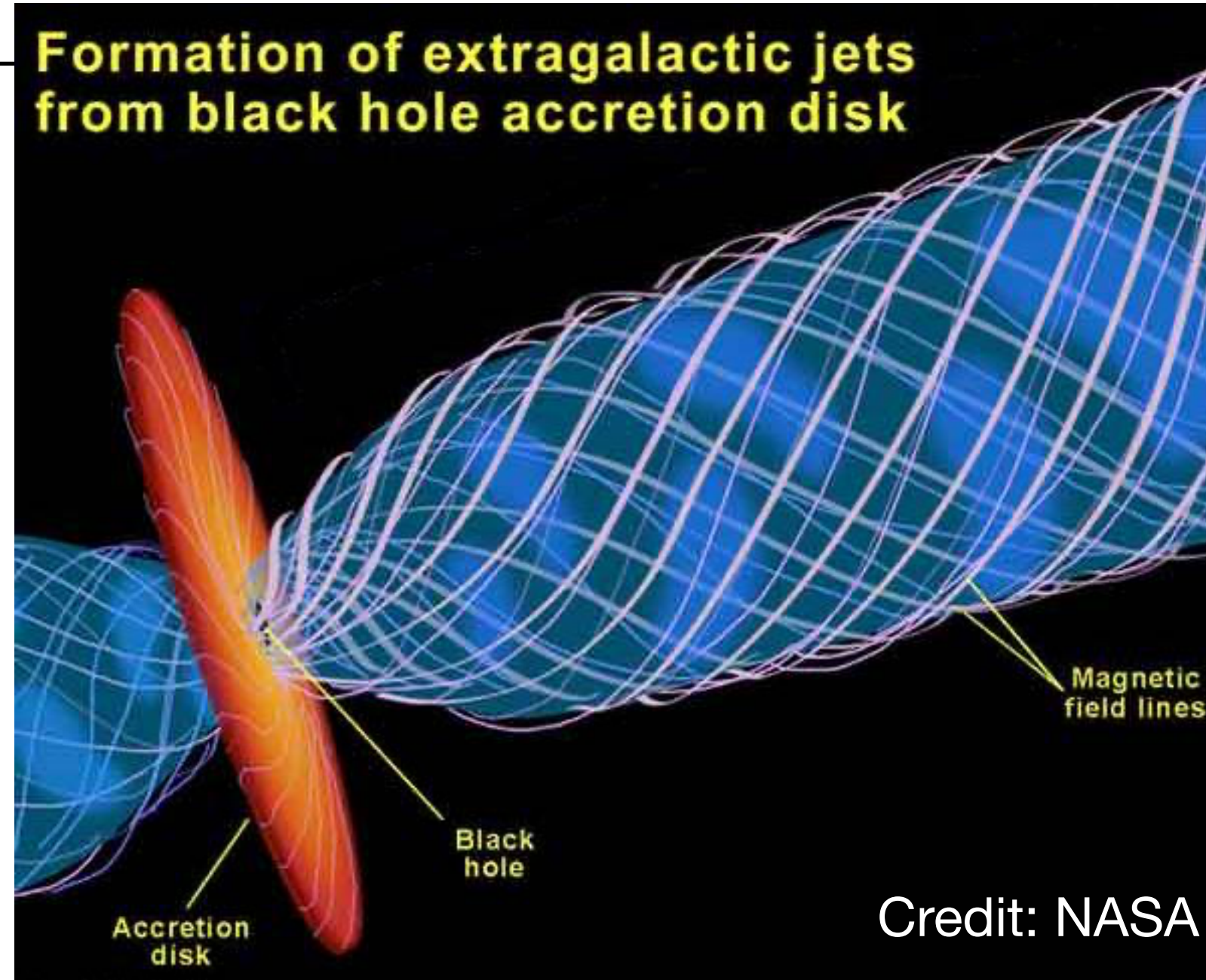
Formation of extragalactic jets from black hole accretion disk



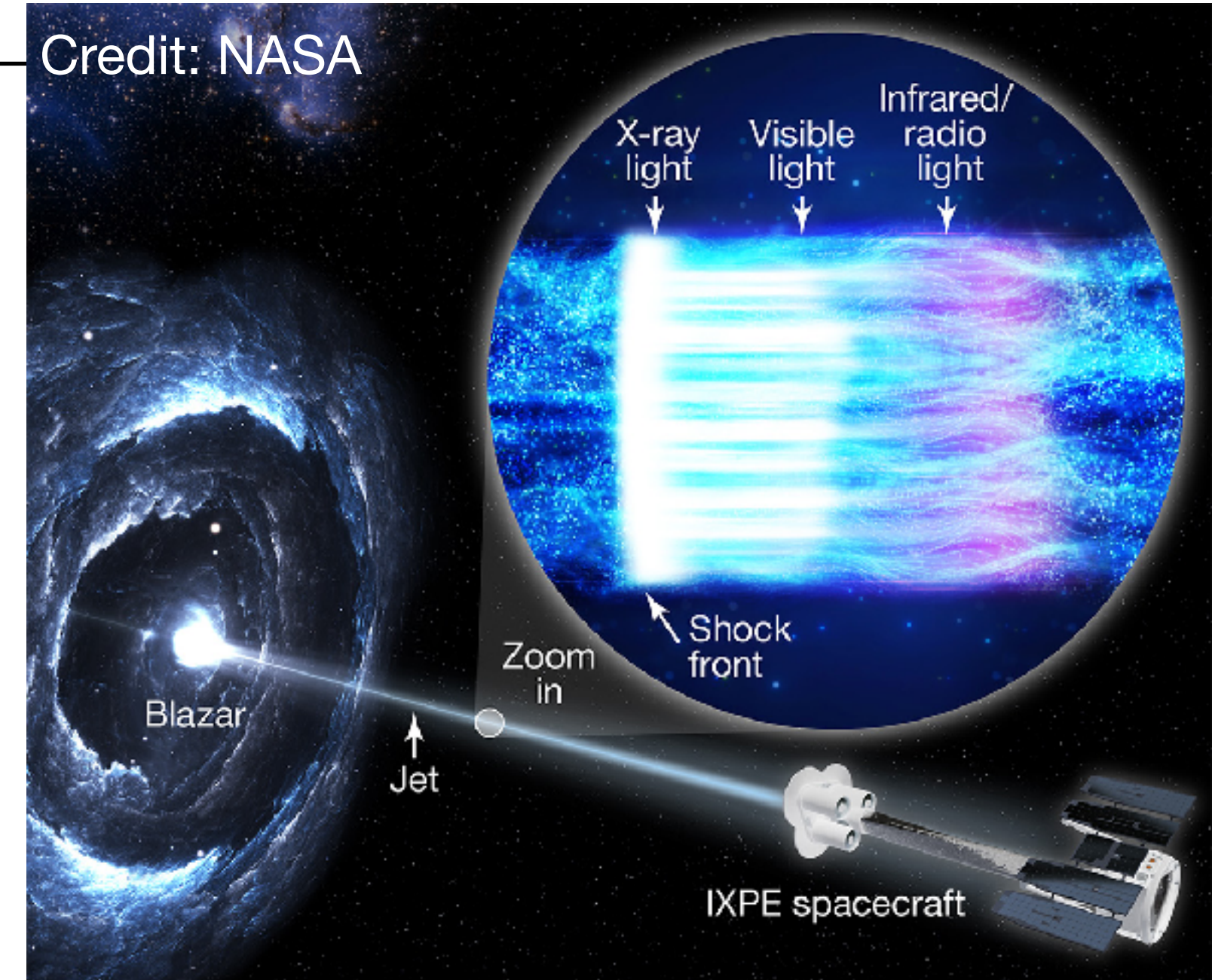
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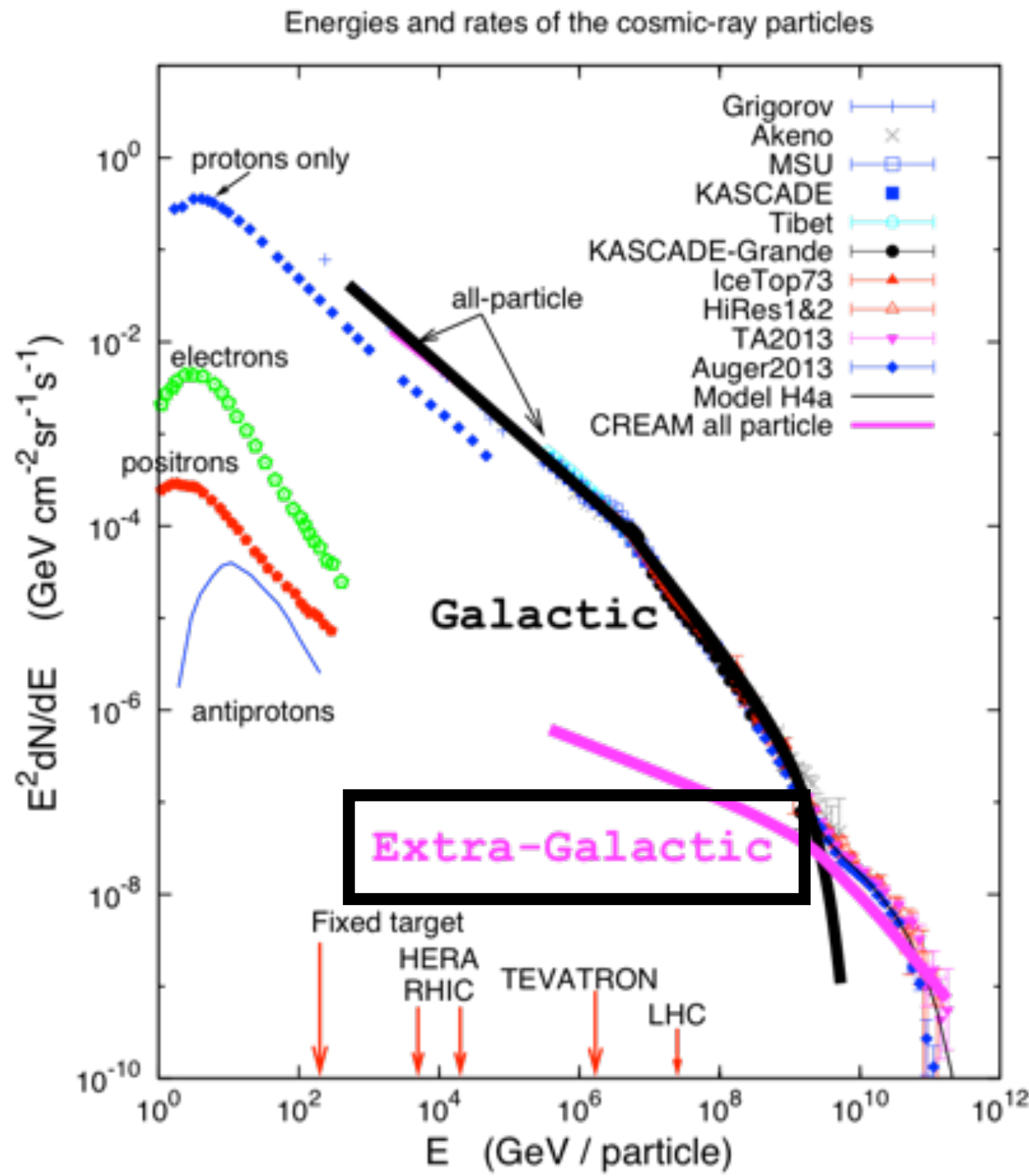
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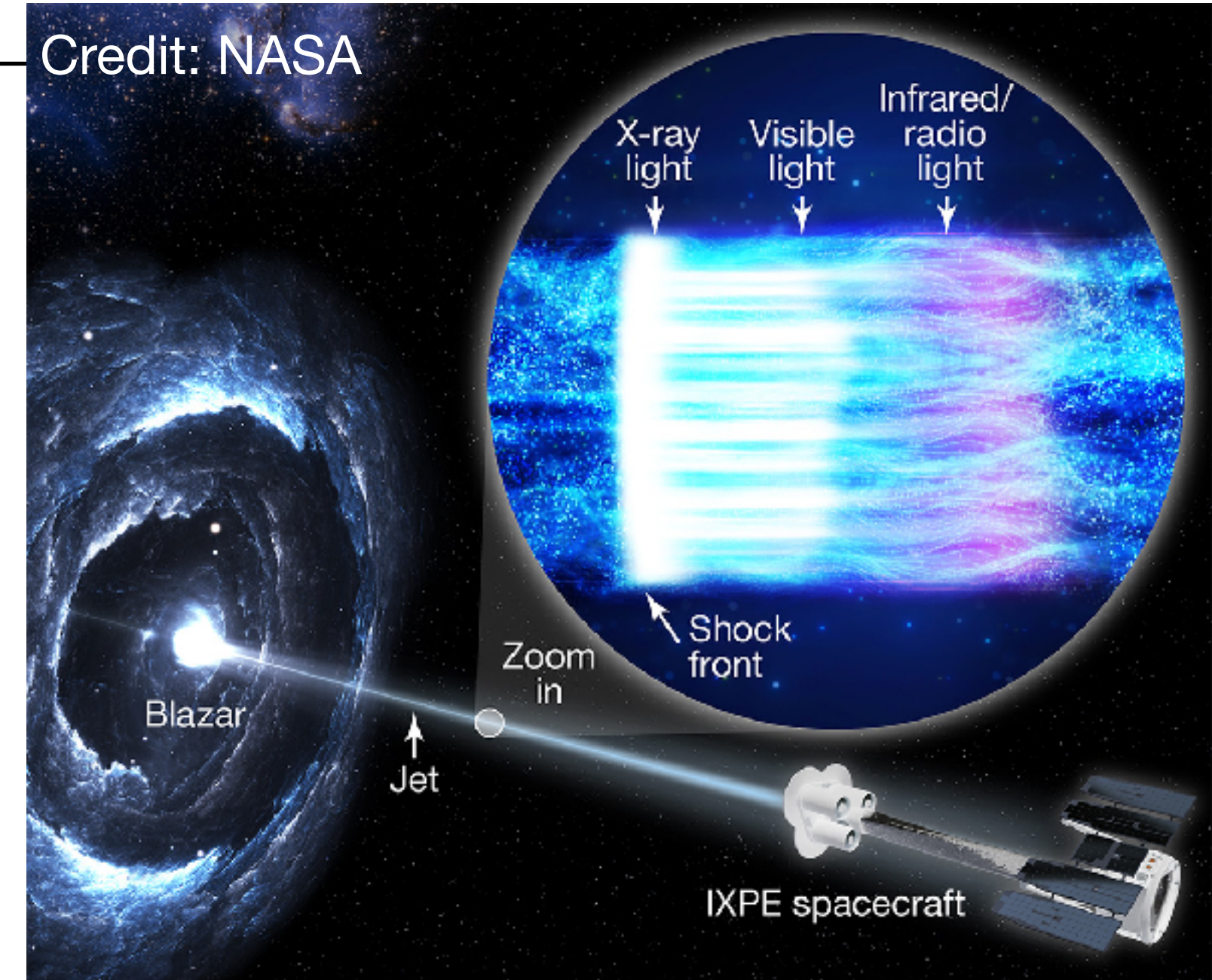
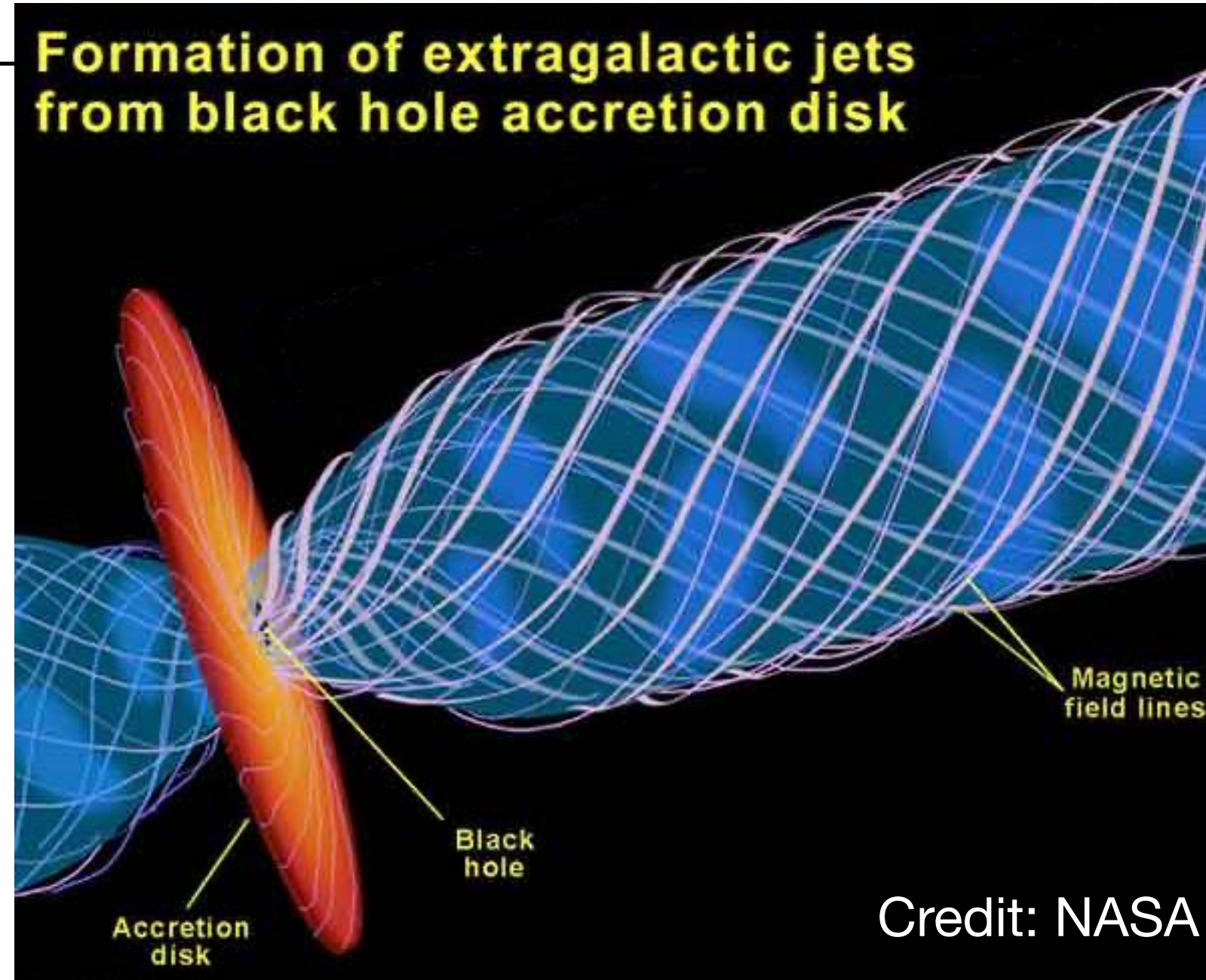
Credit: NASA



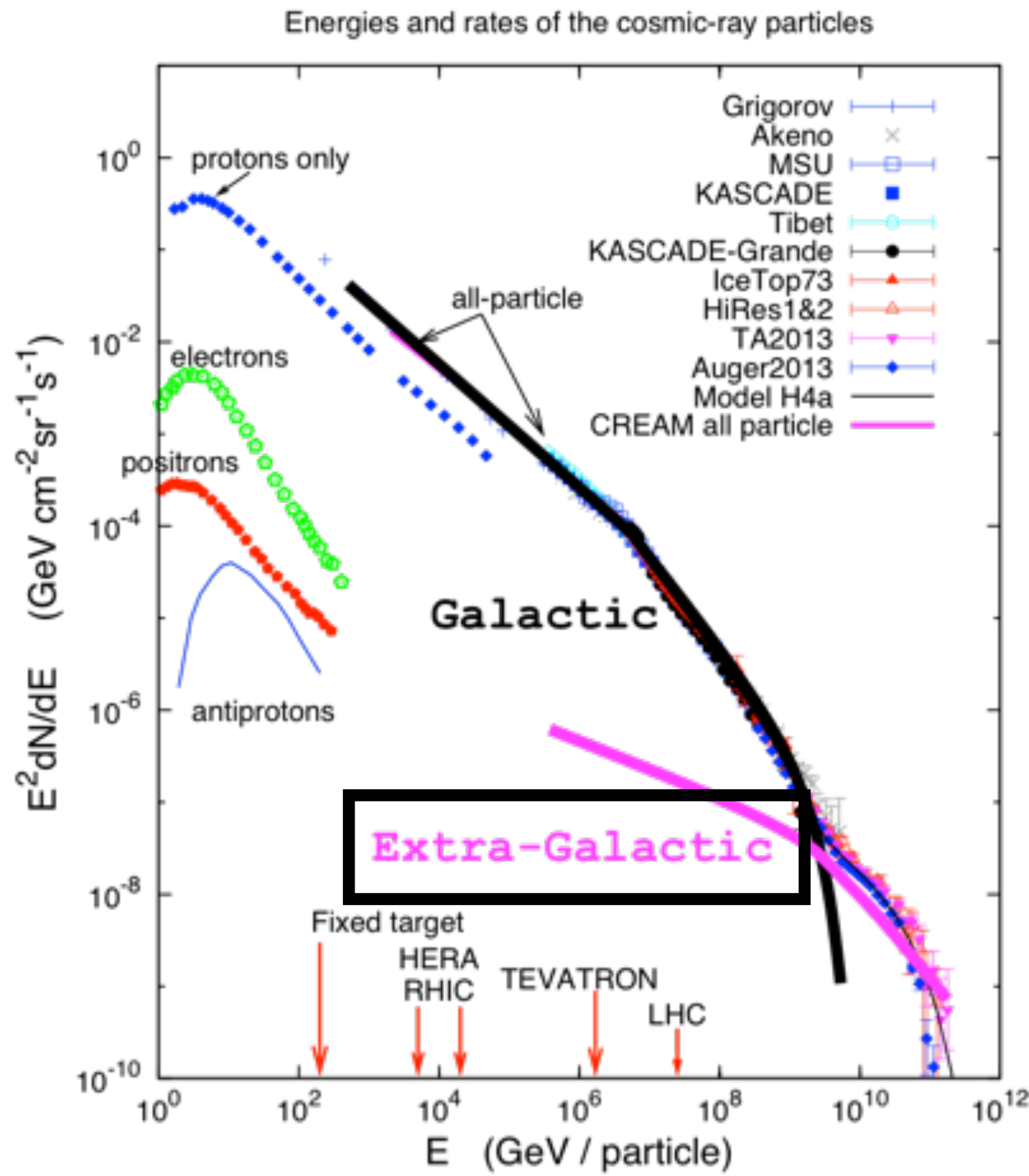
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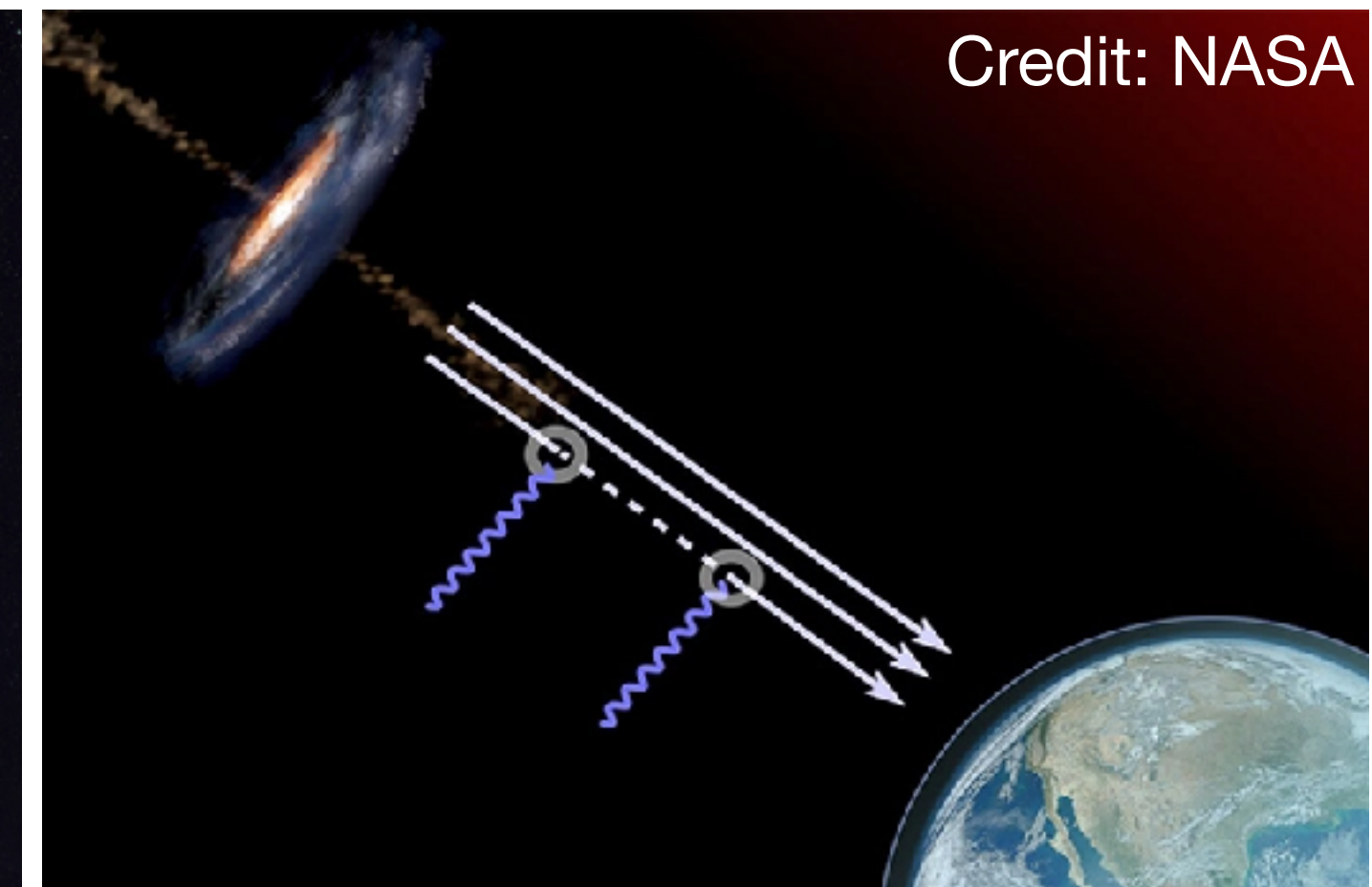
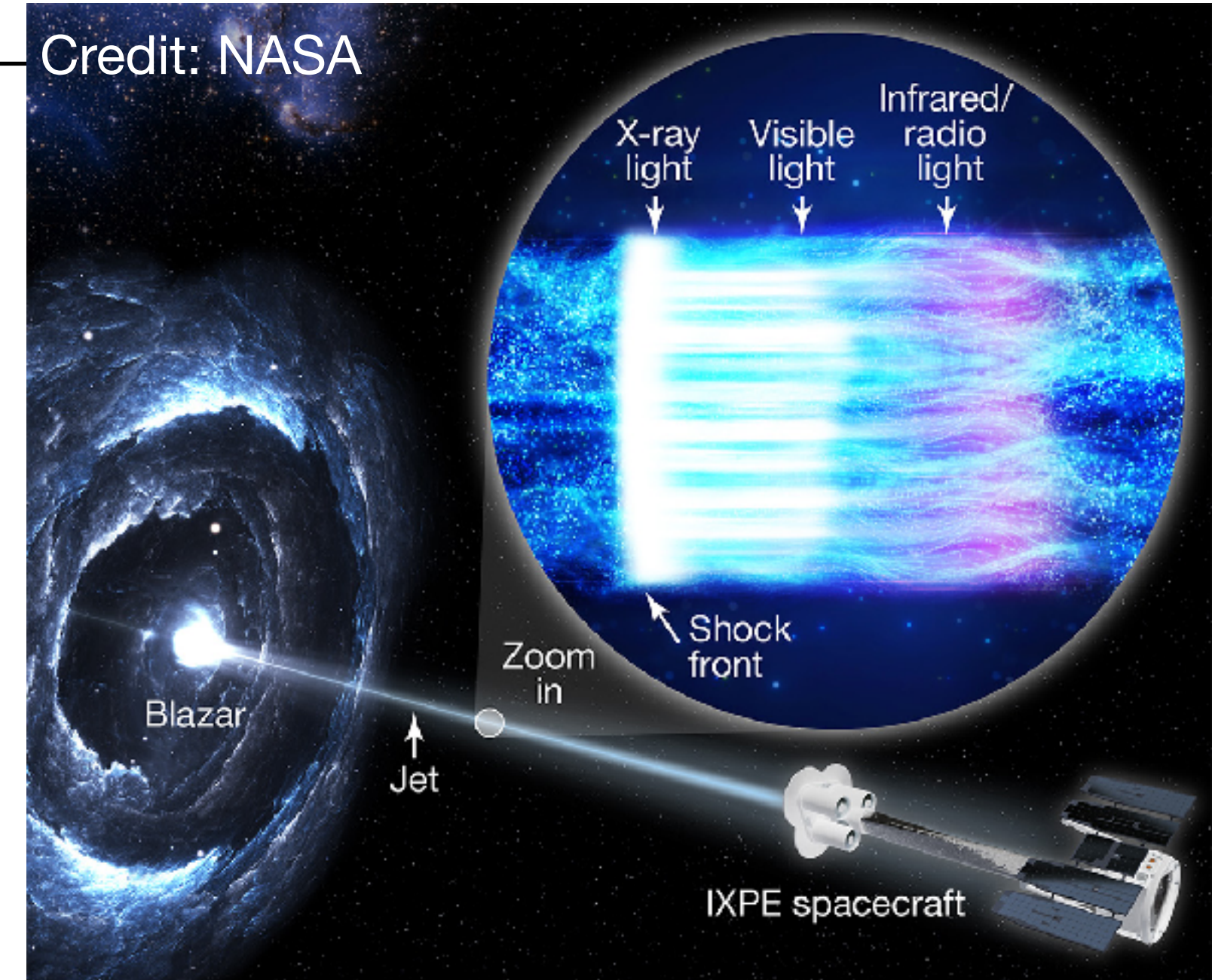
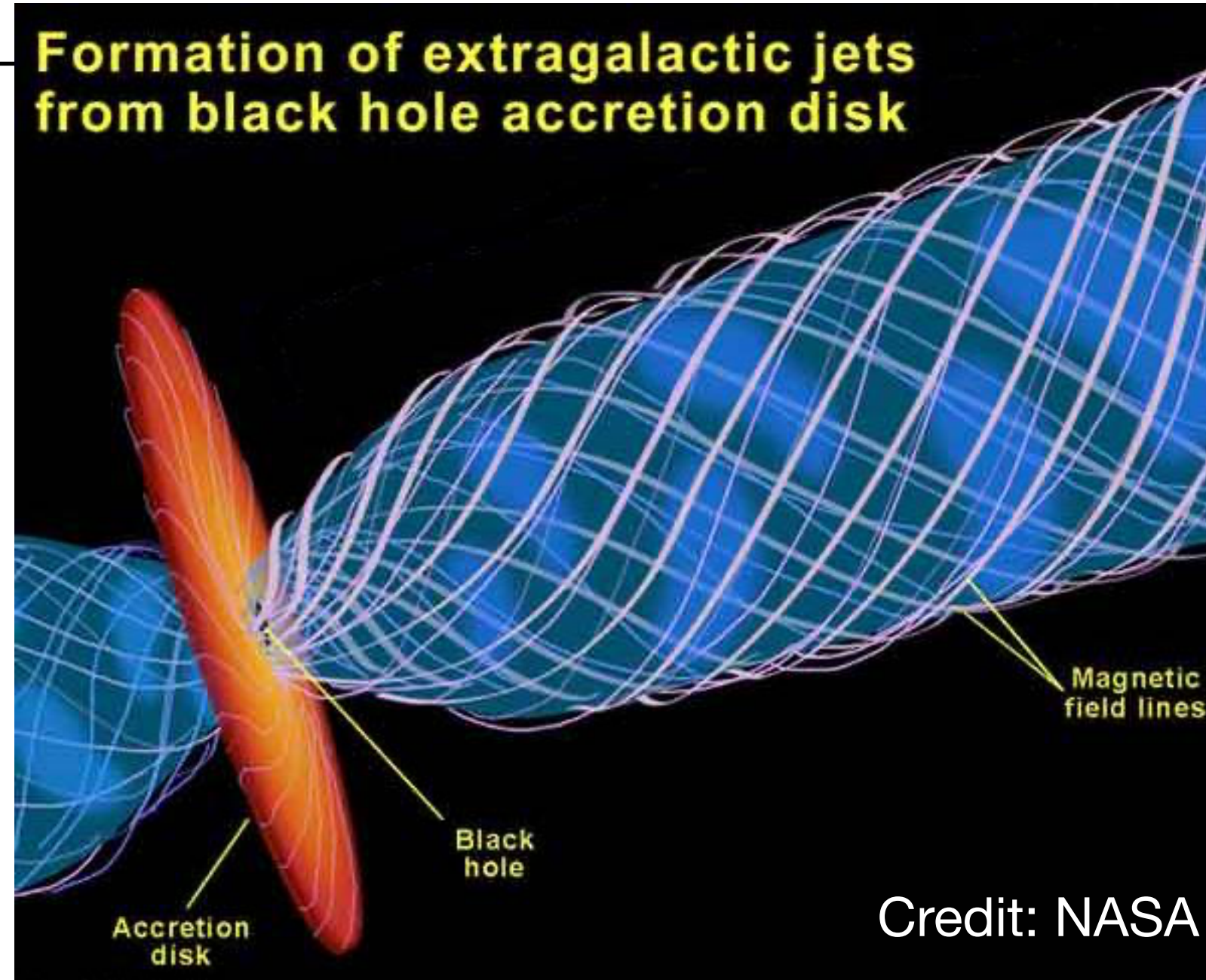
## Formation of extragalactic jets from black hole accretion disk



# Extragalactic $\gamma$ -ray observations



## Formation of extragalactic jets from black hole accretion disk



# Cherenkov technique

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The LAT has been monitoring the  $\gamma$ -ray sky for the past 18 years up to a few GeV, but what about up to TeV energies?

# Cherenkov technique

The LAT has been monitoring the  $\gamma$ -ray sky for the past 18 years up to a few GeV, but what about up to TeV energies?

Imaging Atmospheric Cherenkov Telescope (IACT) technique



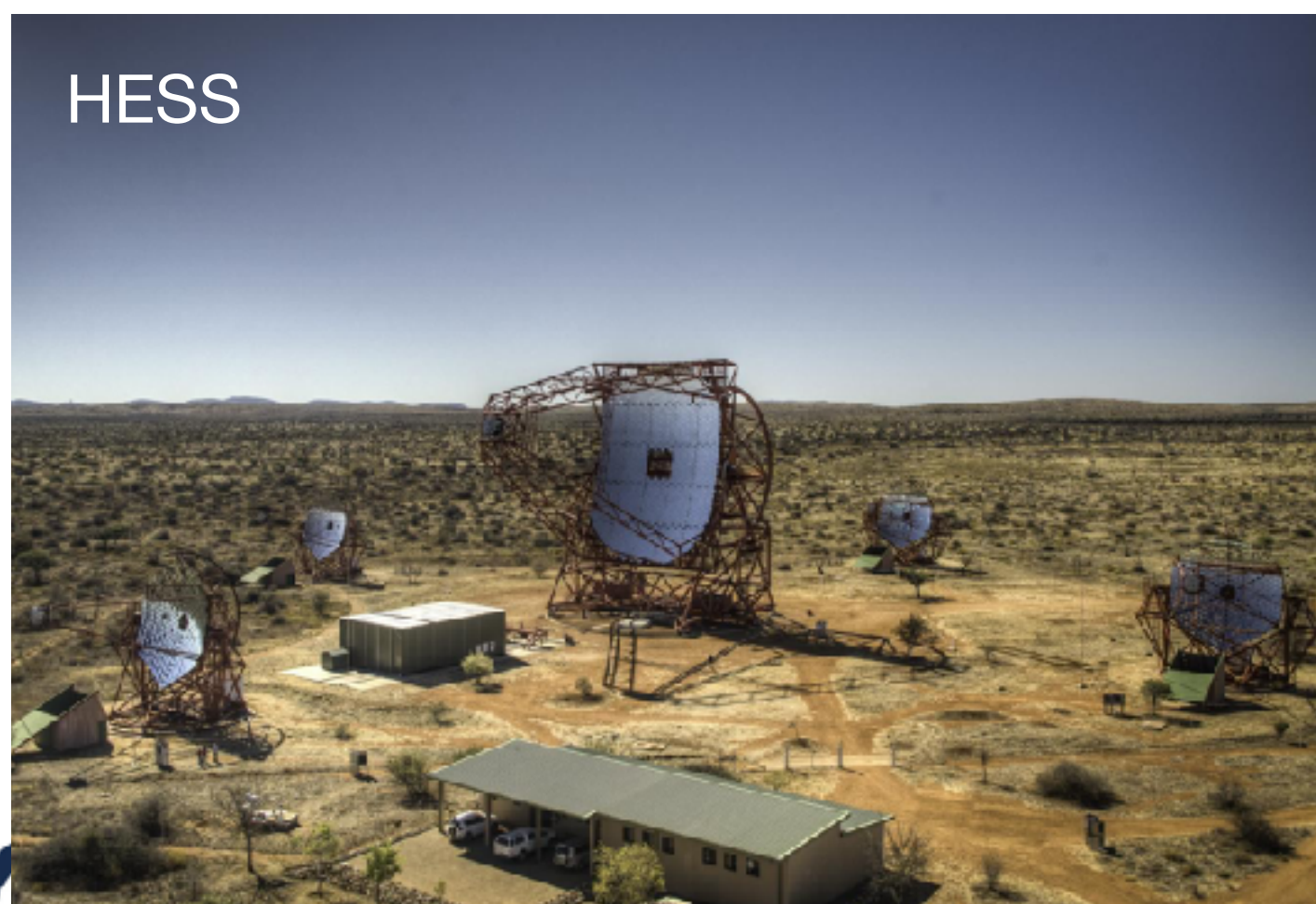
Credit: Daniel López / IAC





# Cherenkov technique

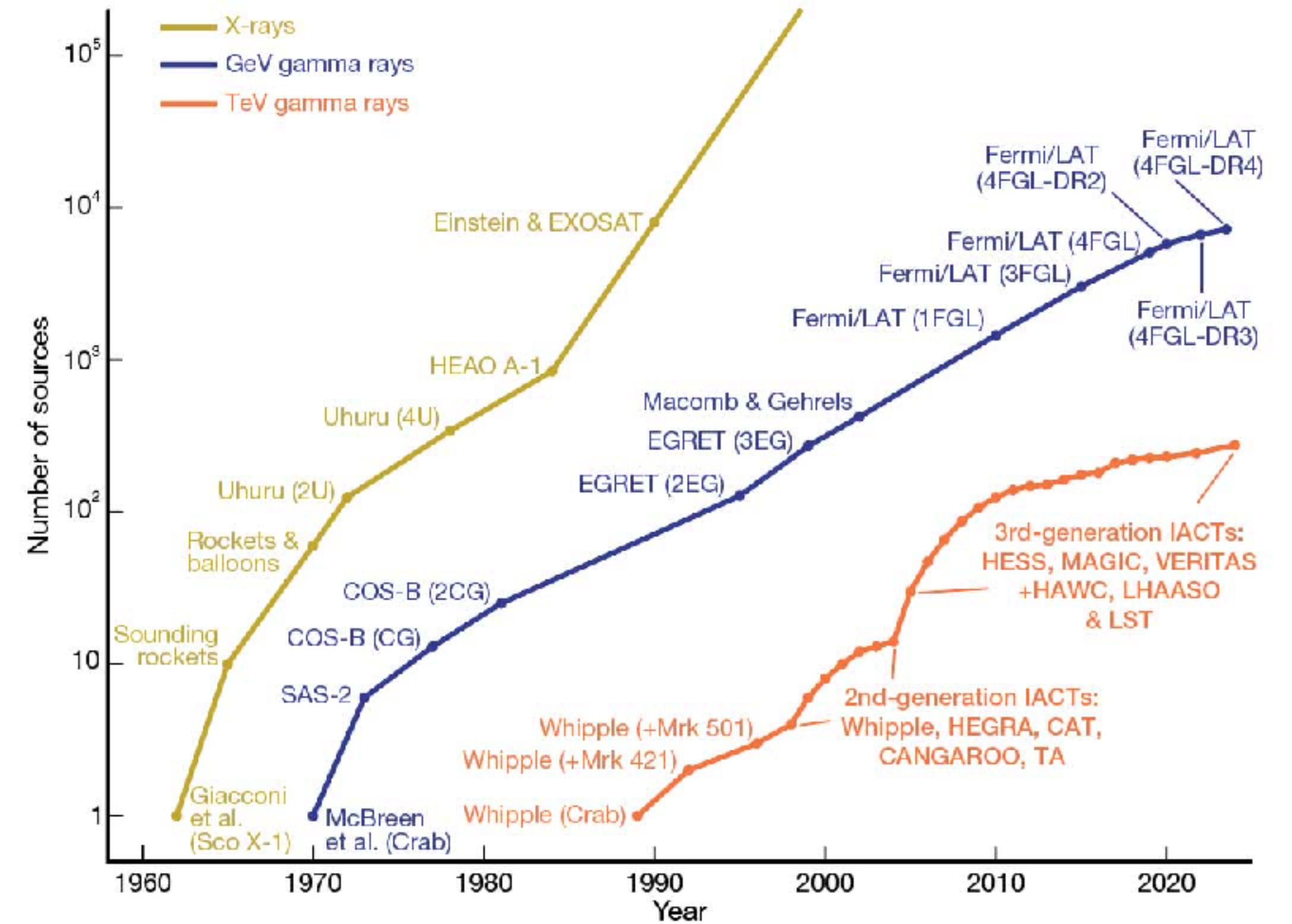
Current generation: **MAGIC** (La Palma, Spain), **HESS** (Namibia), **VERITAS** (Arizona, US)



Credit: CTAO

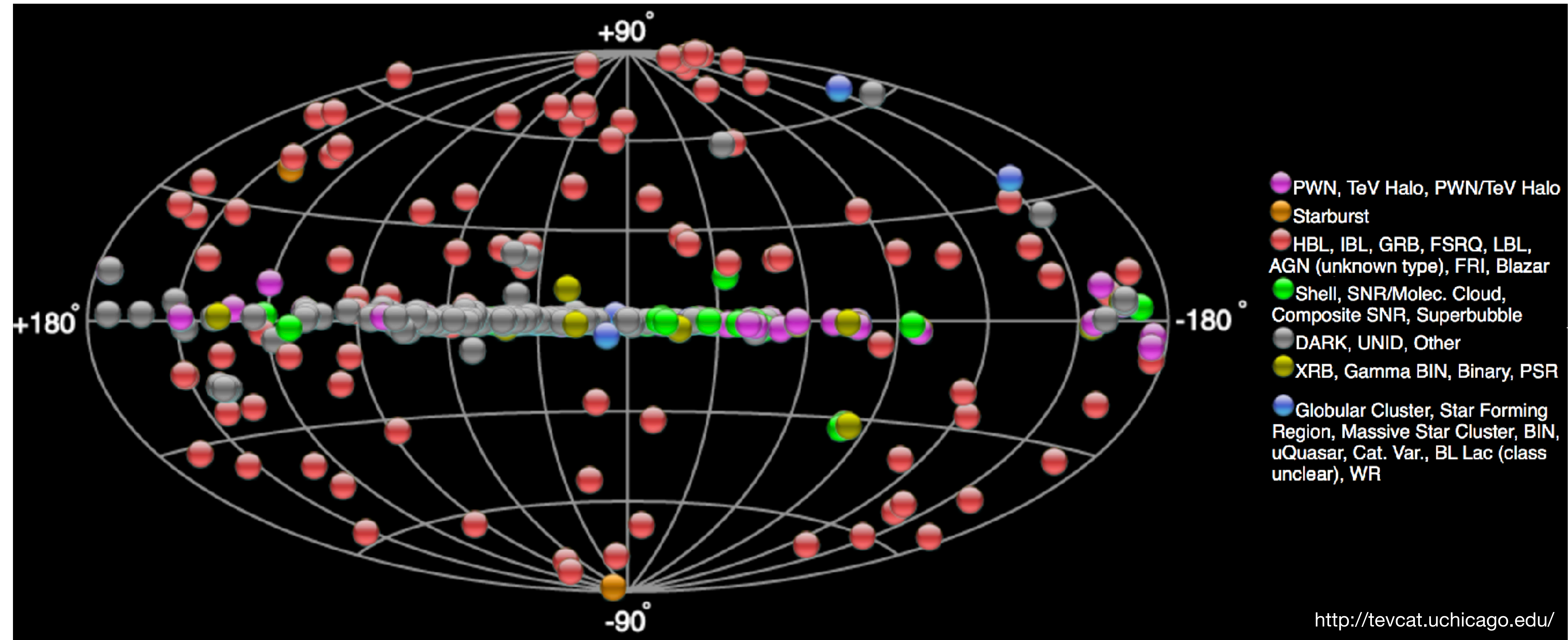
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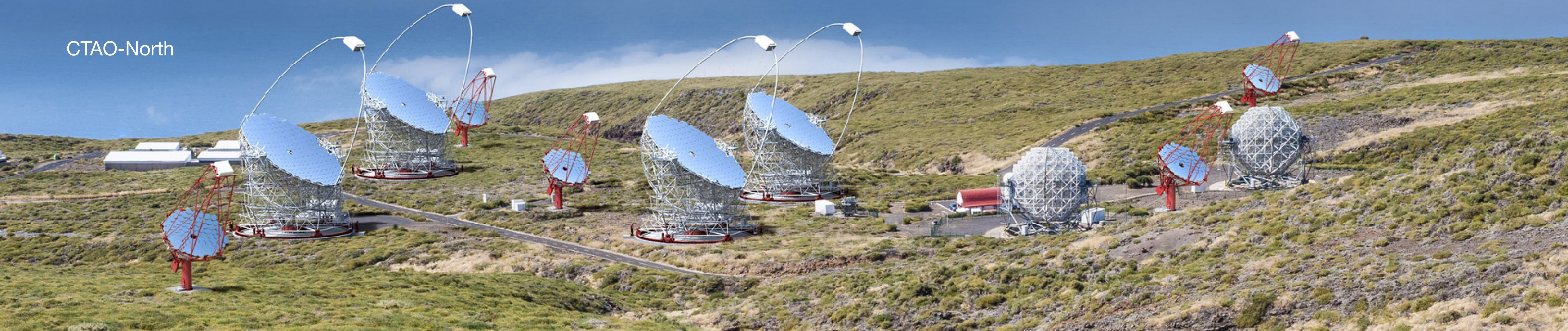
# Very-high-energy (VHE) $\gamma$ -ray sky



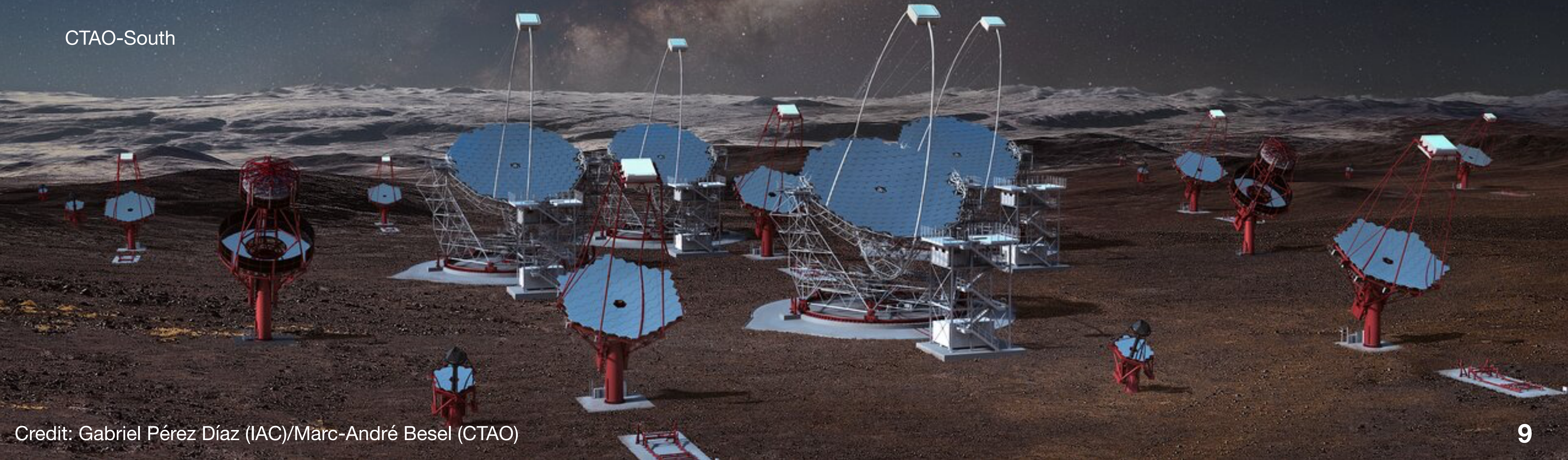
<http://tevcat.uchicago.edu/>

# Cherenkov Telescope Array Observatory

CTAO-North



CTAO-South



# Cherenkov Telescope Array Observatory

New  $\gamma$ -ray observatory under construction

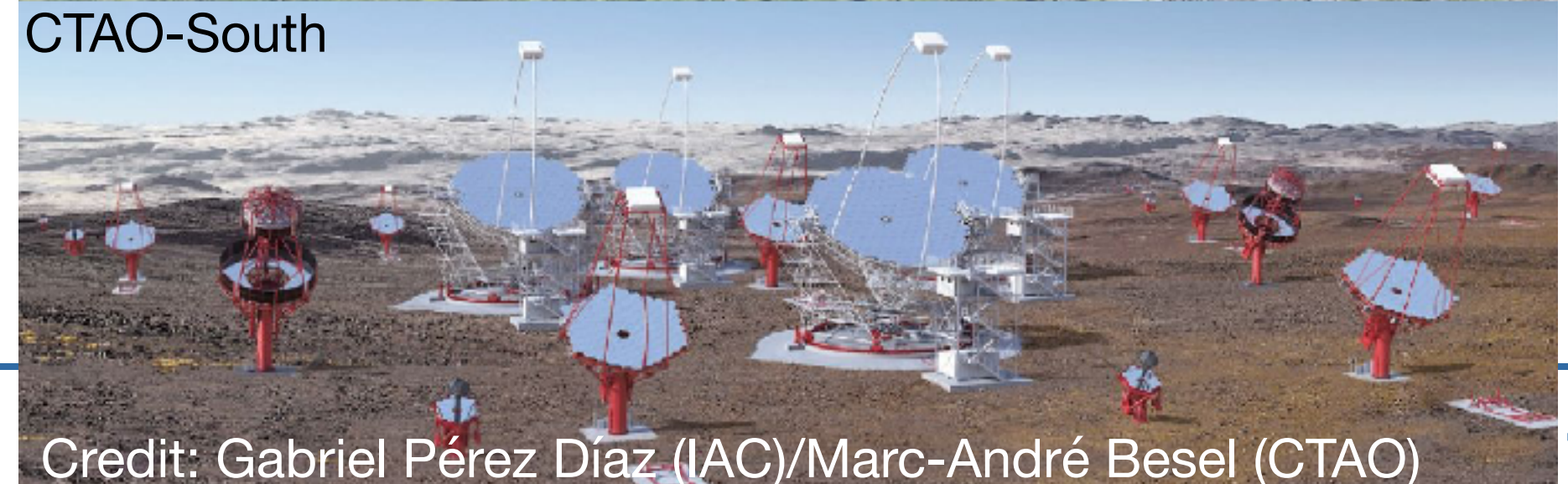
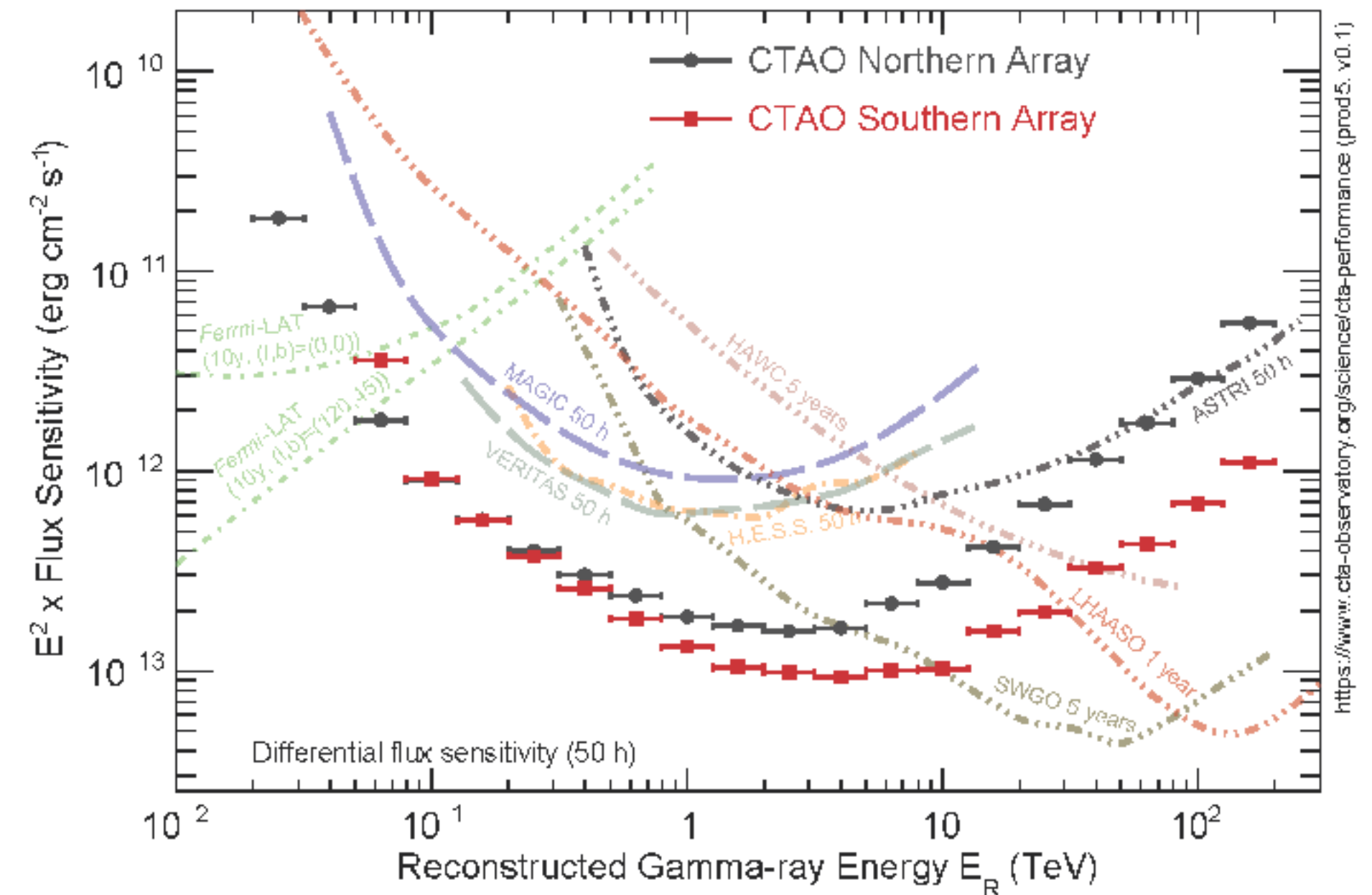
Two sites:

- CTAO-North: La Palma (Canary Islands, Spain)
- CTAO-South: Paranal Observatory (Atacama Desert, Chile)

Better performance than the current generation:

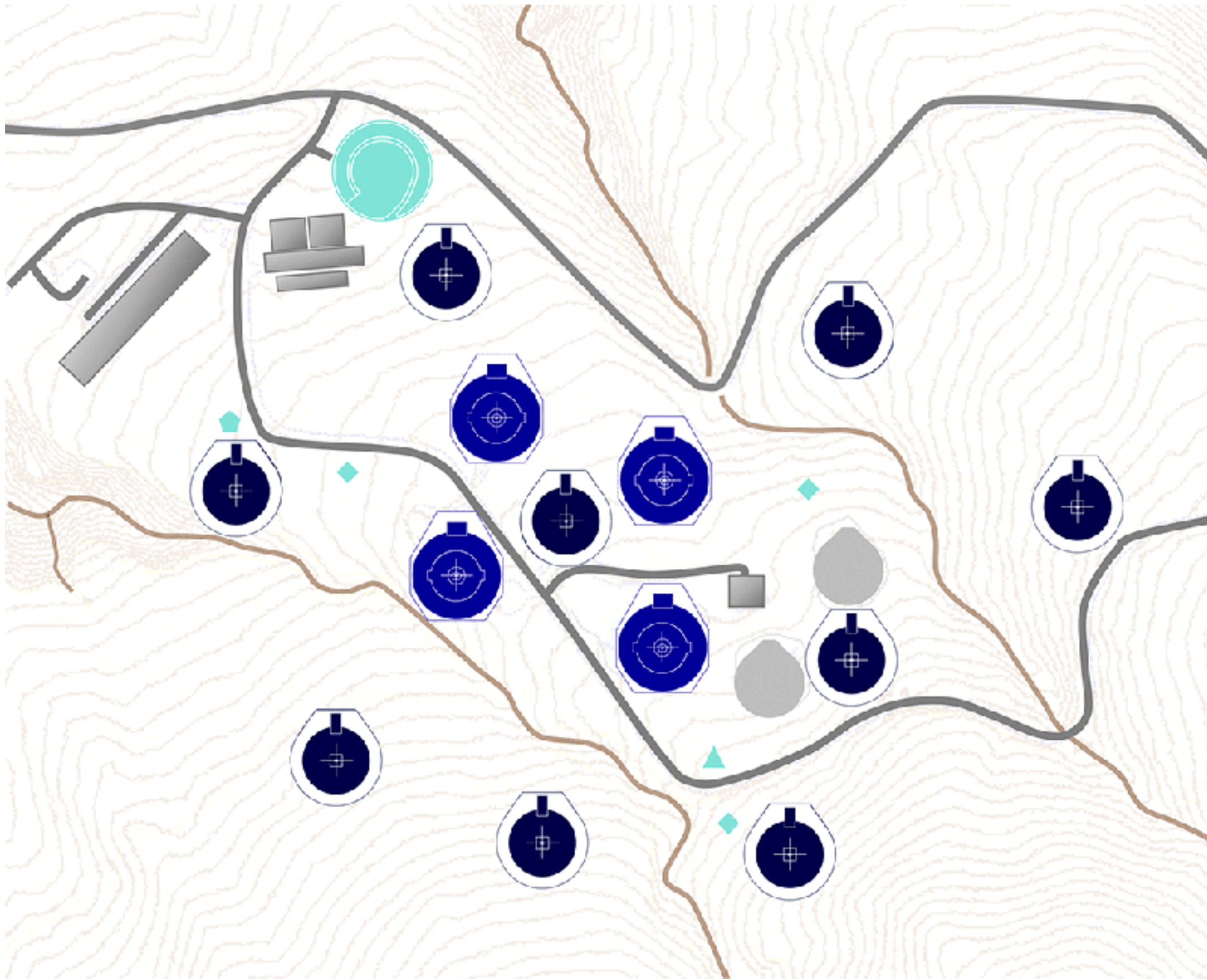
- Better sensitivity (x10)
- Wider energy range (20 GeV - 300 TeV)

First telescope in commissioning and taking data: **LST-1**

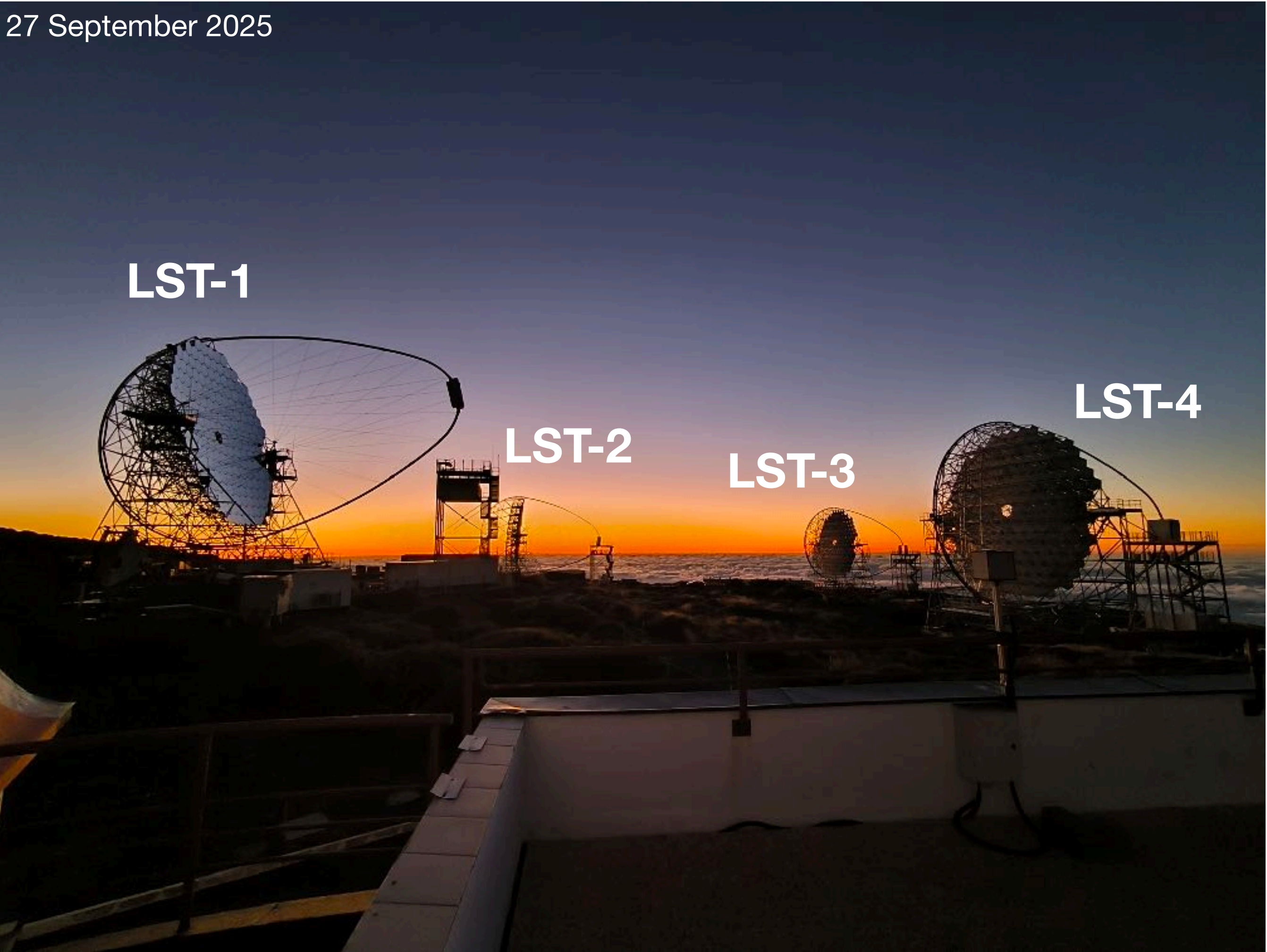


# Cherenkov Telescope Array Observatory

CTAO-North

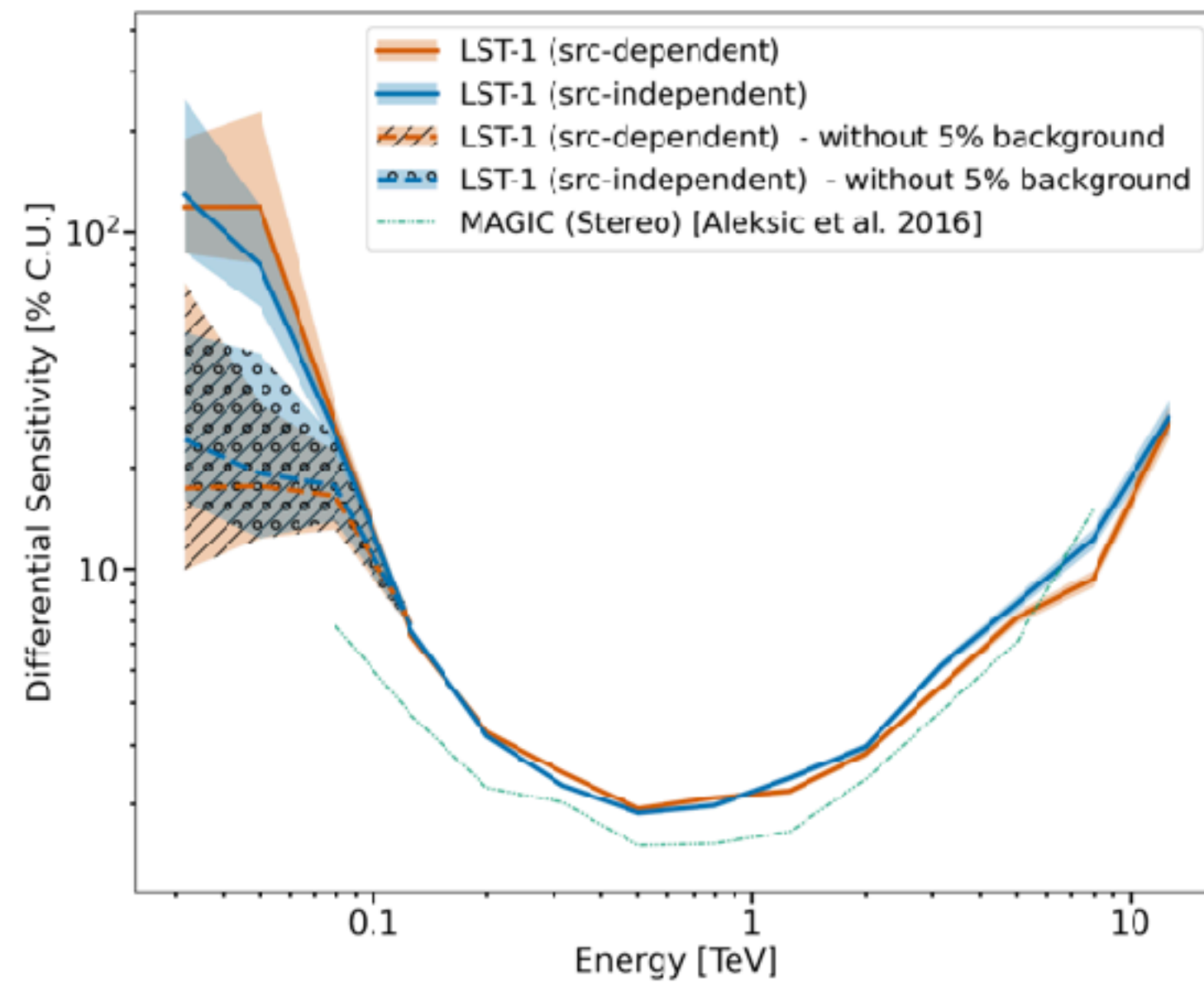


27 September 2025

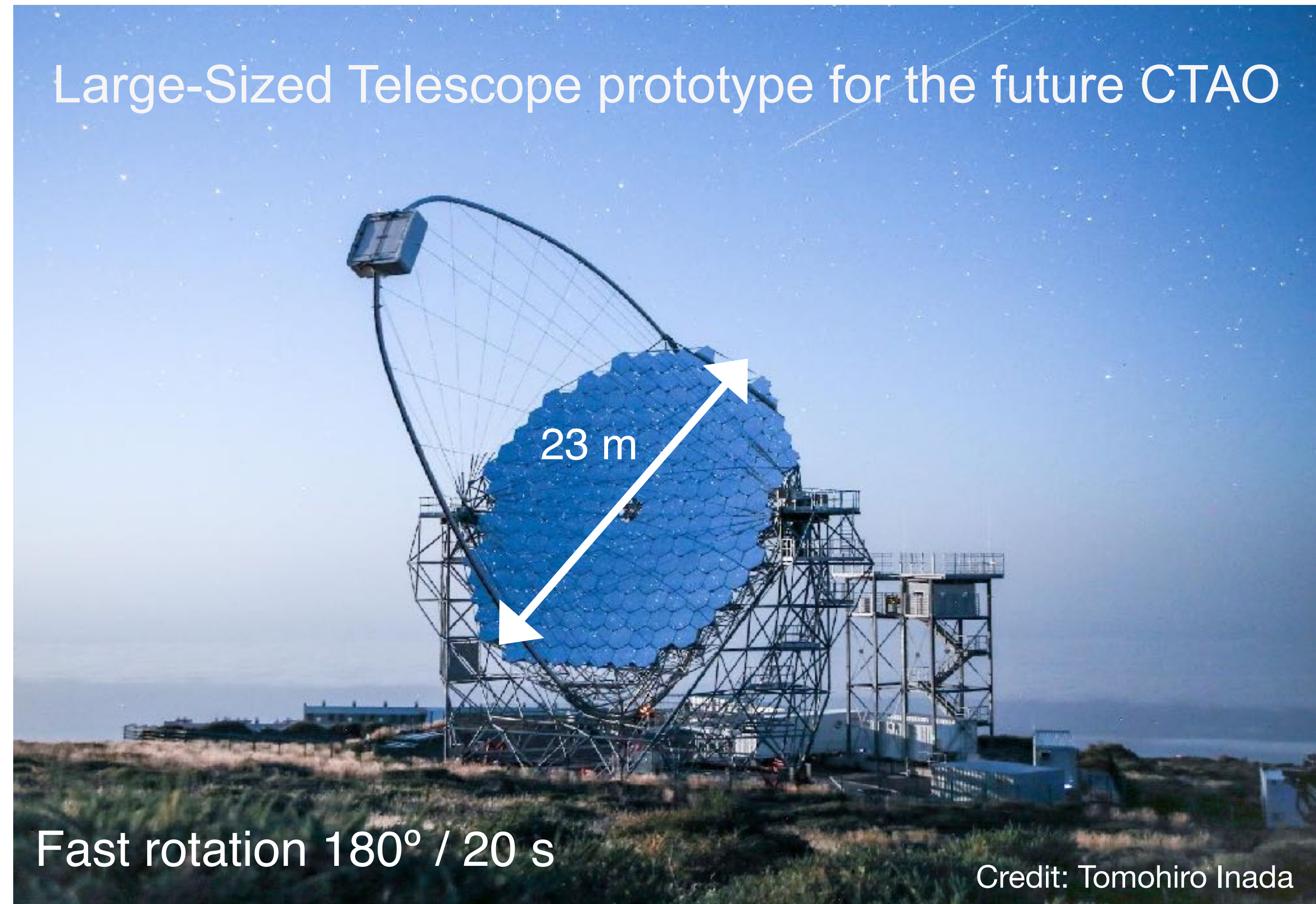


# Large-Sized Telescope (LST-1)

- First telescope of the northern array
- Operating since 2020
- **Lowest energy threshold** among current Cherenkov telescopes:  $\sim 30$  GeV

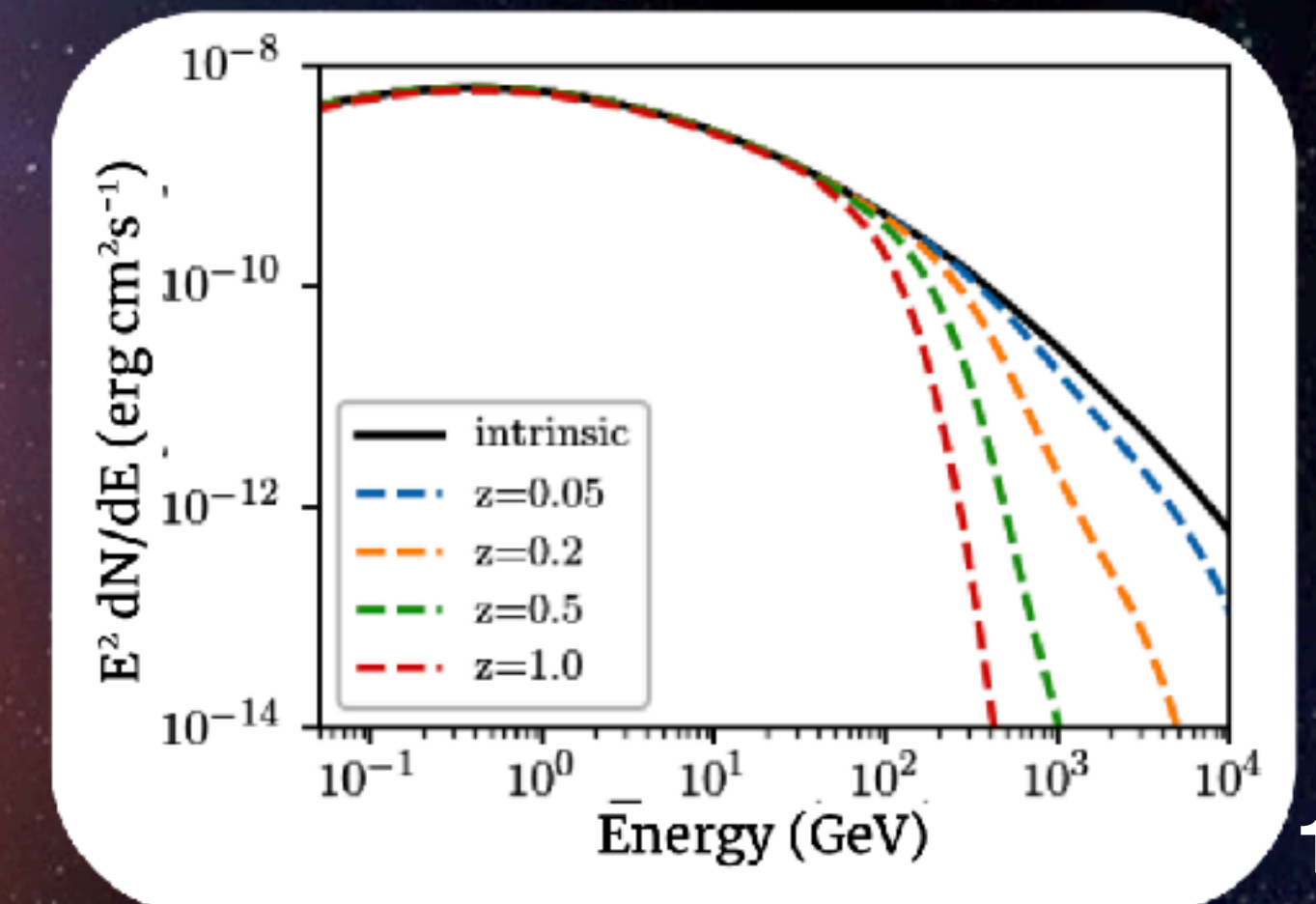
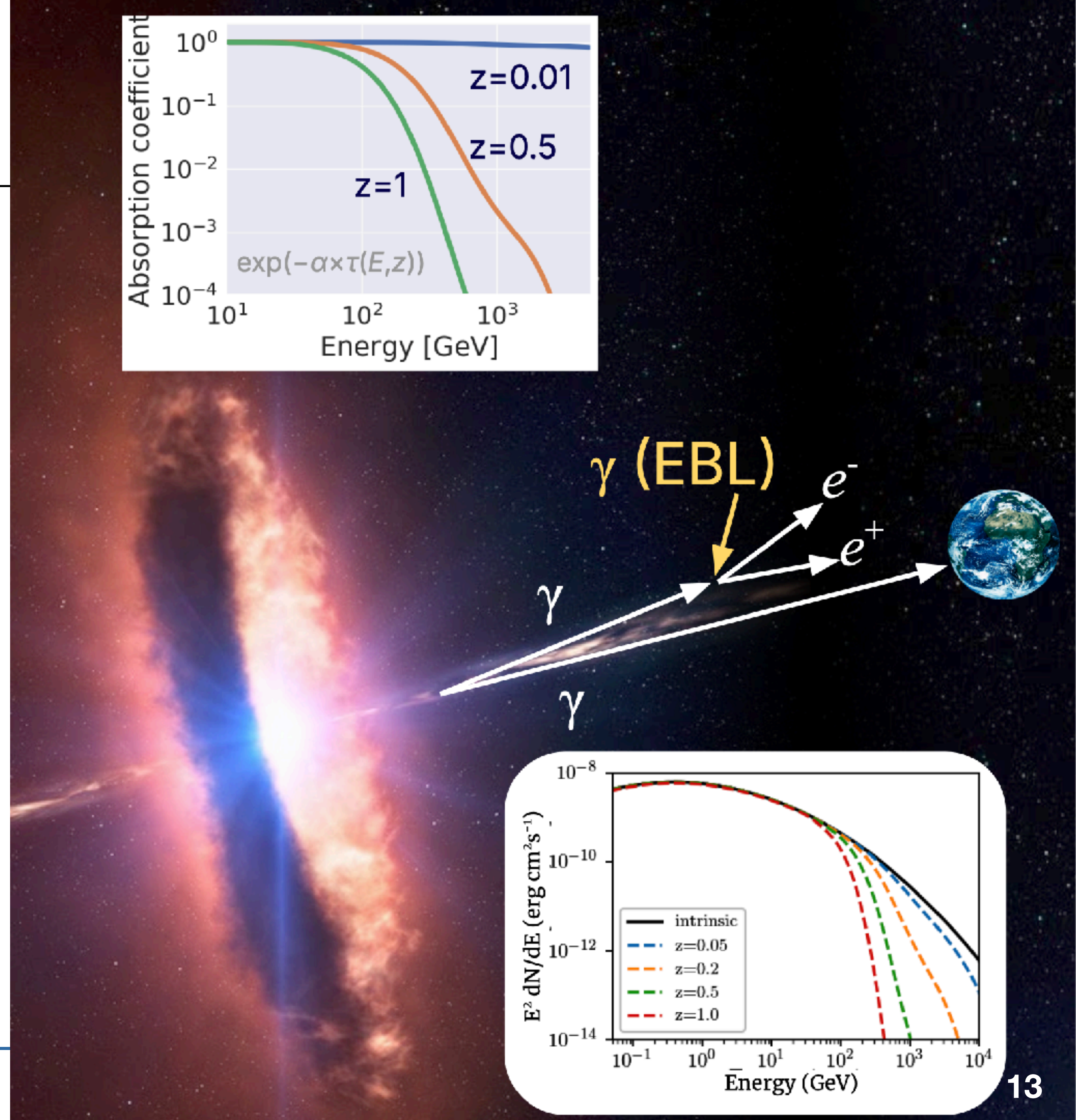
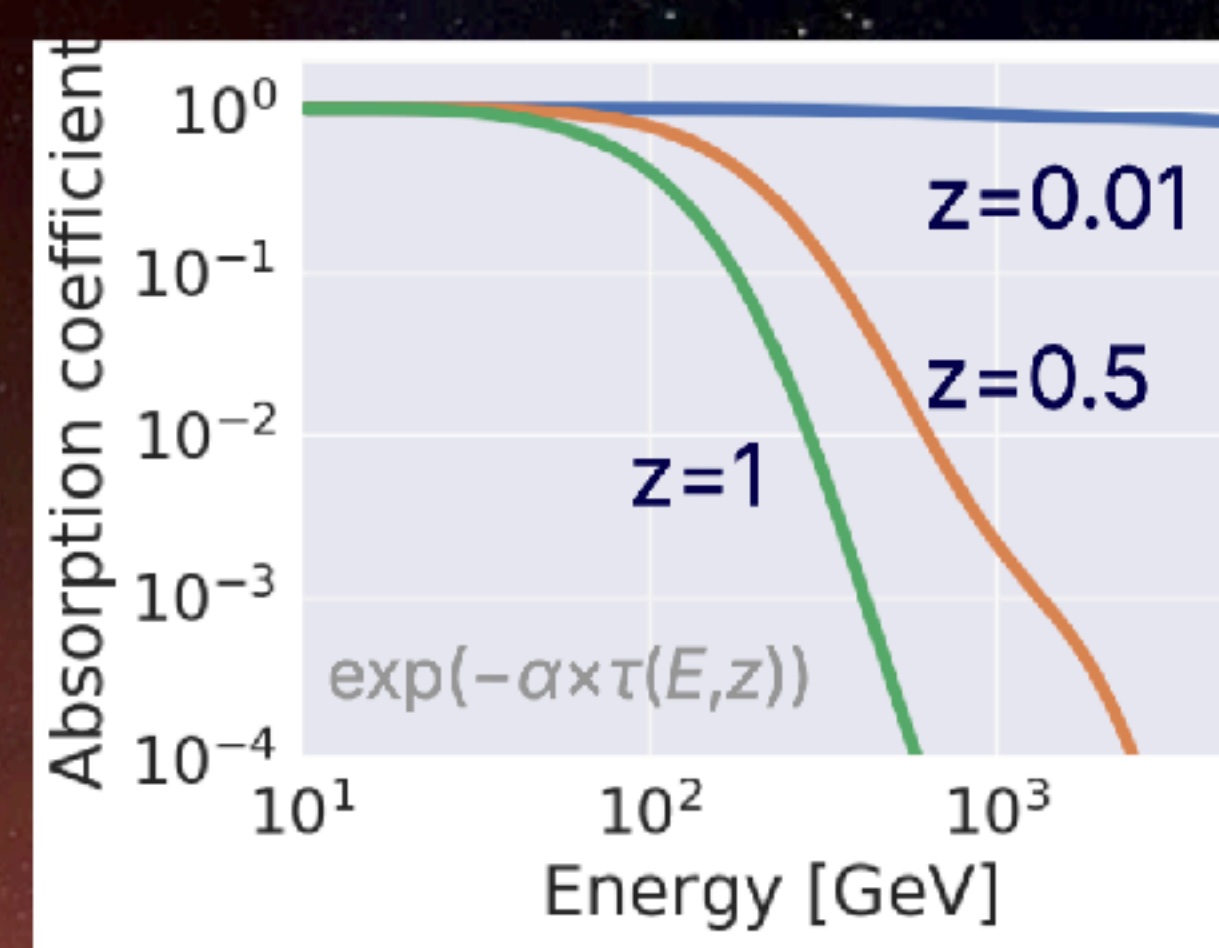


Abe et al. (2023)



# Large-Sized Telescope (LST-1)

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- **Lowest energy threshold** among current Cherenkov telescopes:  $\sim 30$  GeV
- **Key for distant extragalactic sources:** VHE ( $>100$  GeV)  $\gamma$  rays strongly **attenuated** due to **extragalactic background light (EBL)**
- Pushes the boundary of visible VHE  $\gamma$ -ray universe  $z \gtrsim 1$  from ground-based telescopes



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# Extragalactic observations with LST-1

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# A blazar zoo

LST's and CTAO's low energy threshold aims to expand the visible Universe to  $z \sim 2$

Already  $>1000$  hours of observation spent on AGN since 2018

(Almost) all of them previously known at TeVs

- Near sources: Mrk 421, Mrk 501, 1ES 1959+650, BL Lacertae...
- Distant sources: 1ES 0647+250, PG 1553+113...

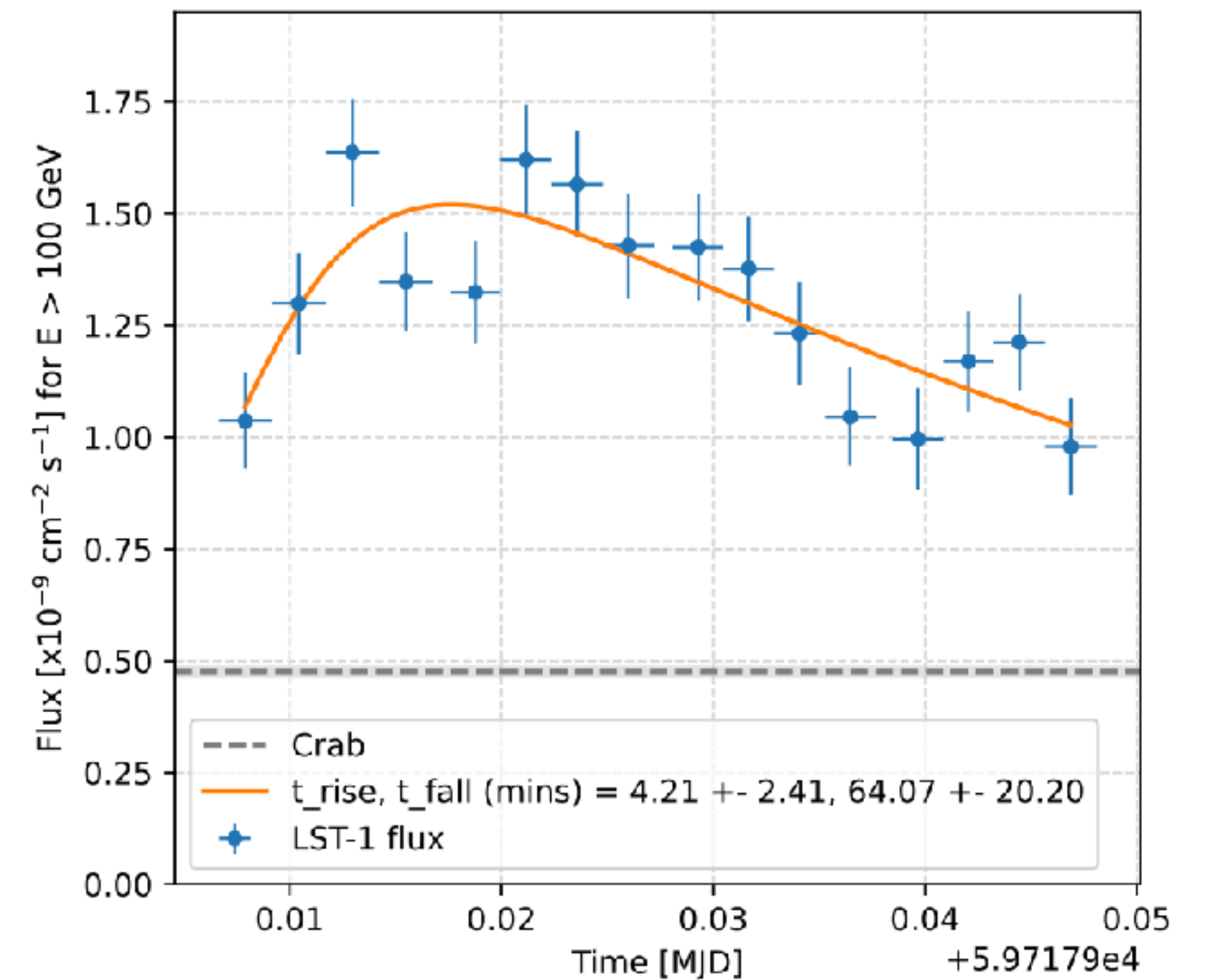


Credit: NASA, ESA, J. Olmsted (STScI)

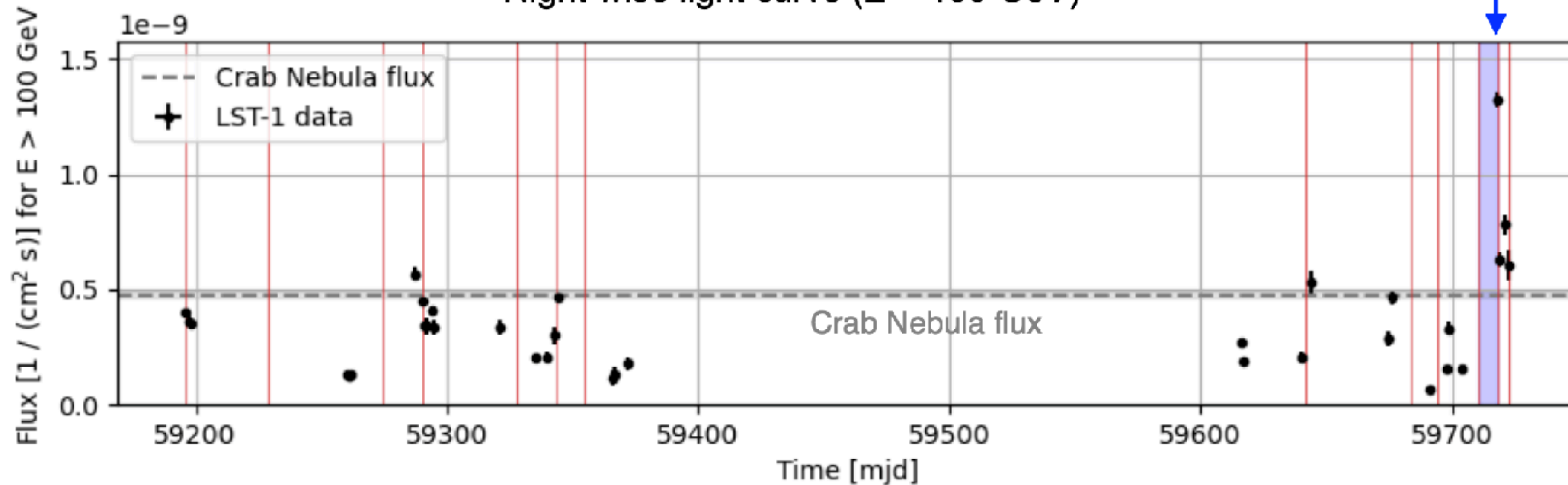
# A blazar zoo

## Mrk 421: Regular monitoring between 2020 and 2022 with 32 h exposure

- Flare in May 2022
  - ~3 C.U. at the peak
  - Intranight variability
- SED down to ~25 GeV using a power law function with exponential with cutoff



Night-wise light curve ( $E > 100$  GeV)

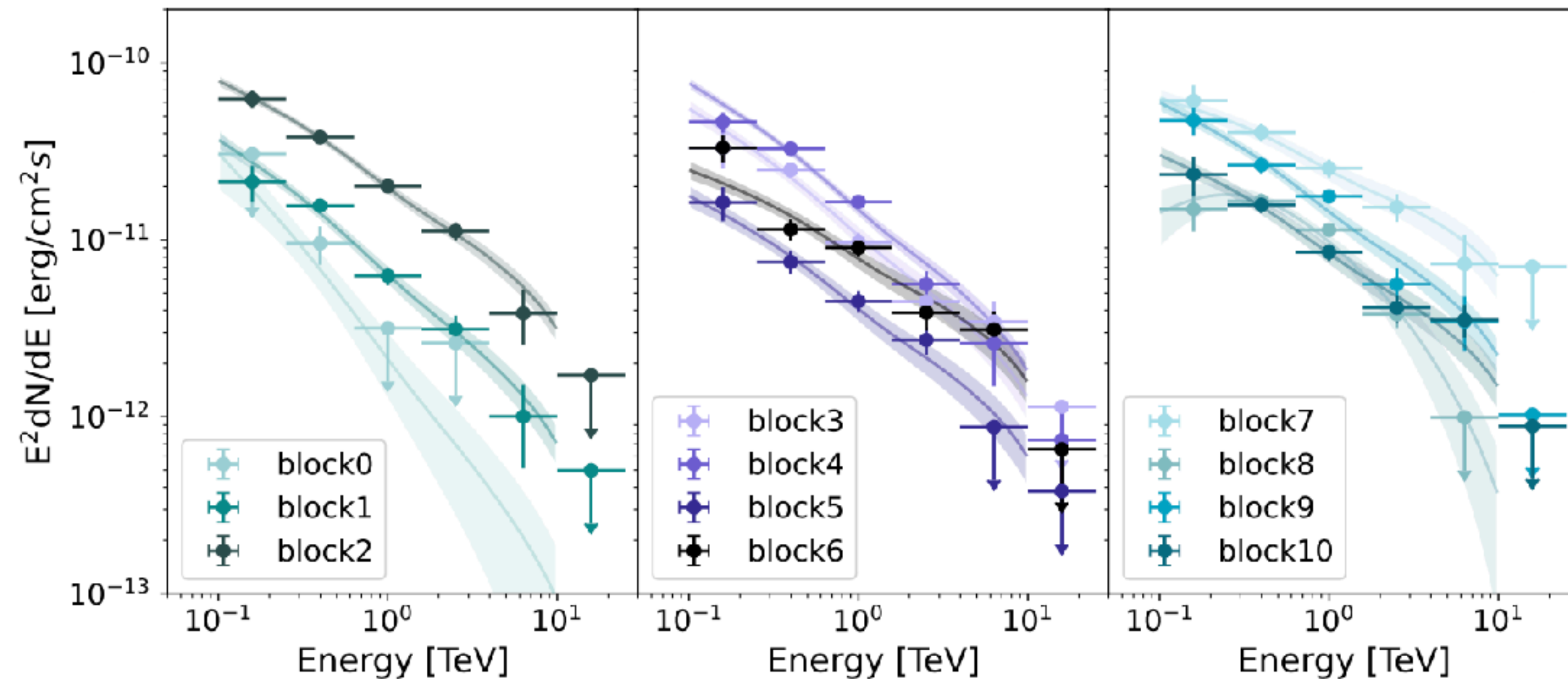
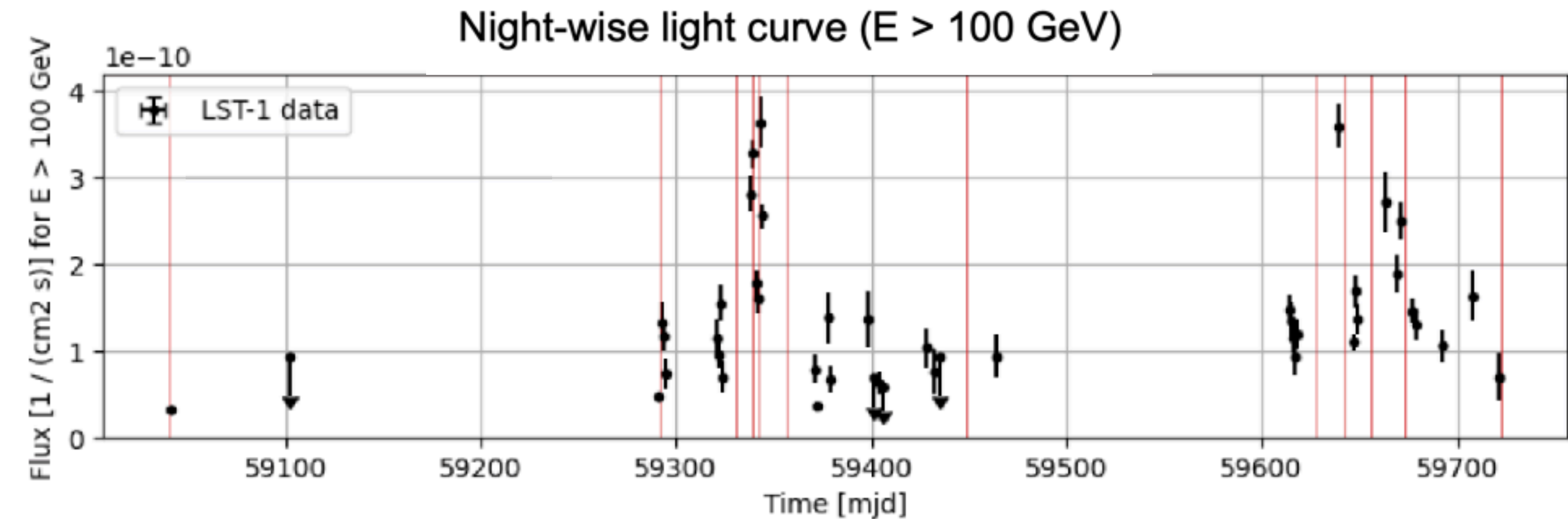


$E > 100$  GeV

# A blazar zoo

## Mrk 501:

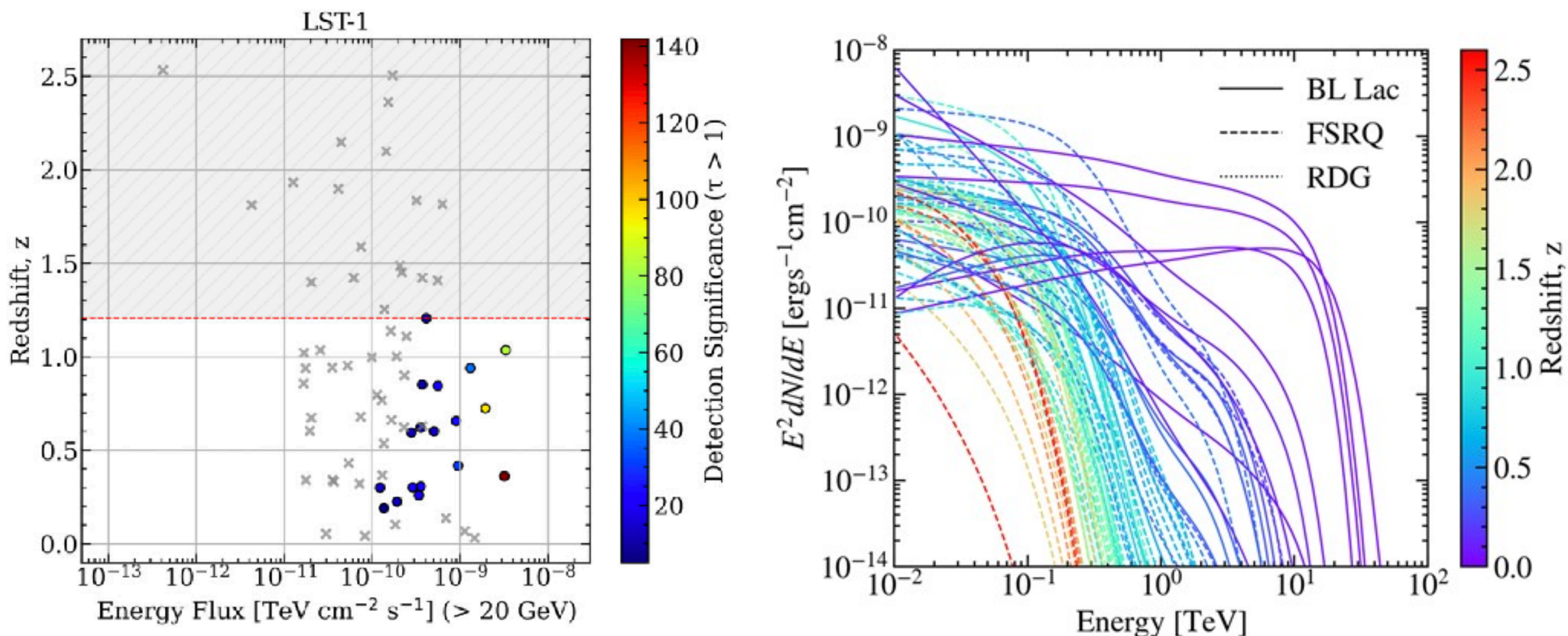
- Observed ~40 hours between 2020-07-10 and 2022-05-22
- Detected on a daily basis but fainter than Crab
- Bayesian block analysis to identify different flux state
- SED for each block reveals spectral variability



# A blazar zoo

Blazar detectability study with LST-1

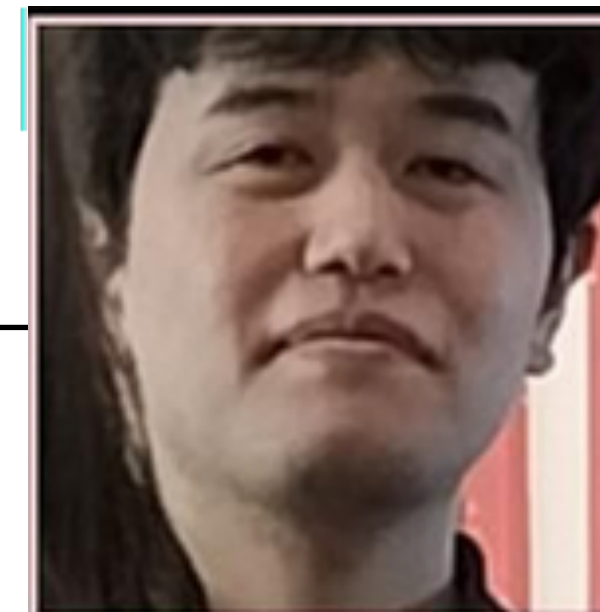
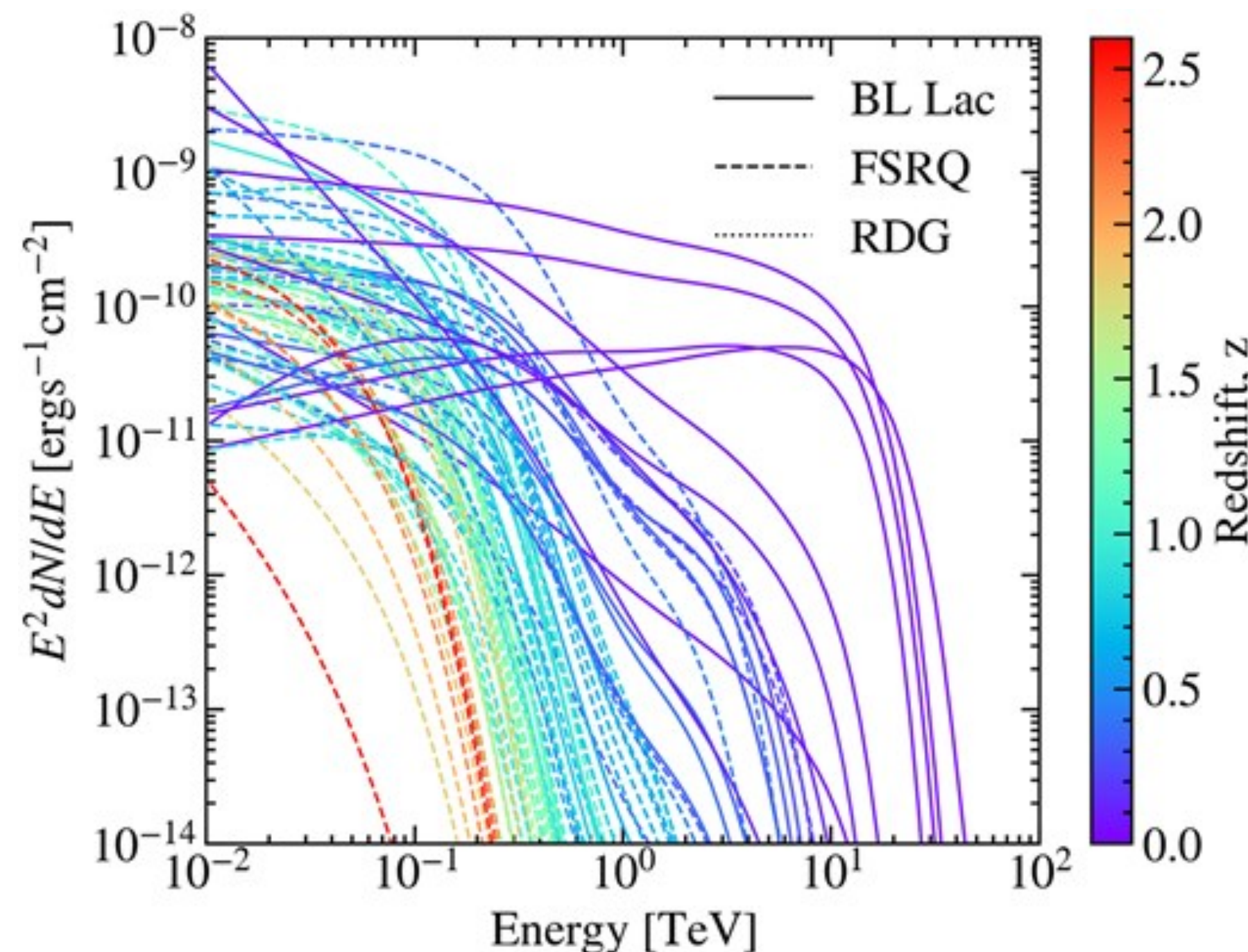
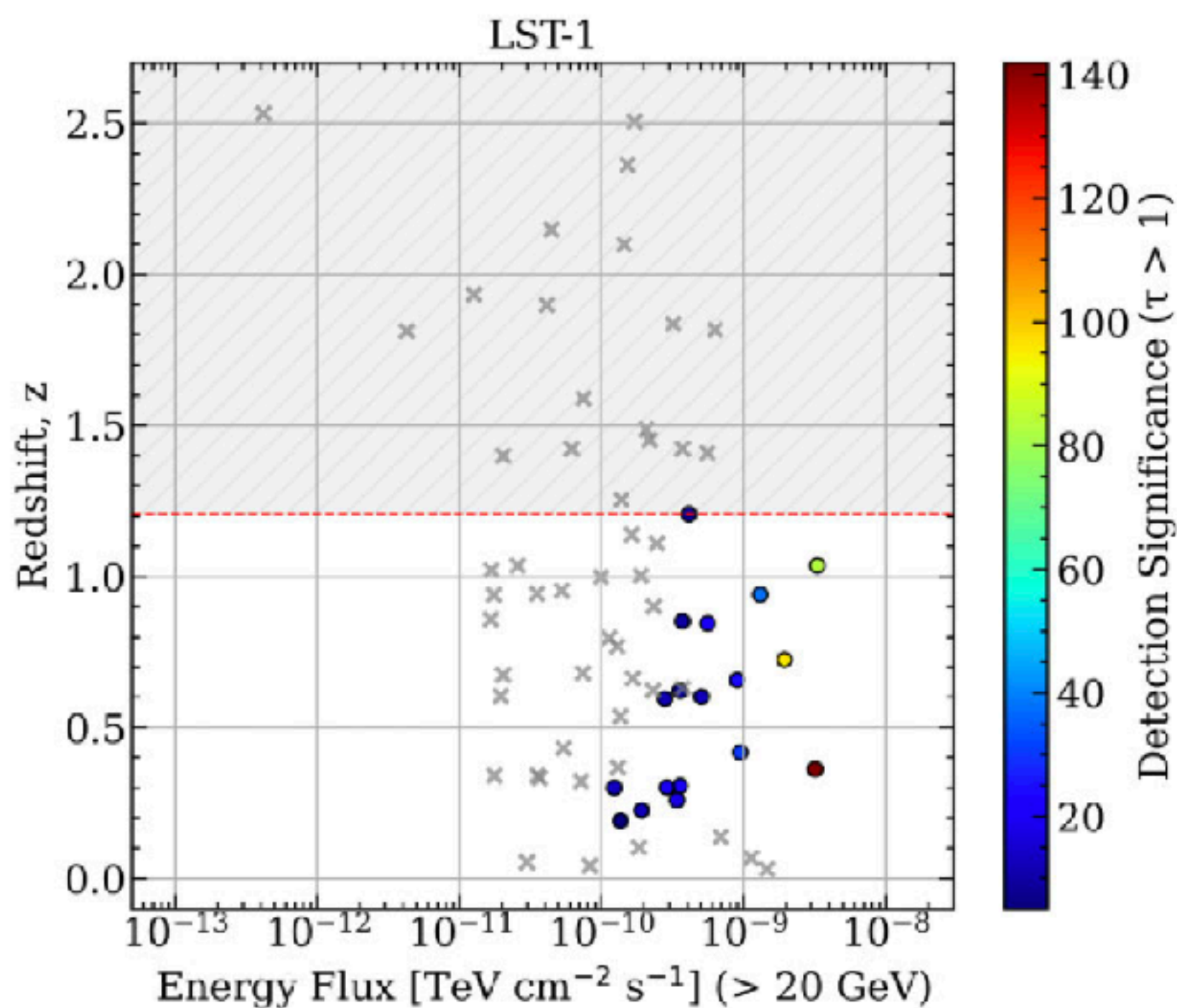
Possibility of reaching redshift  $z=1.2$  for exceptional flares shows LST-1's good performance at low energies



# A blazar zoo

Blazar detectability study with LST-1

Possibility of reaching redshift  $z=1.2$  for exceptional flares shows LST-1's good performance at low energies



R. Takeishi



L. Heckmann



C. Priyadarshi



M. Nievas Rosillo



J. Baxter

Results published in MNRAS (CTAO-LST Collaboration, MNRAS, 544, 1, 699)

Strong Target of Opportunity (ToO) program

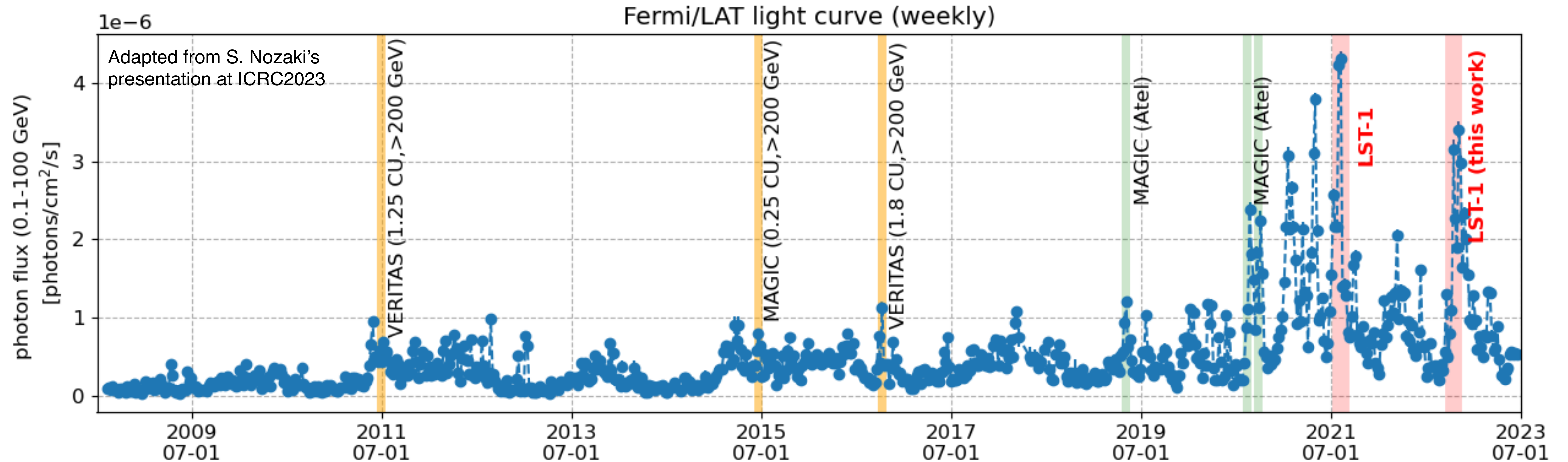
Relying on external alerts from other facilities,  
mainly *Fermi*-LAT

- [Daily automatic light curve analysis](#) (FlaapLUC, see [Lenain, 2017](#))
- [Cluster of high-energy photons](#) (Flaschep, developed by S. Nozaki)
- [Optical flux](#) (ZTF, developed by M. Nievas Rosillo)

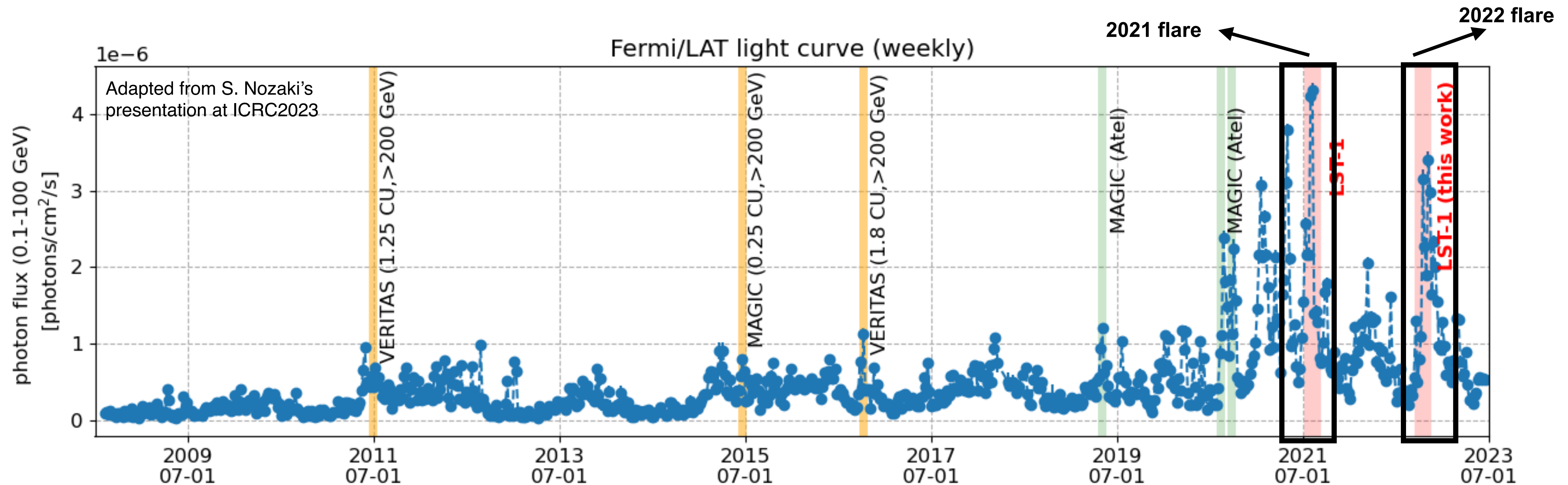


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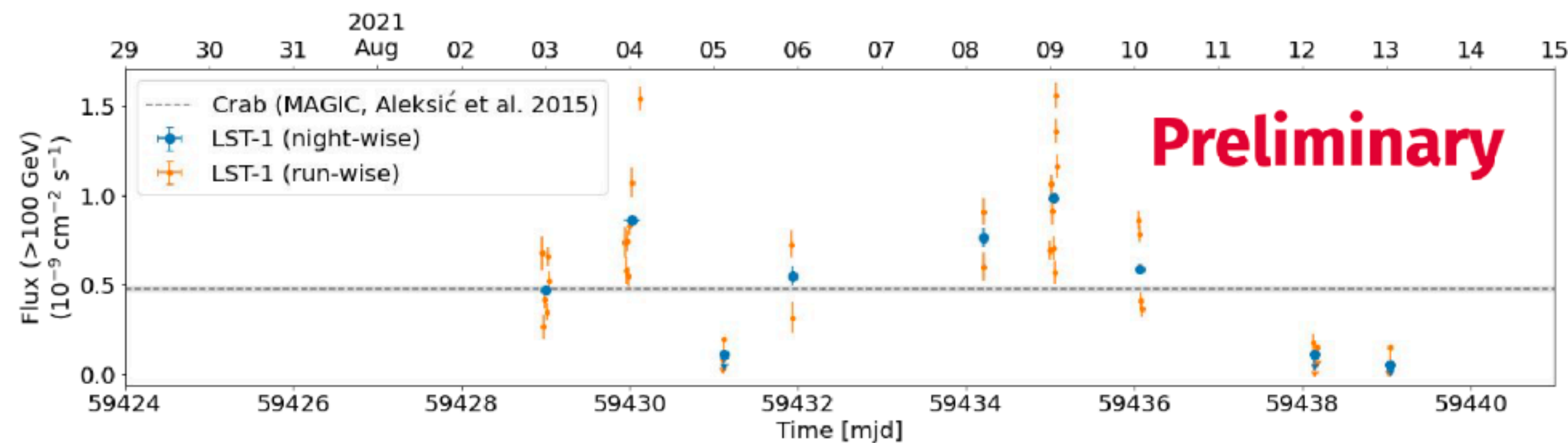
- BL Lac detected several times in VHE, always in flaring state
- Two major flares in 2021 and 2022, brightest emission ever observed from BL Lac in VHE



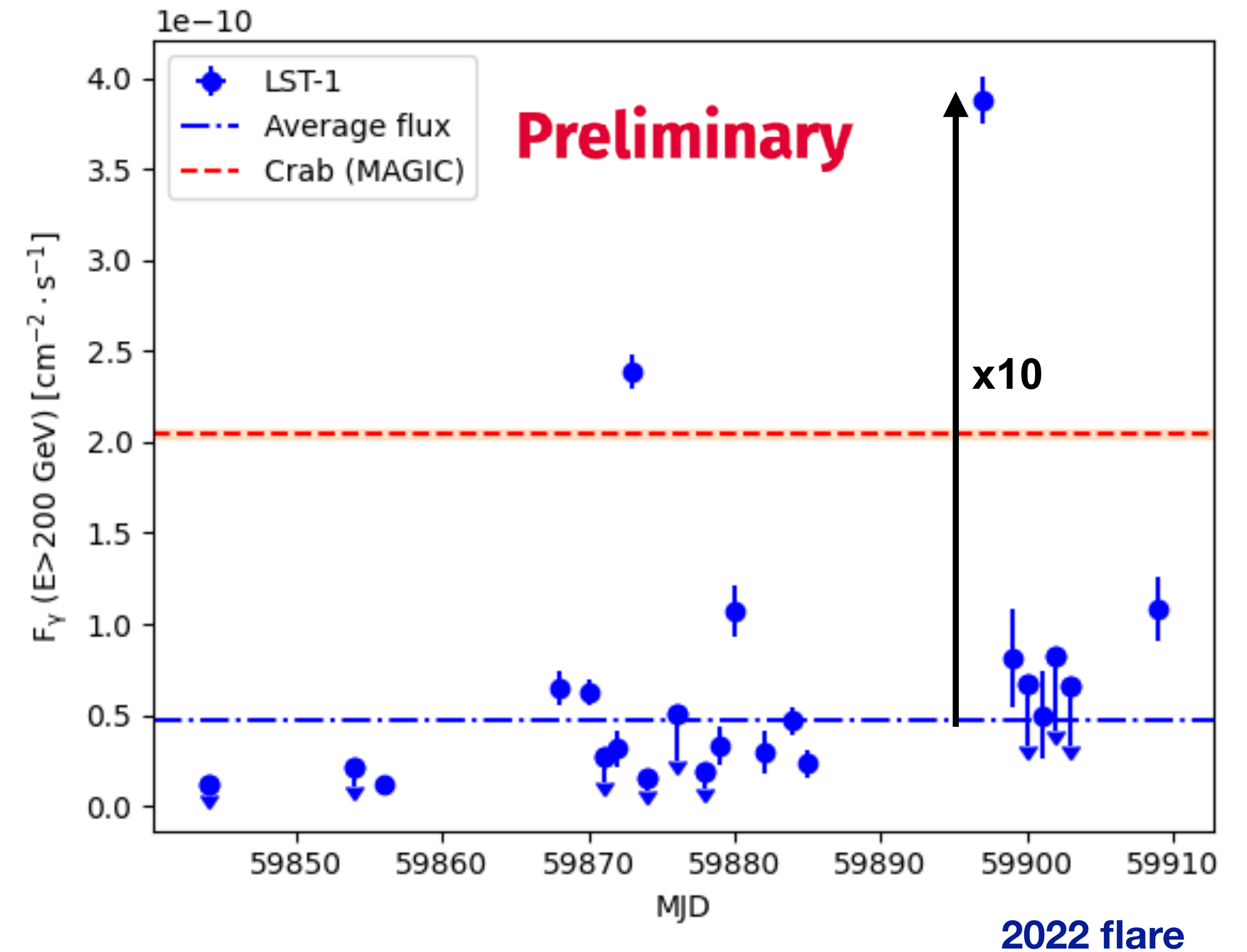
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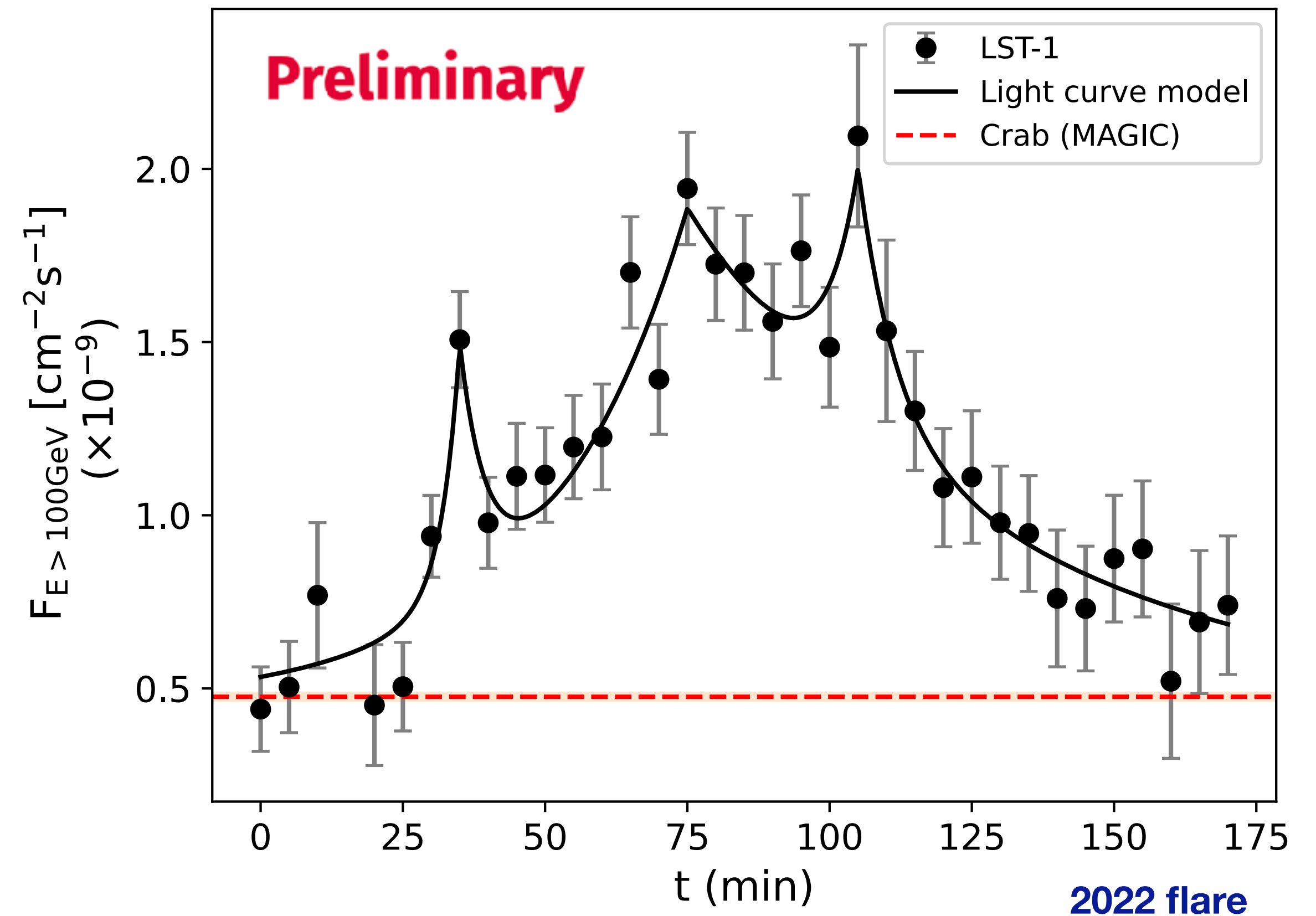
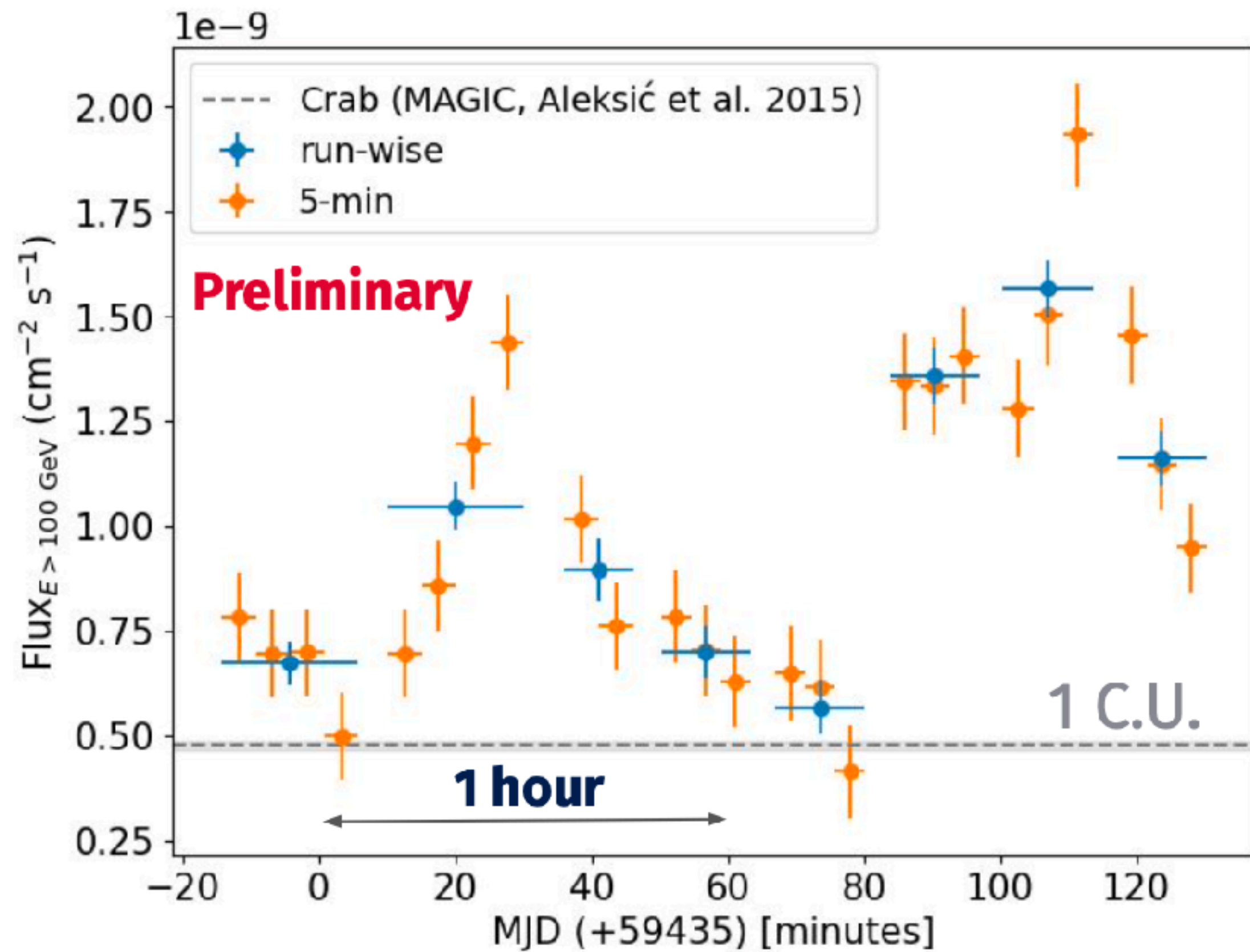
- LST-1 observed for ~10 hours in August 2021, and ~36 hours between September and November 2022, after data quality selection
- **Highest VHE  $\gamma$ -ray flares** ever detected from BL Lac
- **Very large variability**, more than 1 order of magnitude



2021 flare (adapted from Seiya Nozaki's presentation at ICRC2023)



- Significant **intranight VHE  $\gamma$ -ray variability** during both flares



2021 flare (adapted from Seiya Nozaki's presentation at ICRC2023)

- 20 Oct. 2022: well defined rise and decay of the flare with several substructures, average emission  $\sim 2$  C.U. above 100 GeV
- Maximum emission  $\sim 4.4$  C.U. above 100 GeV, variations from  $\sim 1$  C.U. to 4.4 C.U. in less than 1 hour

Exponential rise and decay (see Aharonian et al., 2007)

$$F(t) = F_b + \begin{cases} F_0 e^{-(t_{peak}-t)/t_r} & t < t_{peak}; \\ F_0 e^{-(t-t_{peak})/t_d} & t > t_{peak}; \end{cases} \longrightarrow \tau_{rise/fall} = t_{r/d} \times \ln 2$$

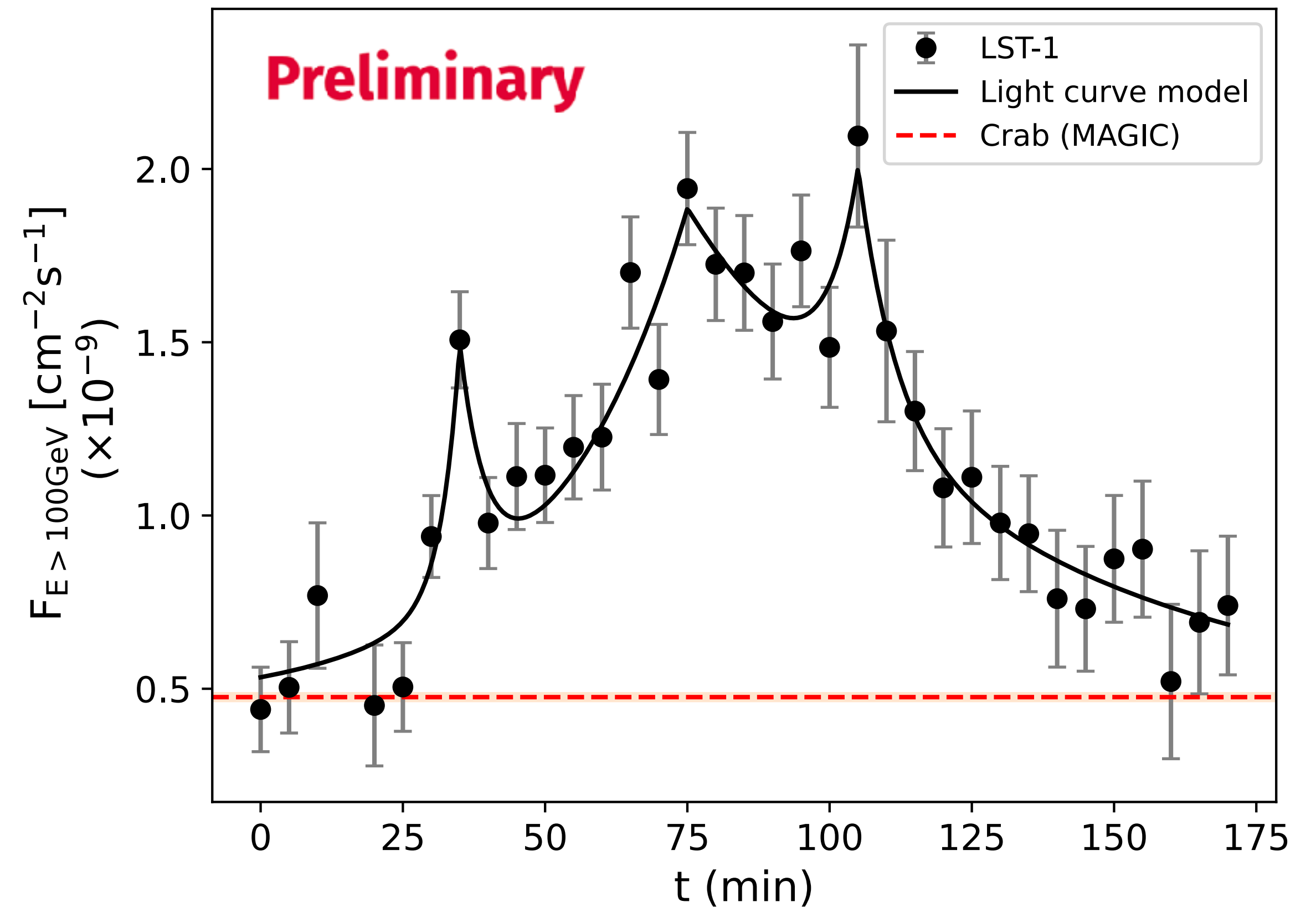
Doubling flux timescale (see Zhang et al., 1999)

$$t_{doubling,i} = \frac{F_i + F_{i+1}}{2} \frac{t_{i+1} - t_i}{|F_{i+1} - F_i|}$$

- $t_{min} = 8.3 \pm 2.5 \text{ min}$

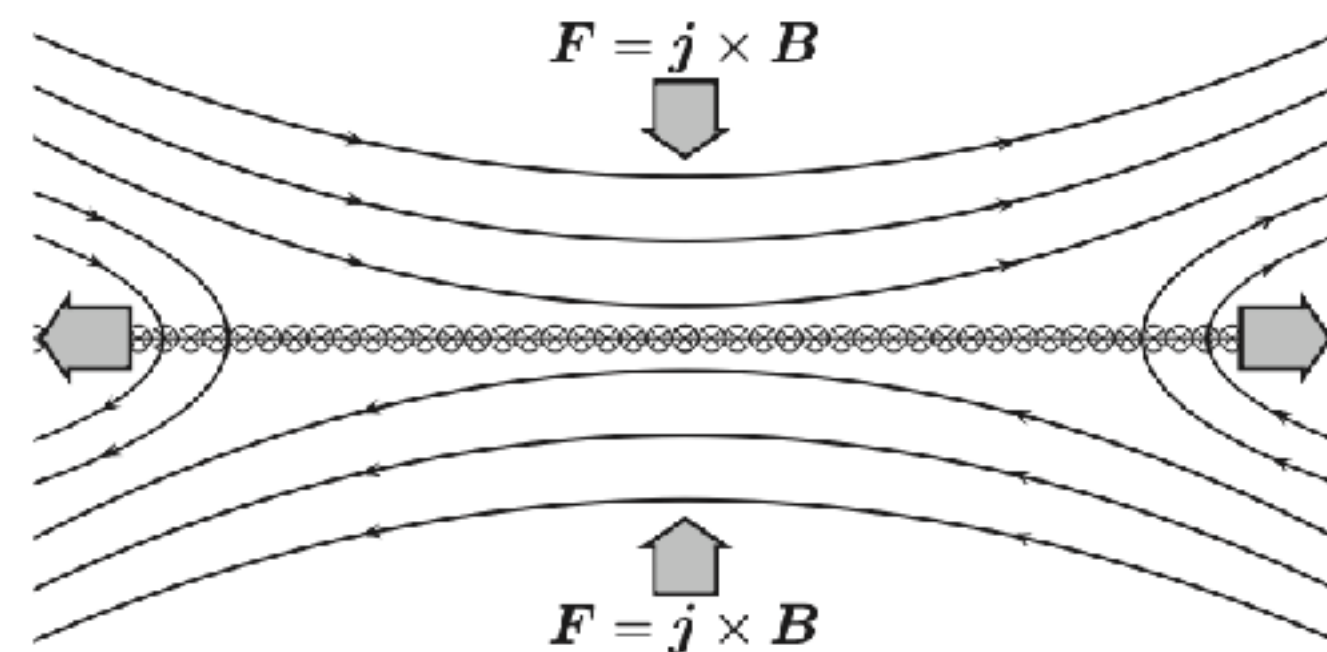
Constraint on the size of the emitting region (causality arguments)

$$R \leq \frac{c \cdot t_{var} \cdot \delta}{(1+z)} \sim 0.3 - 1.2 \cdot 10^{14} \text{ cm for } \delta \sim 10 - 50$$



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## Acceleration via magnetic reconnection

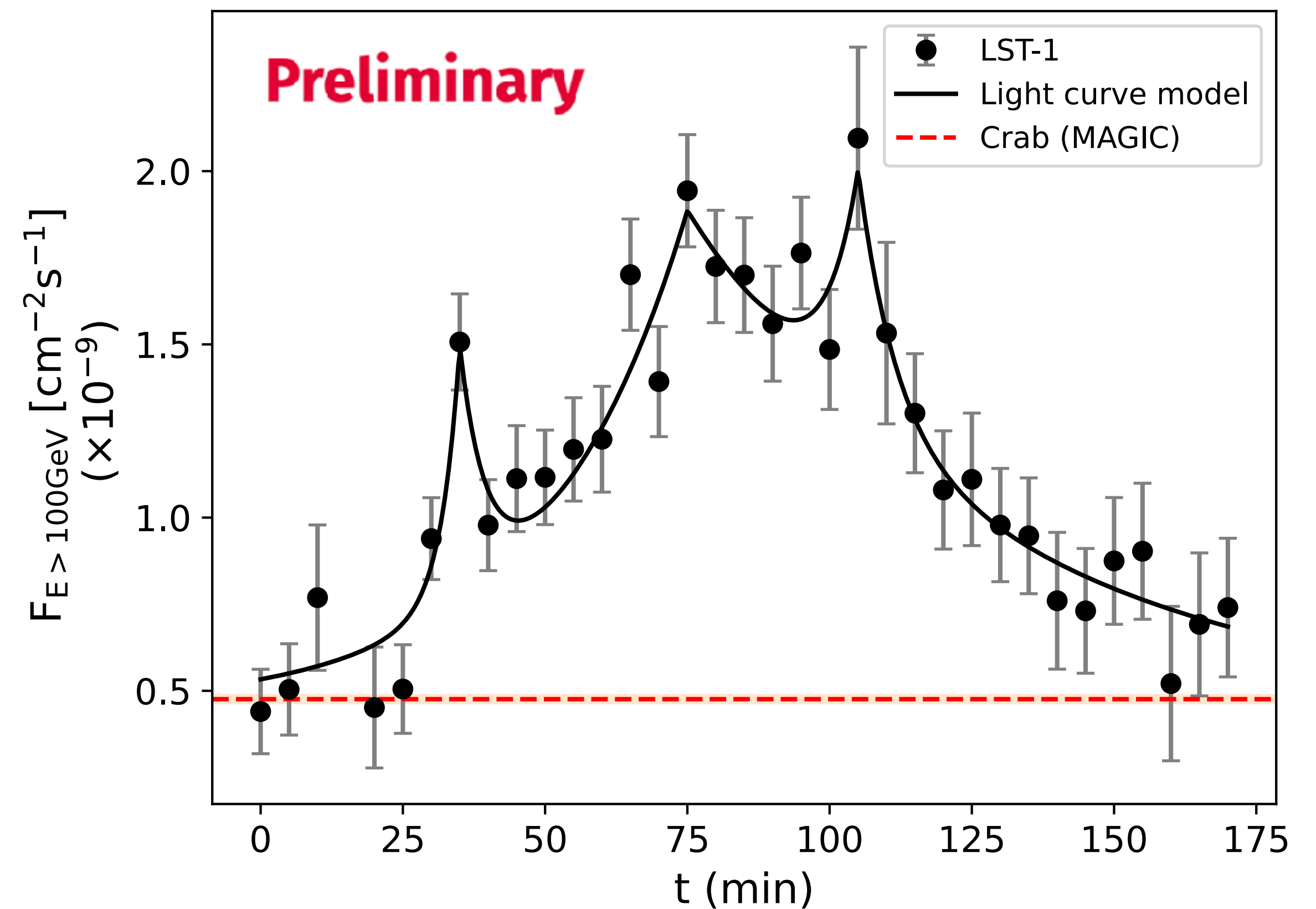


Morris et al. (2019)

Reconnection plasmoids can produce very fast (minute) TeV flares (Morris et al., 2019; Zhang et al., 2024)

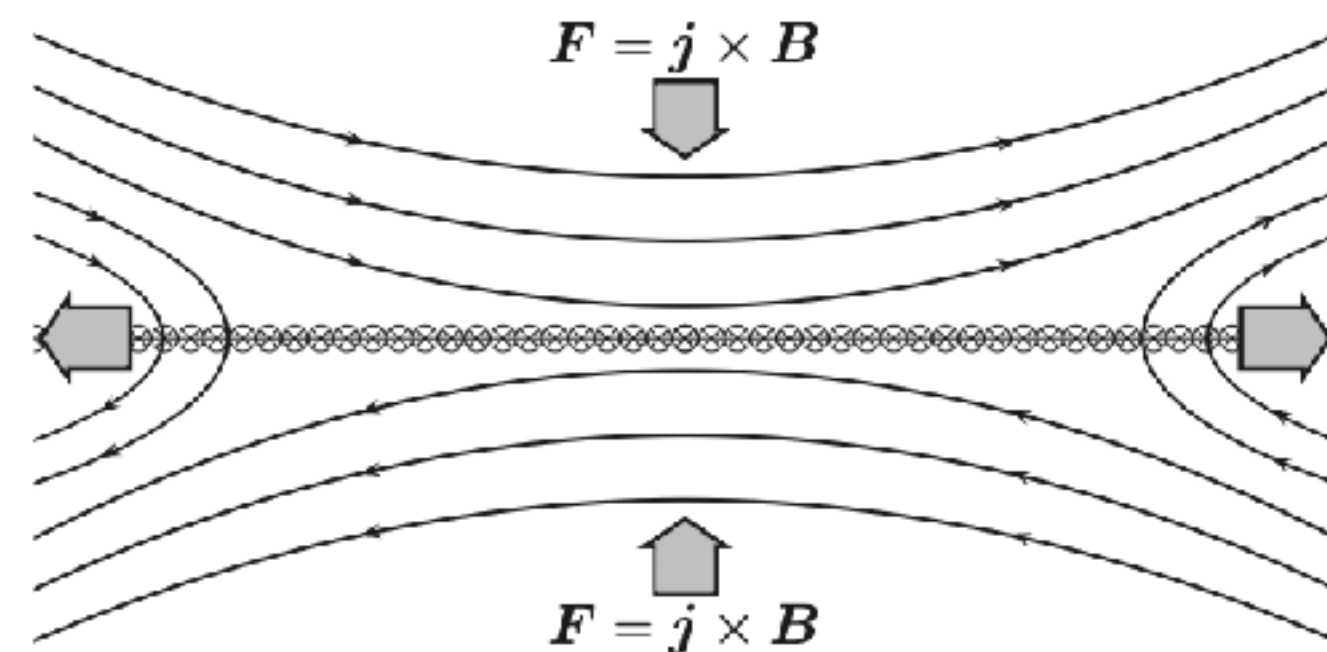
Supported by particle-in-cell (PIC) simulations

Solves “Doppler crisis” problem



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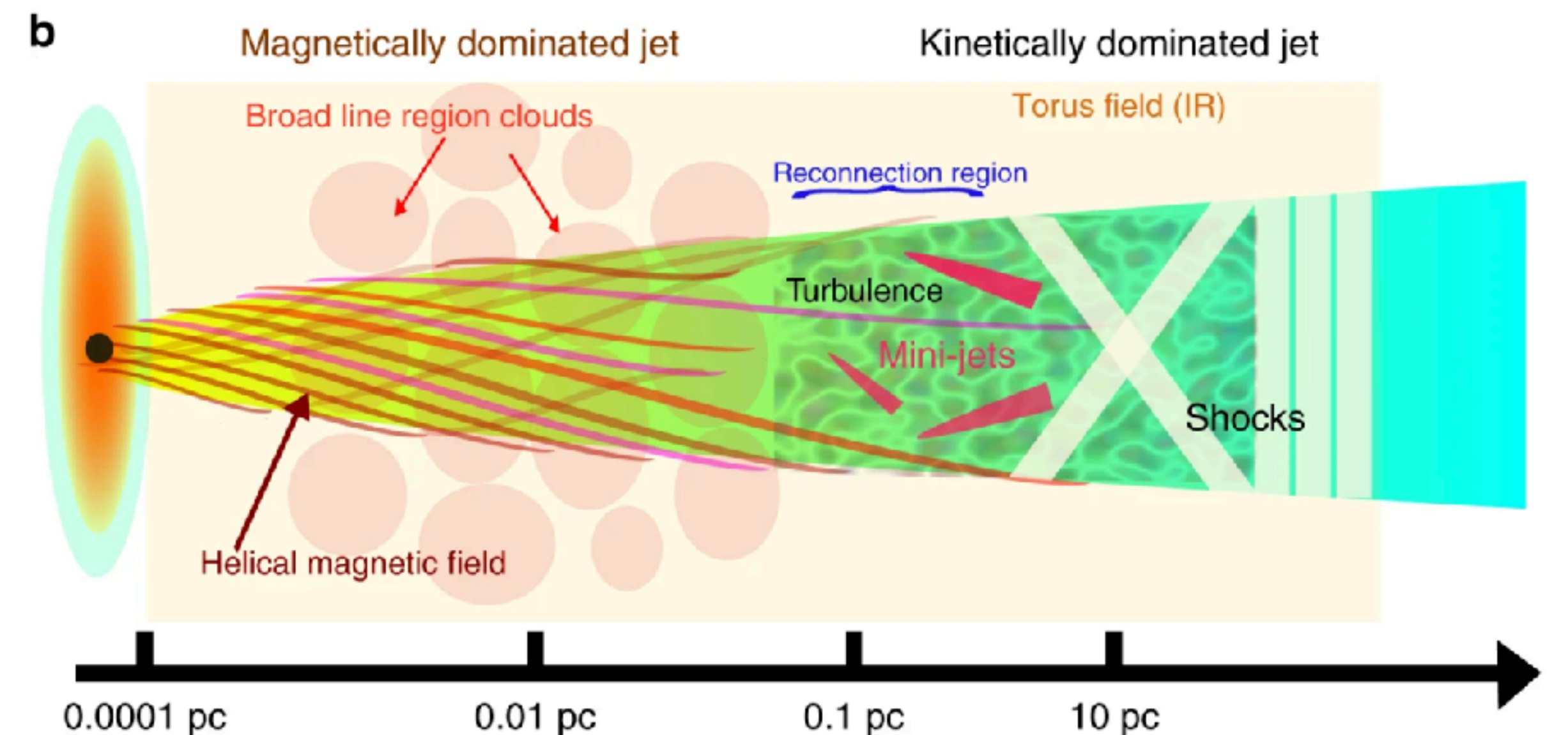


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Shukla & Mannheim (2020)

# BL Lacertae

## Multi-wavelength campaign on BL Lacertae

### LST-1 (23 m IACT, La Palma)

- VHE  $\gamma$  rays

### Fermi-LAT

- (HE,  $E > 100$  MeV)  $\gamma$  rays

### Swift (XRT + UVOT)

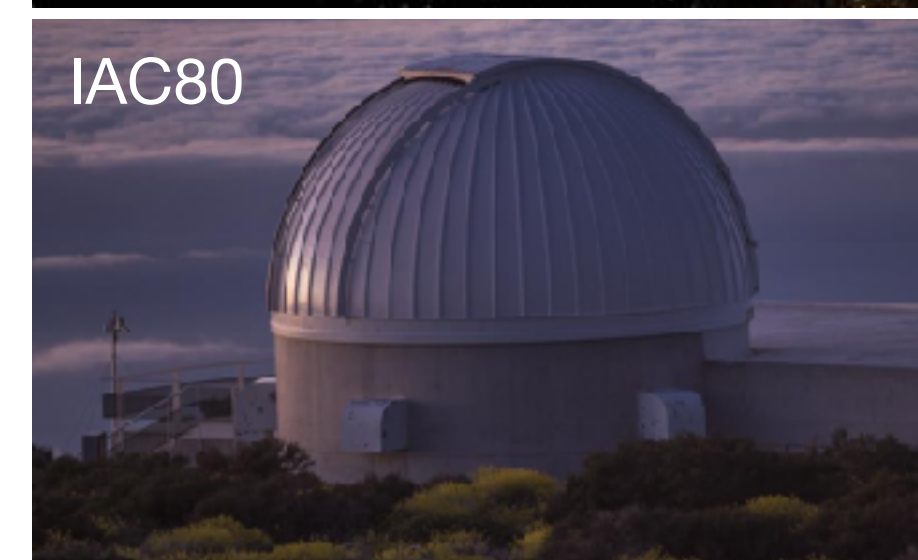
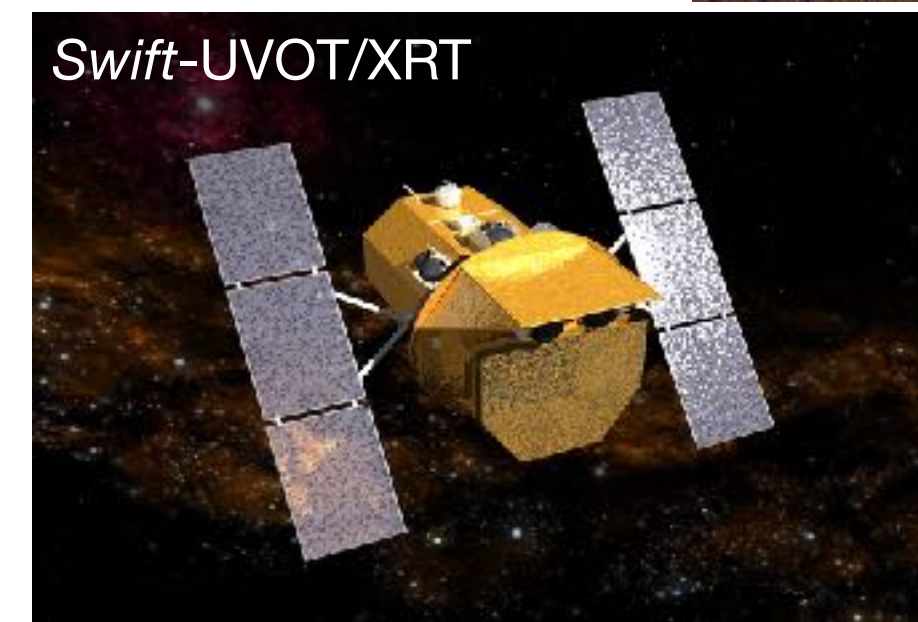
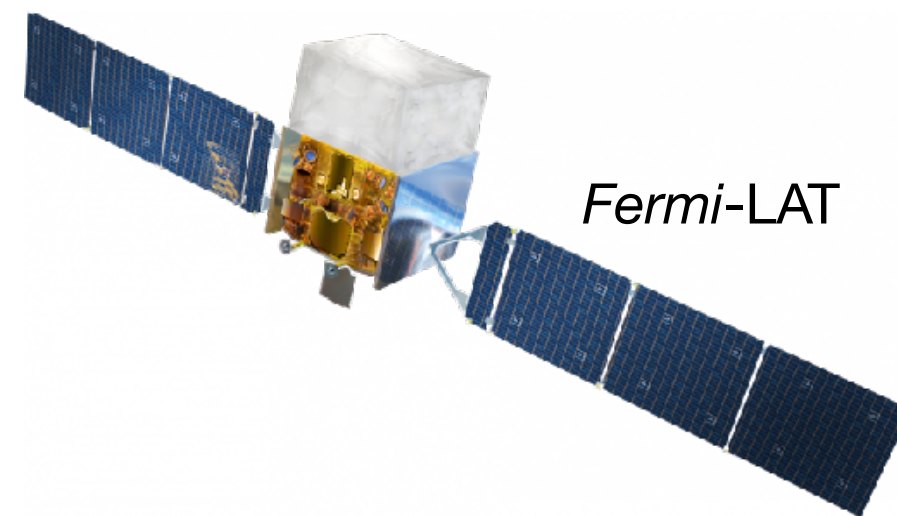
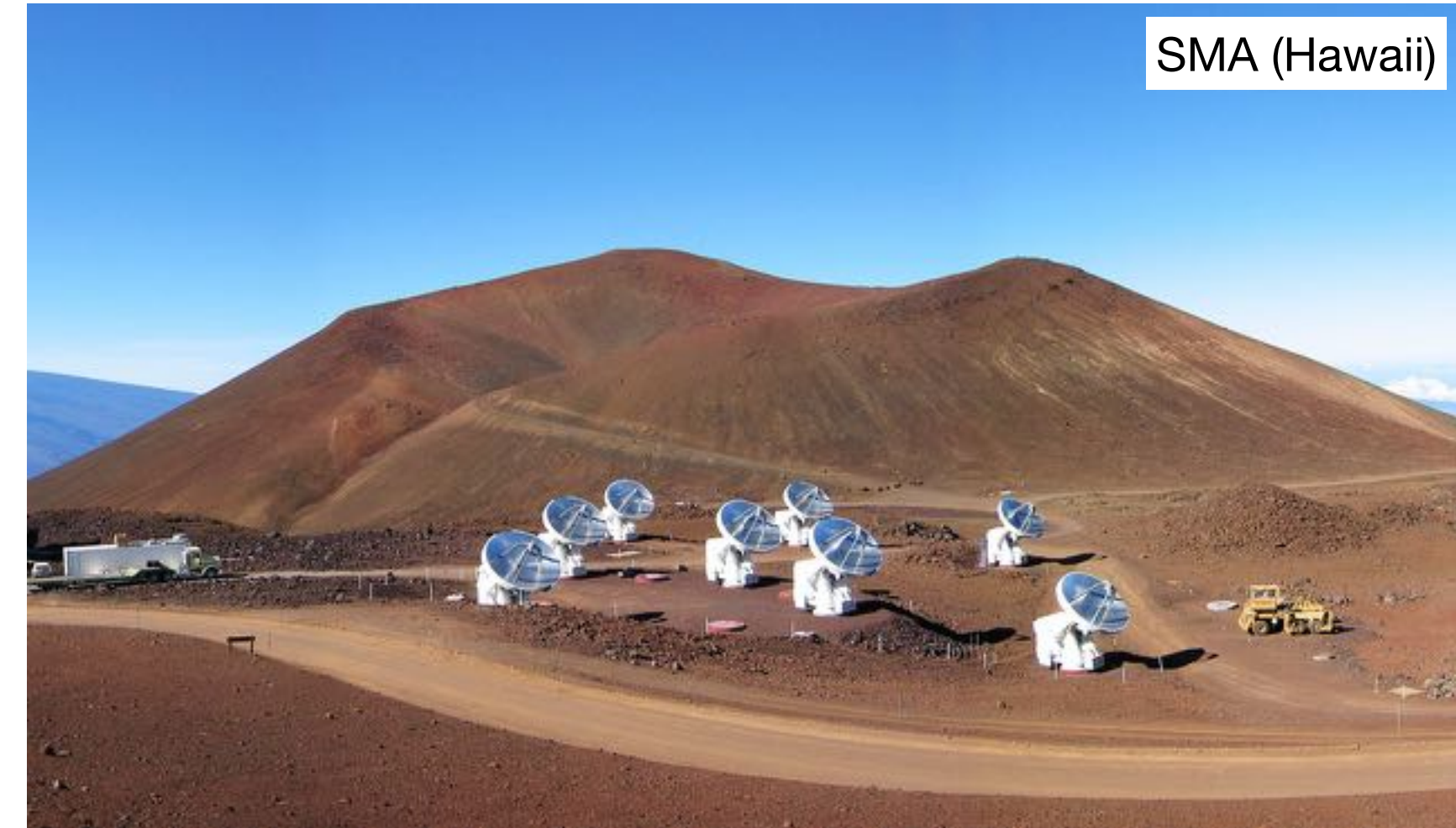
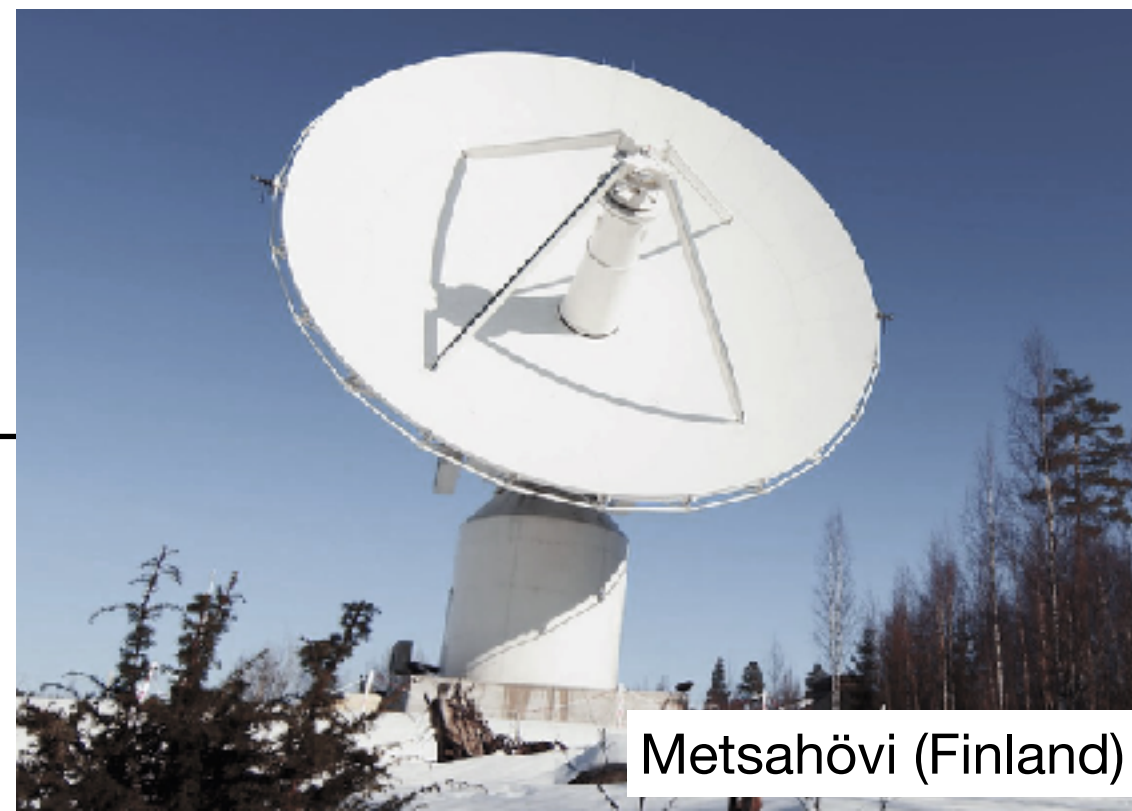
- X-rays (0.3 - 10 keV) + optical/UV (6 filters)

### Optical telescopes:

- IAC80, Sierra Nevada Observatory, Las Cumbres, Tuorla (Joan Oró Telescope), ASAS-SN, ZTF
- Johnson BVRI and Sloan gri photometry

### Radio/millimeter:

- Metsähovi, SMA



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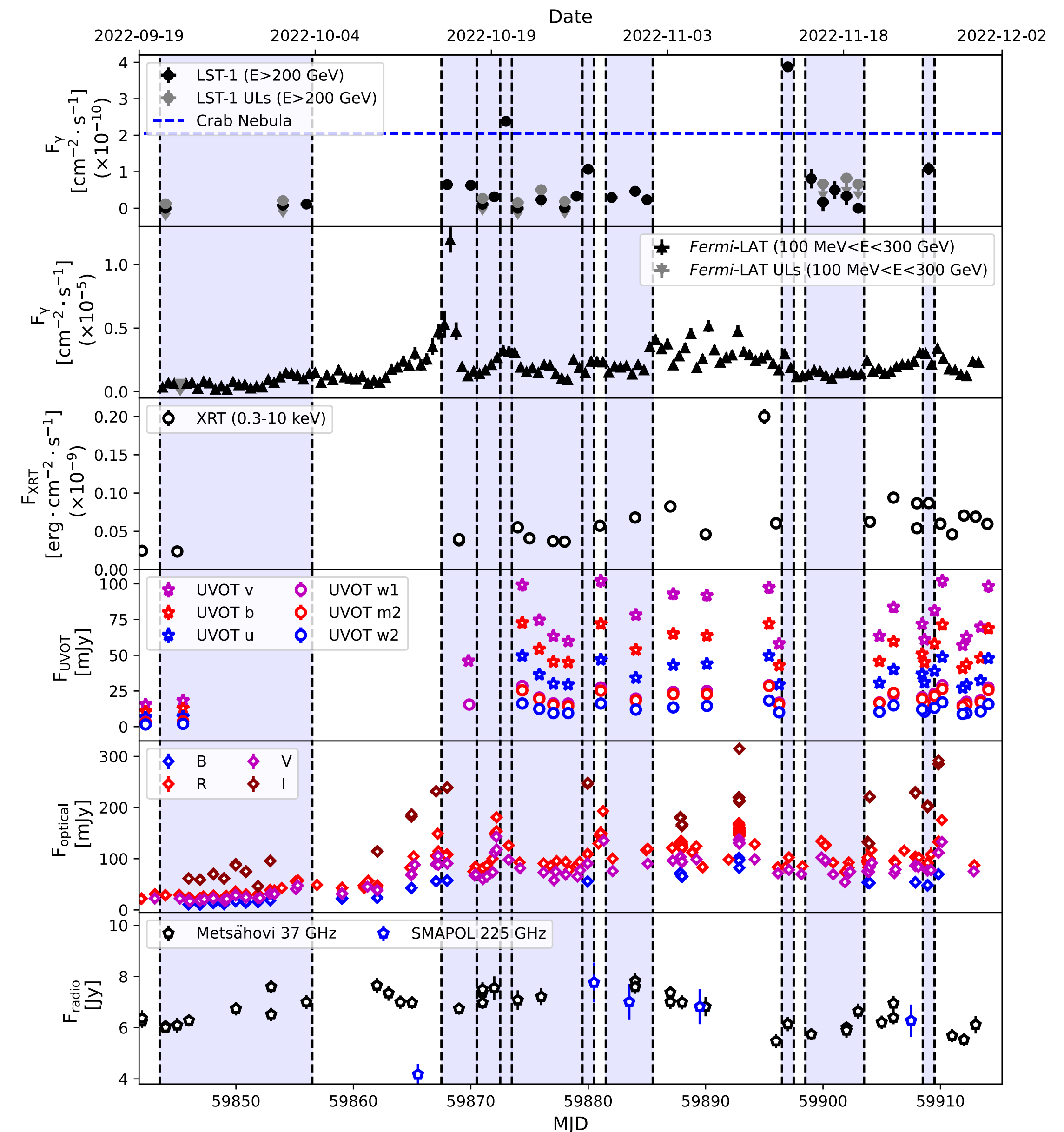
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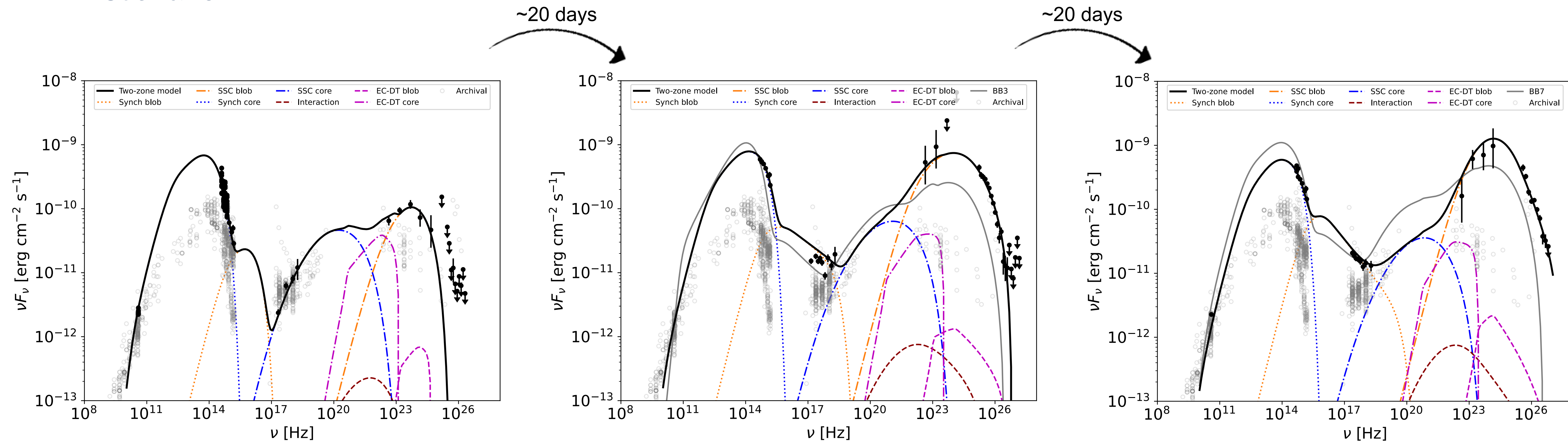
### Radio/millimeter:

- Metsähovi, SMA

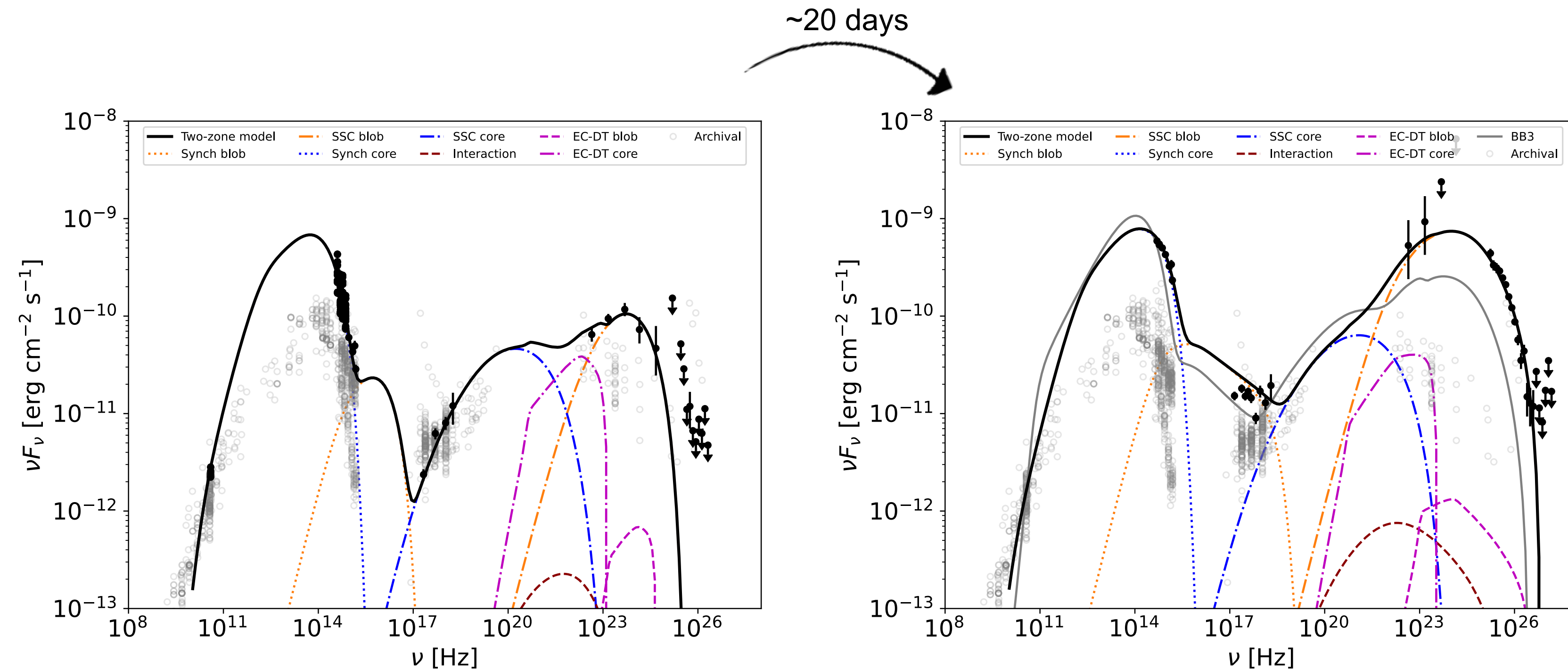


Periods consistent with a constant VHE  $\gamma$ -ray emission with a **Bayesian Block analysis**

- “Time-dependent” modeling of the broad-band flare SEDs is currently ongoing
- Aim: trace back the MWL emissions evolution during the flare by evaluating a temporal series of SEDs
- Intranight VHE  $\gamma$ -ray variability is likely to come from magnetic reconnection -> possible mini-jets in a jet scenario



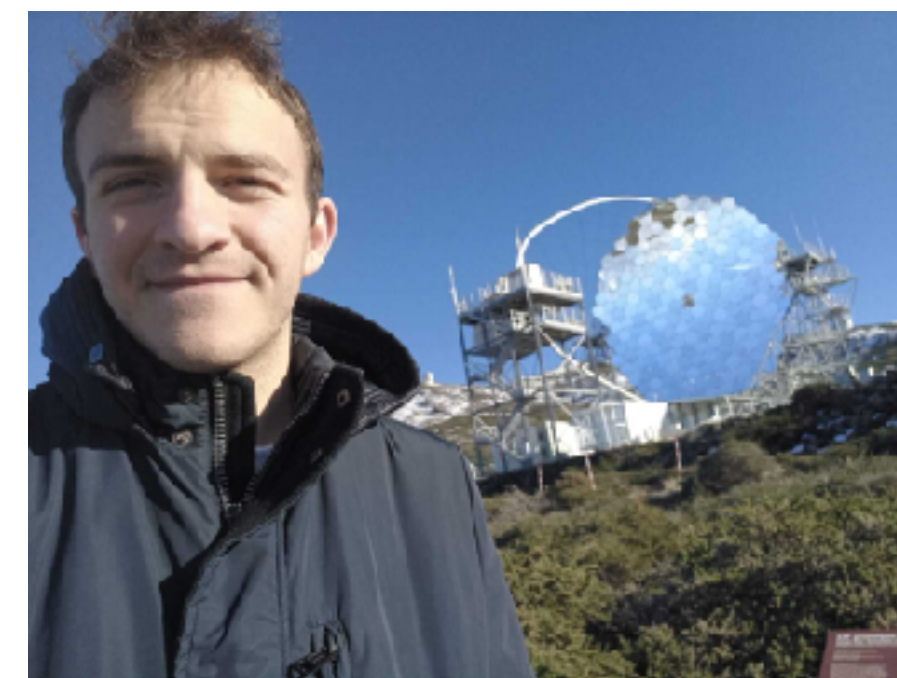
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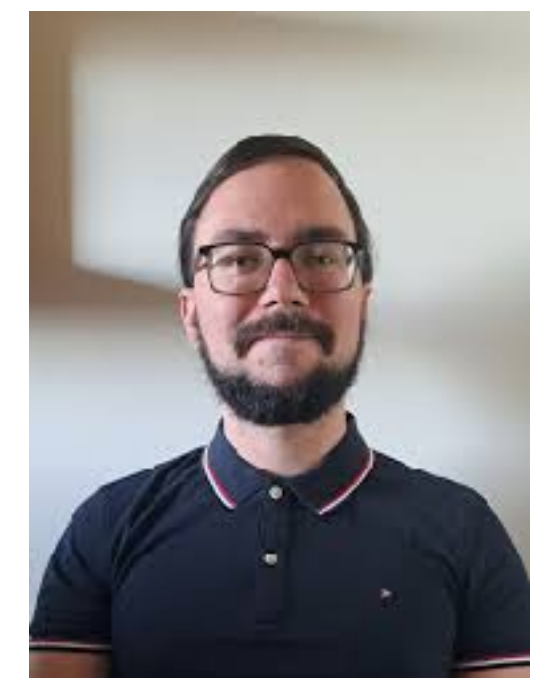
J. Otero Santos



D. Morcuende



D. Cerasole



G. Emery

Results published in A&A (CTAO-LST Collaboration, A&A, 710, A41)

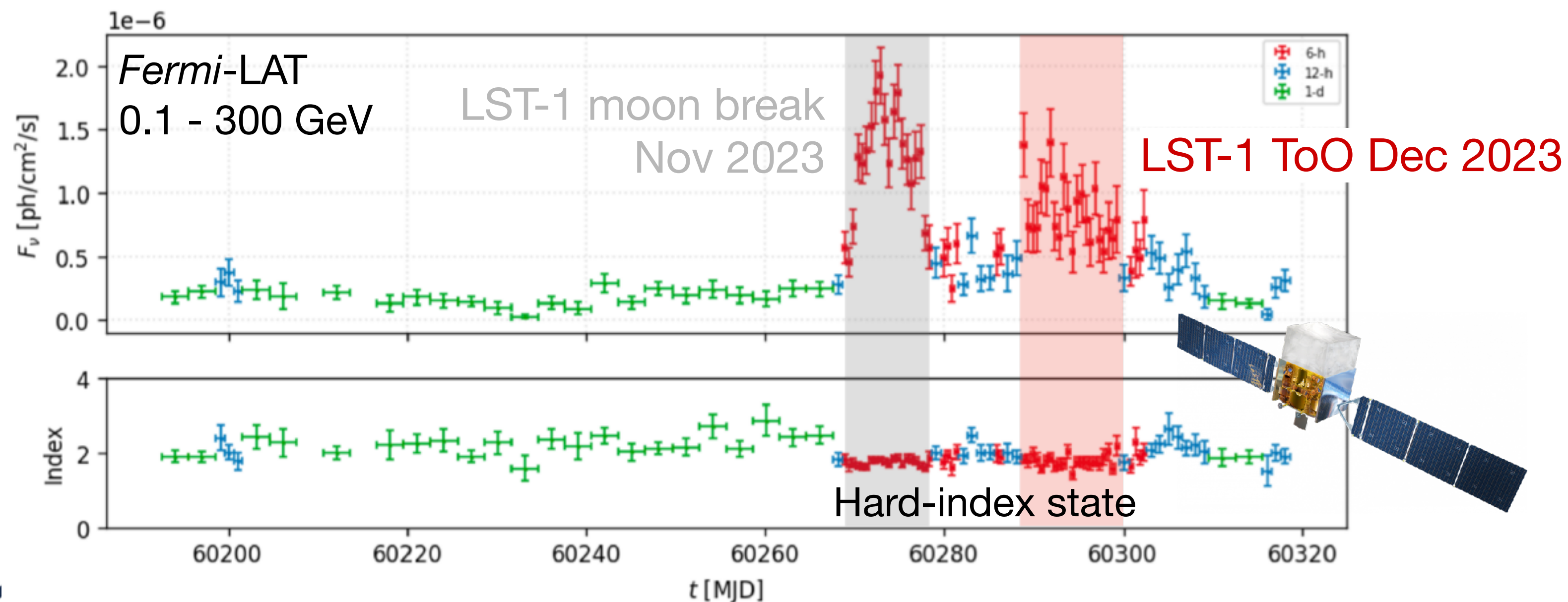
# Flat Spectrum Radio Quasar OP 313

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- OP 313: Distant ( $z = 0.9973$ ) flat-spectrum radio quasar (FSRQ)
  - Only 9 known at VHE  $\gamma$  rays before

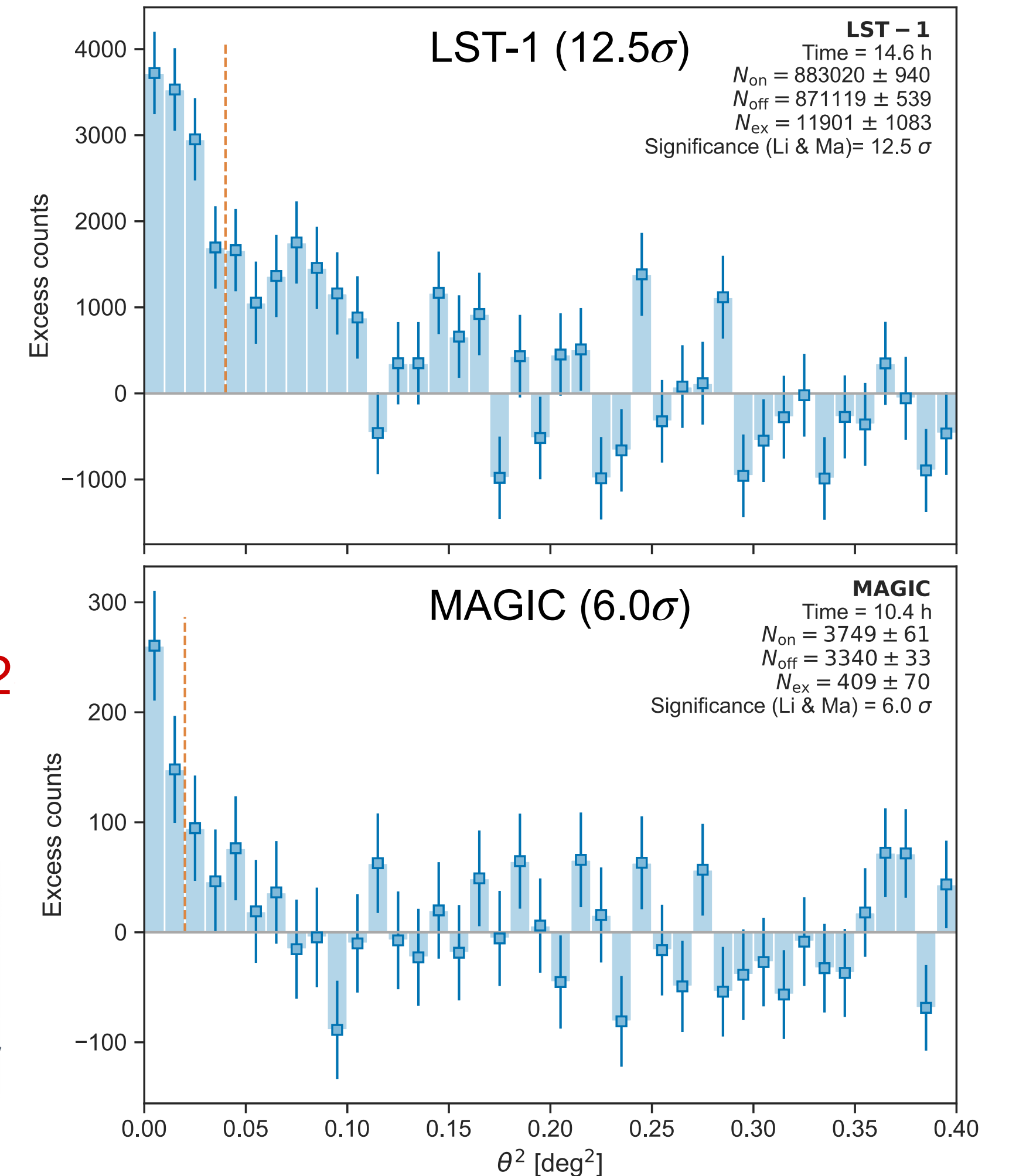
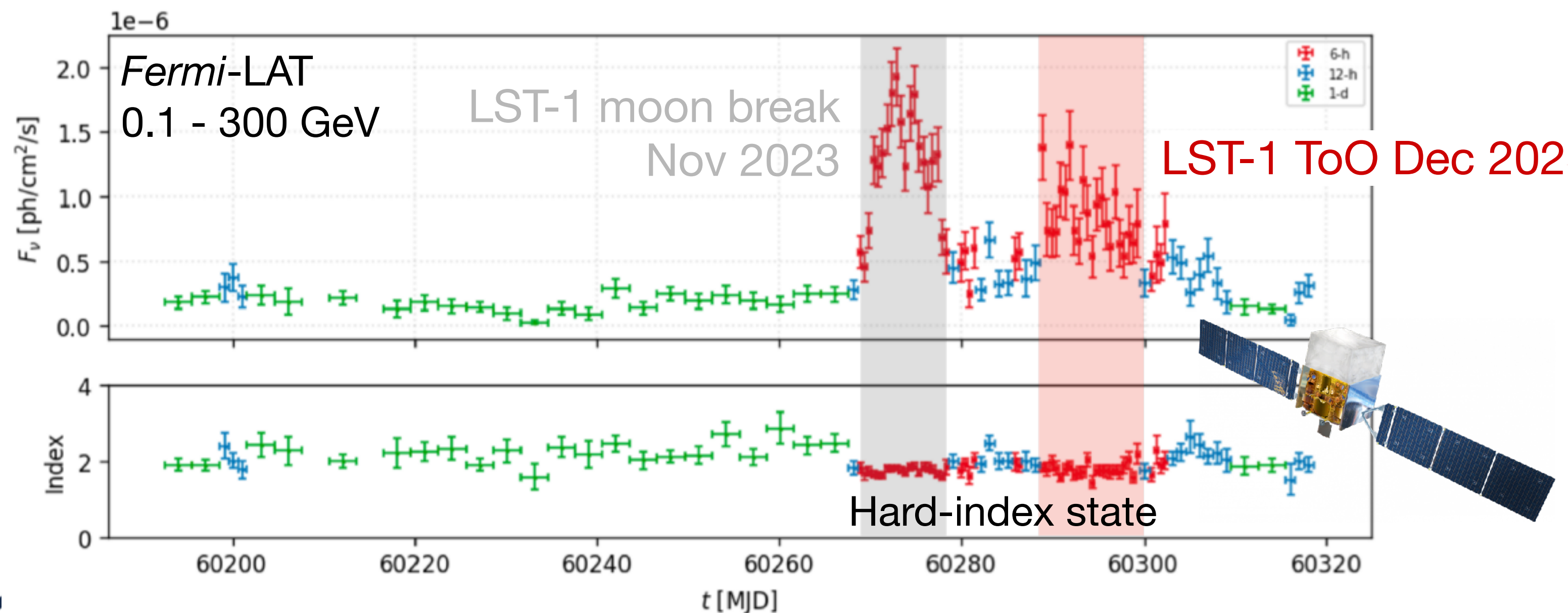
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# Flat Spectrum Radio Quasar OP 313

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  - Only 9 known at VHE  $\gamma$  rays before
- LST-1 daily observations from Dec 9 to 18, 2023 (15 h) + few days in Jan 2024 (5 h)
- Detected in December 2023 by LST-1 and MAGIC ( $>5\sigma$ ) significance, no detection in January 2024



## First VHE detection of OP 313

- First scientific discovery made with LST-1
- 10th FSRQ ever detected at VHE  $\gamma$ -ray energies
- Most distant AGN ever detected at VHE  $\gamma$ -ray energies

## LST-1 Discovers the Most Distant AGN at Very High Energies

DATE

📅 26 December 2023

TOPICS

☰ Telescopes, Press Releases, CTAO-North, LST, Science

[www.ctao.org](http://www.ctao.org)

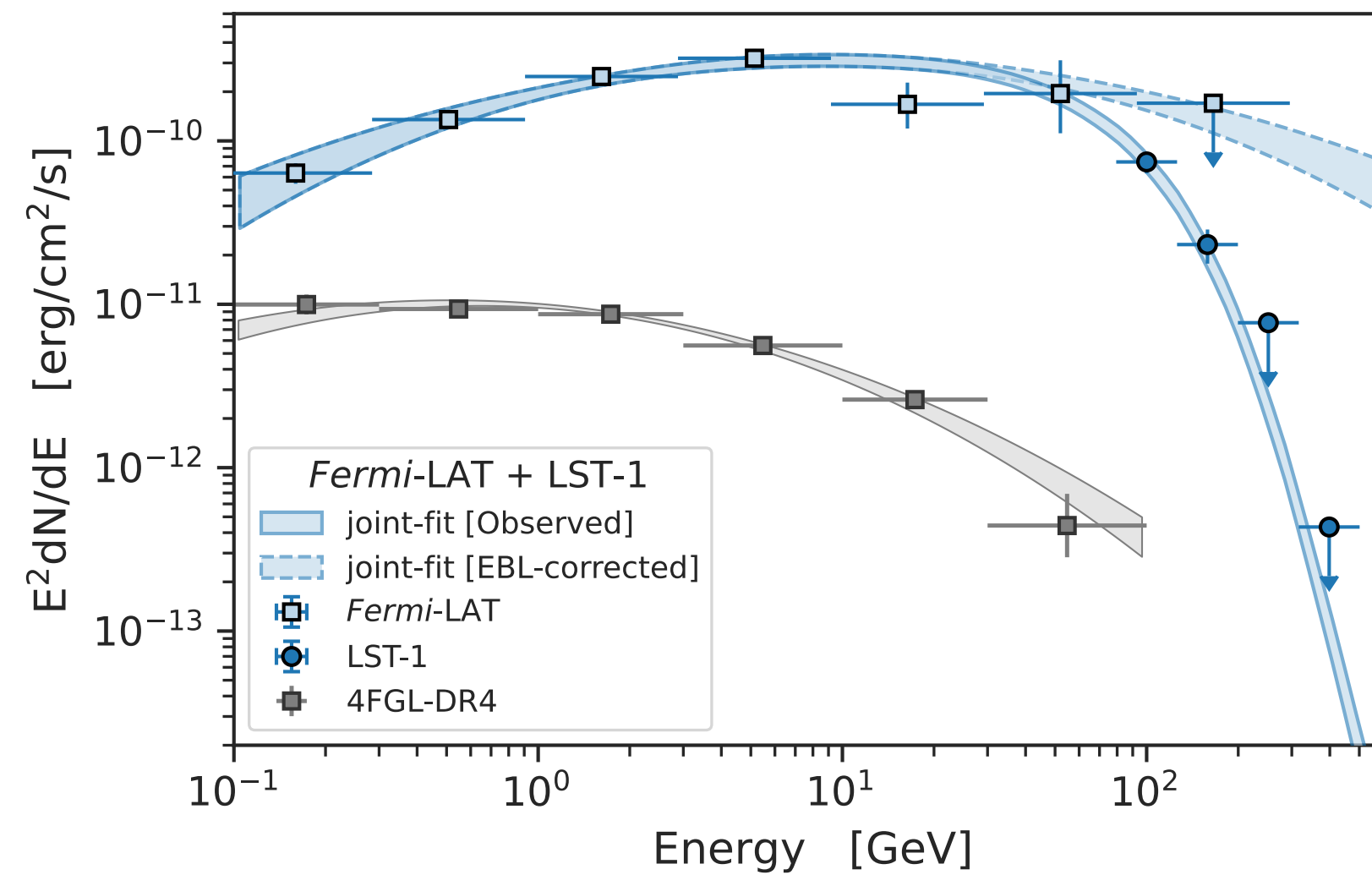


# Flat Spectrum Radio Quasar OP 313

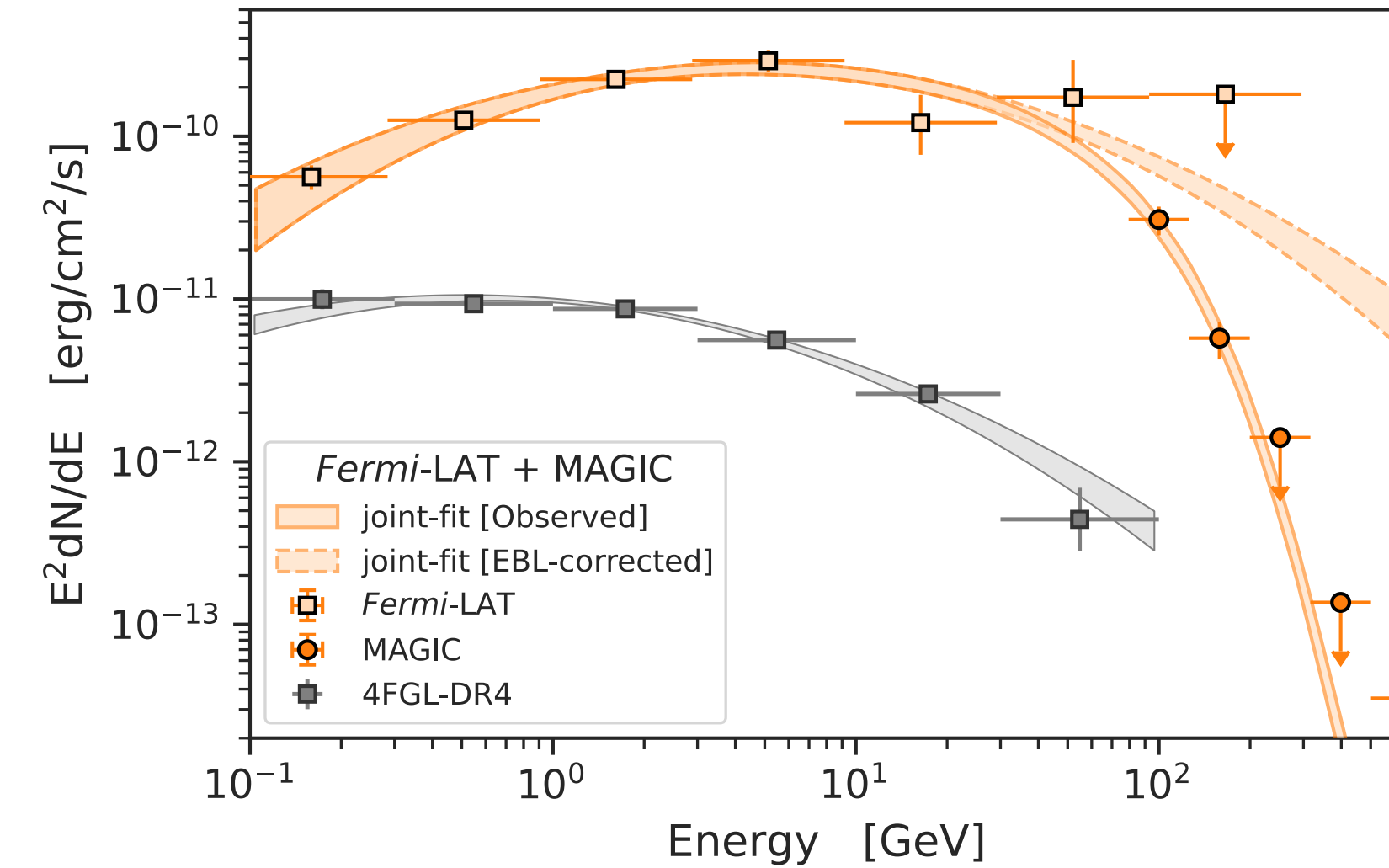
- Strong attenuation at VHE:  $\gamma$ -ray excess detected  $<250$  GeV

- No detection  $>250$  GeV

- Average VHE  $\gamma$ -ray flux ( $>100$  GeV): 30% Crab flux in December 2023



**Fermi-LAT + LST-1**



**Fermi-LAT + MAGIC**

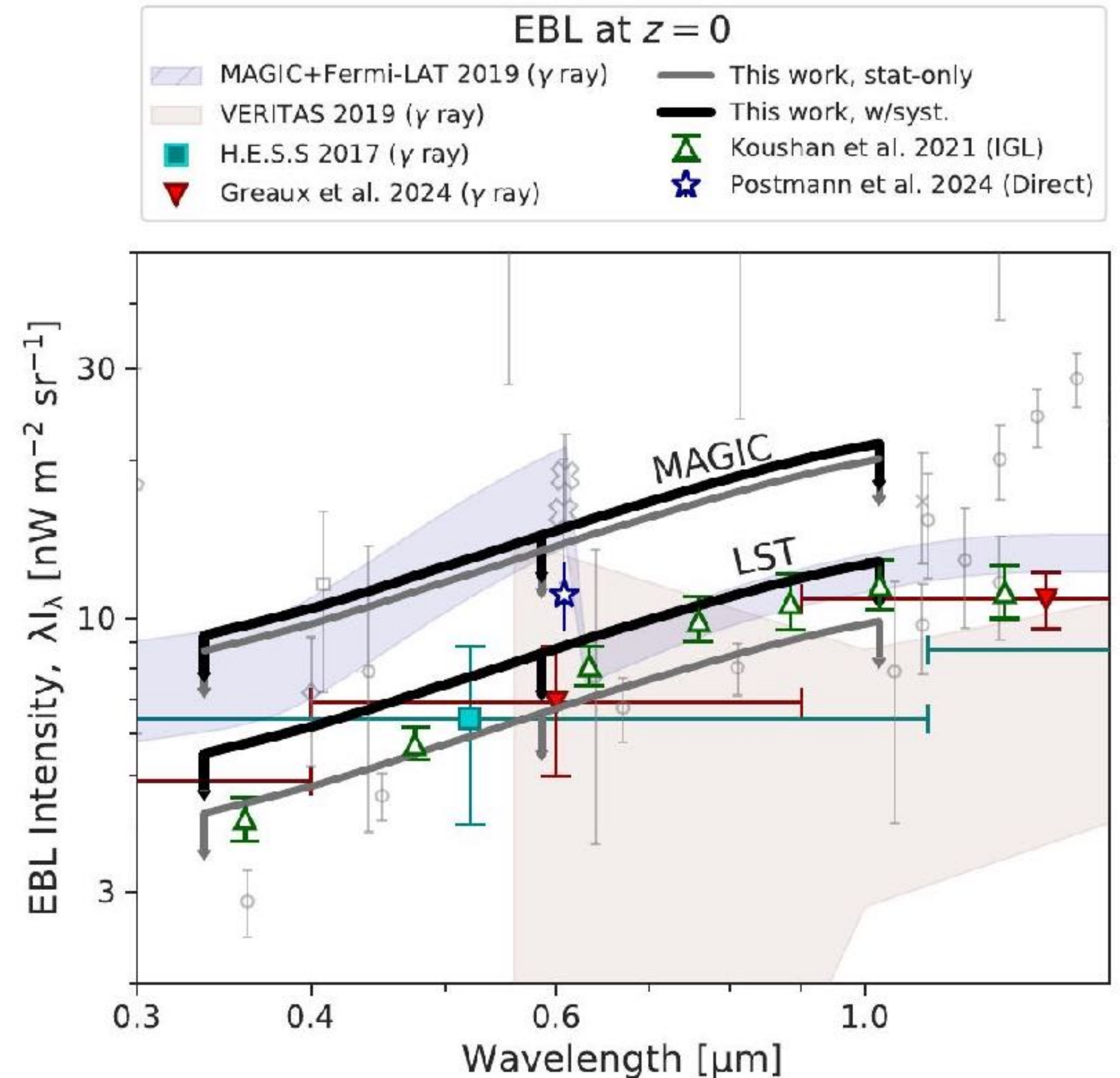
Very steep  $\gamma$ -ray spectrum

- Very distant source: strong EBL absorption
- Efficient cooling of relativistic particles
- FSRQ with bright BLR: internal absorption, emitting region inside or outside the BLR?

# Flat Spectrum Radio Quasar OP 313

Combining HE data from Fermi-LAT and VHE  $\gamma$ -ray data from LST-1 allows us to constrain the EBL intensity

- $F_{\text{obs}} = \exp(-\alpha\tau(z, E_\gamma)) \times F_{\text{int}}$ 
  - $\tau(z, E_\gamma)$ : optical depth for  $\gamma$ -ray propagation
  - $\alpha$ : scaling factor
- Baseline model: Saldana-Lopez et al. (2021)
- Spectral fits performed with  $\alpha$  fixed between 0 and 3, assuming intrinsic models: LP, LPEC, PLEC
- Upper limit scaling factor:  $\alpha_{\text{stat},95\%} = 1.14$
- Corresponding upper limit on EBL density:  $\lambda I_\lambda < 8.74 \text{ nW m}^{-2} \text{ sr}^{-1}$  (including systematics)
- Results in good agreement with [integrated galaxy light \(IGL\)](#) estimates



# Flat Spectrum Radio Quasar OP 313

## LST-1 (23 m IACT, La Palma)

- First CTA-LST prototype; sensitivity down to  $\sim 20$  GeV
- Dec 10–19:  $\sim 15$  h (flare state)  $\rightarrow$  VHE detection
- Jan 2024:  $\sim 5$  h (low state)  $\rightarrow$  no detection

## MAGIC (2 $\times$ 17 m IACTs, La Palma)

- Dec 10–19:  $\sim 10$  h (flare)
- Jan 9–20:  $\sim 4$  h (low state)

## Fermi-LAT

- HE  $\gamma$  rays, 50 MeV–1 TeV
- Continuous coverage (Dec–Jan)

## Swift (XRT + UVOT)

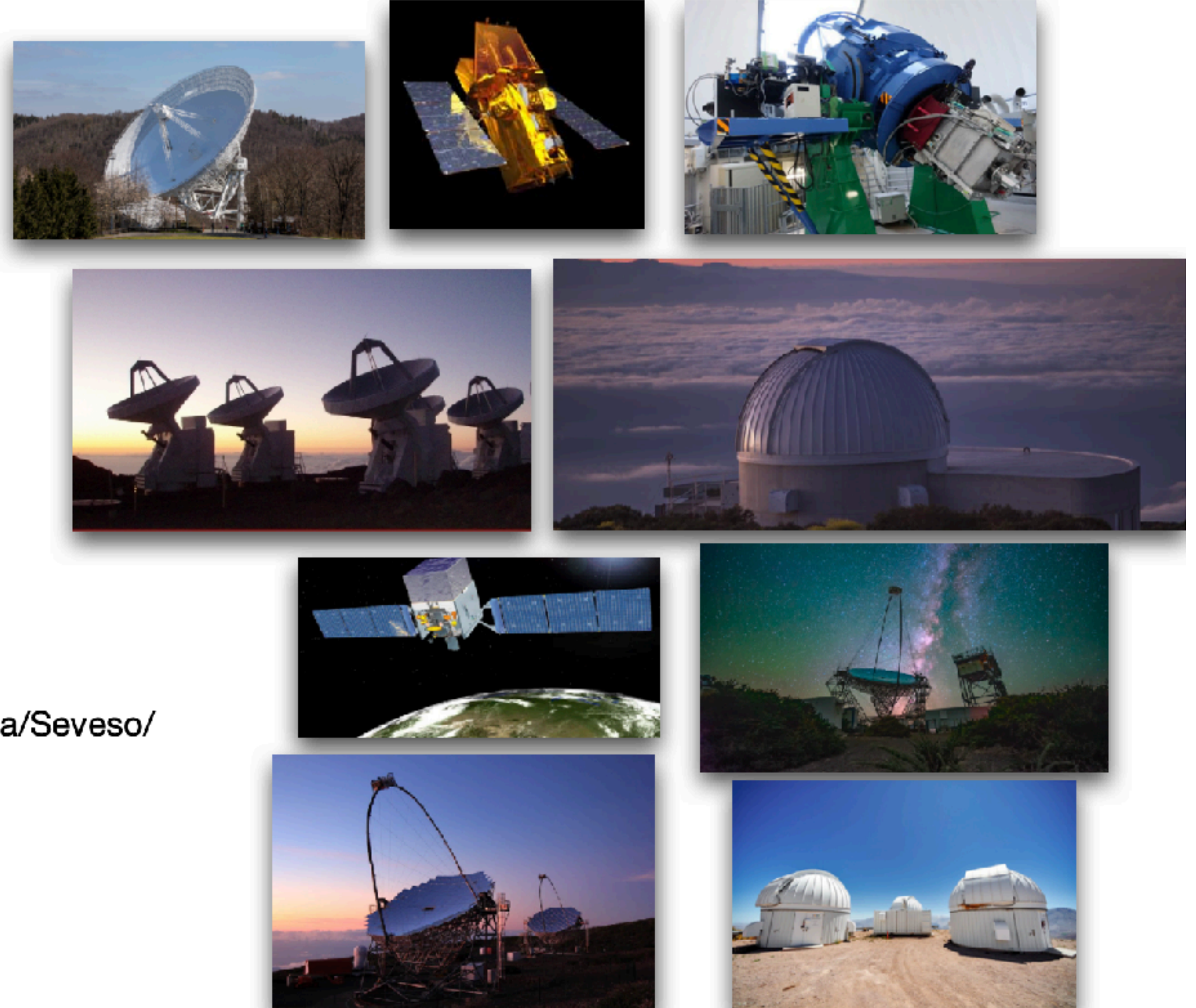
- X-rays (0.3–10 keV), optical/UV (6 filters)

## Optical telescopes

- Sierra Nevada, IAC80, Kanata, Tuorla, Las Cumbres, Siena/Seveso/Montarrenti, surveys (ASAS-SN, ZTF, ATLAS)
- Photometry + polarimetry in BVRI, Sloan g,r,i

## Radio/mm

- SMA (Hawaii): 8 epochs, incl. flare & low state
- Effelsberg (Germany): 4 epochs (multi-band, polarimetry)



# Flat Spectrum Radio Quasar OP 313

## Modelling approach

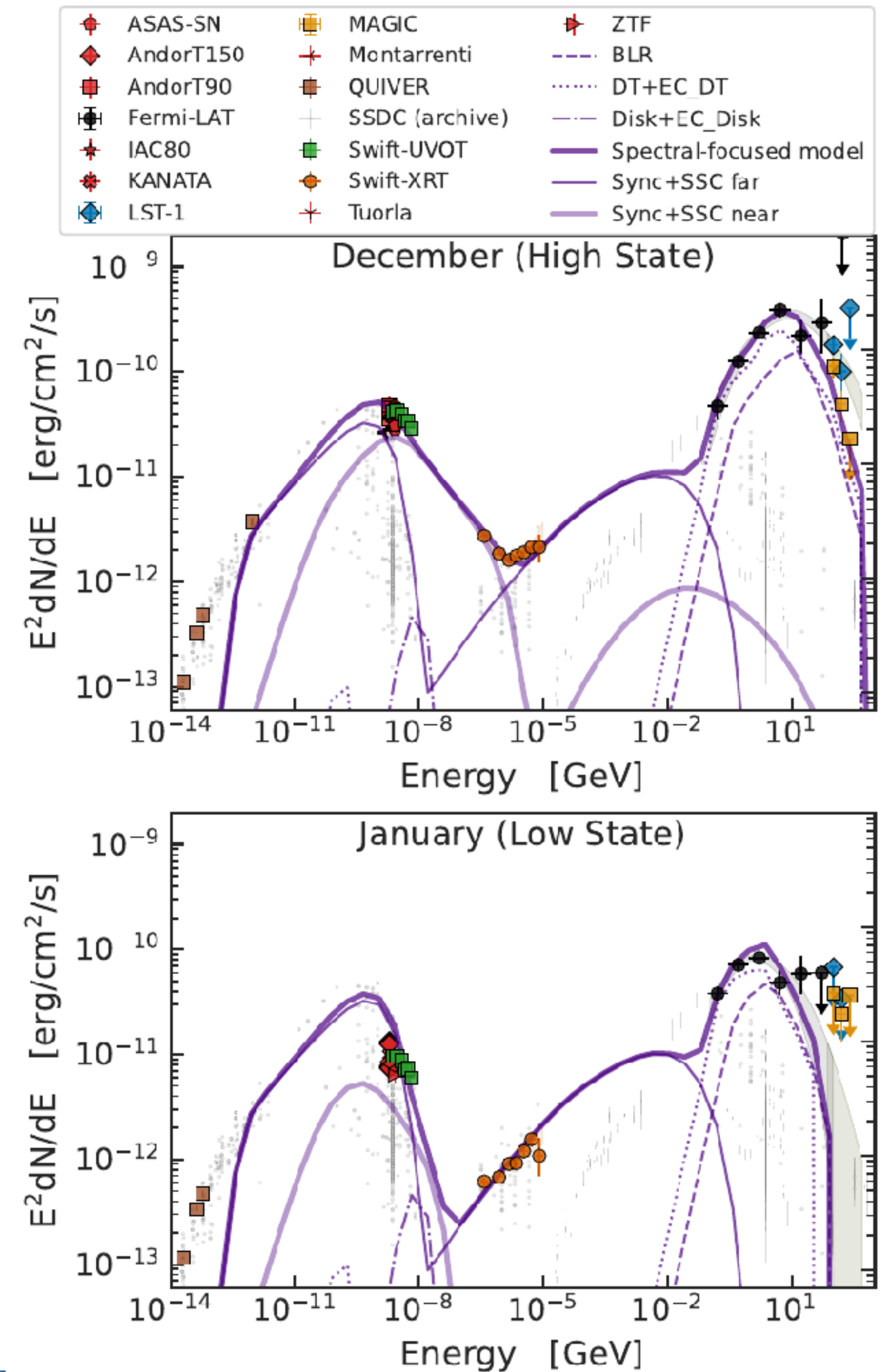
Single zone SSC (synchrotron self-Compton) models insufficient, therefore we adopted two-zone models (near and far zones from the SMBH)

## External components

Mg II line from SDSS spectrum to estimate BLR/disc/torus luminosity and BH mass

## Two modelling scenarios

- Spectral-focused model: optimized to reproduce the SED
  - Stable “far” zone (radio, optical and partly X-rays)
  - Variable “near” zone (low-energy X-rays and  $\gamma$  rays)
    - Close to BLR  $\rightarrow$  BLR and torus contribute to EC
    - Needs high Doppler factor  $\sim 100$
    - Changes between high/low state explained by decrease in electron brean and maximum energy



# Flat Spectrum Radio Quasar OP 313

## Modelling approach

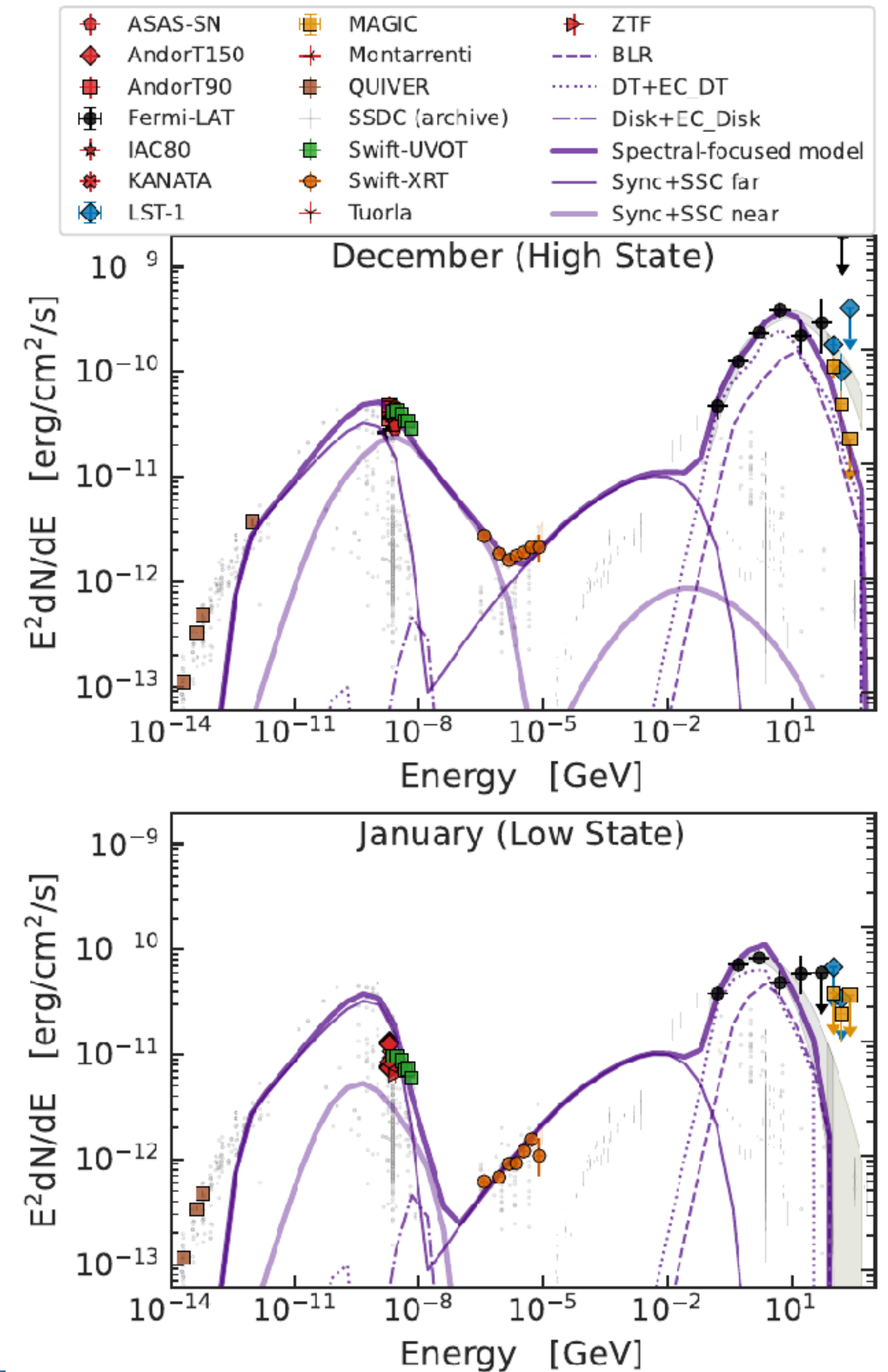
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## External components

Mg II line from SDSS spectrum to estimate BLR/disc/torus luminosity and BH mass

## Two modelling scenarios

- Timing-focused model: based on multi-wavelength correlations
  - Stable “far” zone (radio)
  - Variable “near” zone (optical/UV to  $\gamma$  rays)
    - Well beyond the BLR  $\rightarrow$  torus is the dominant target field for EC
    - Doppler factor  $\sim 50$
    - Changes between high/low state explained by index softening and decrease in electron break energy



# Flat Spectrum Radio Quasar OP 313

## Modelling approach

Single zone SSC (synchrotron self-Compton) models insufficient, therefore we adopted two-zone models (near and far zones from the SMBH)

## External components

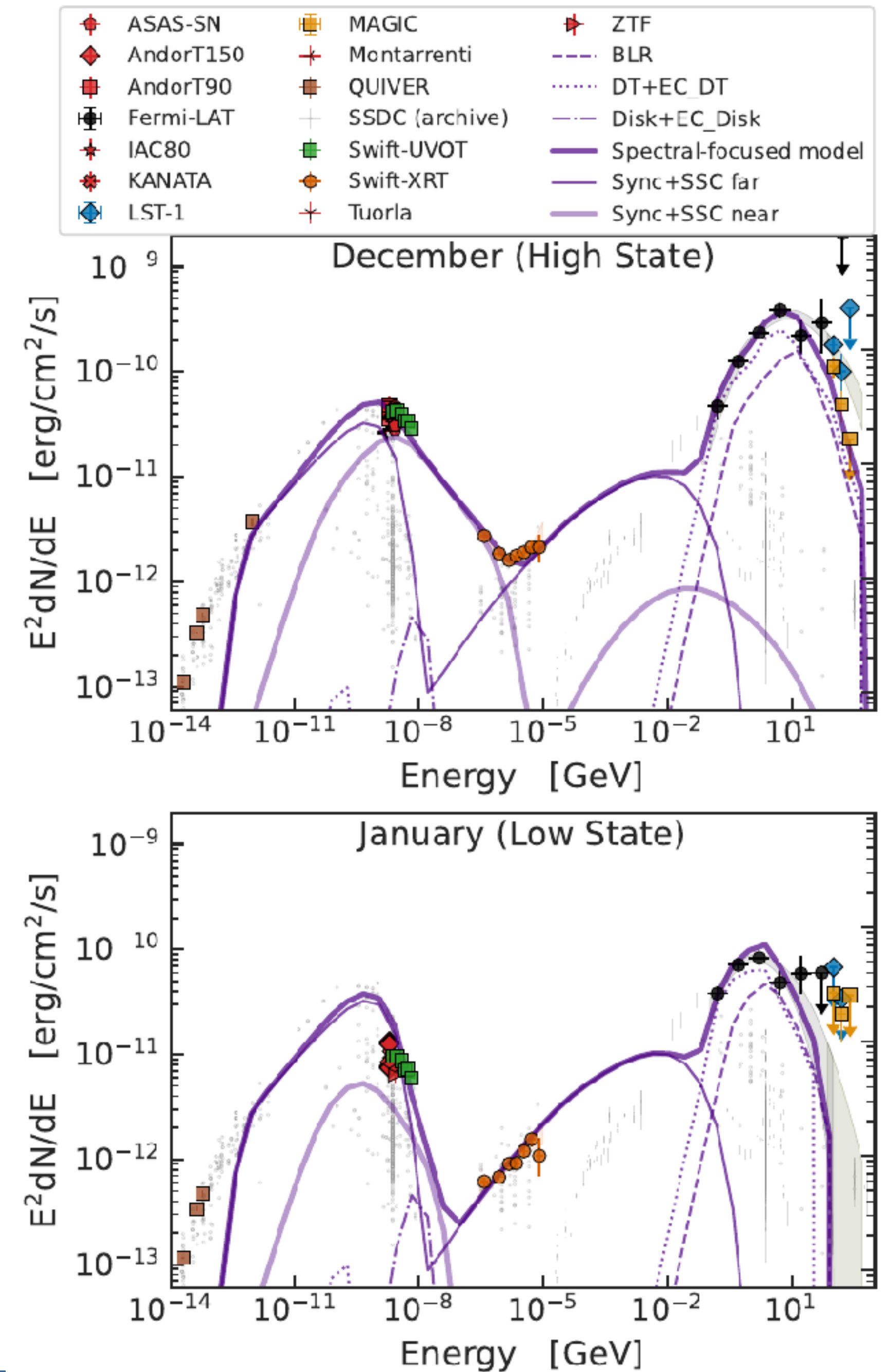
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## Two modelling scenarios

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- Timing-focused model: based on multi-wavelength correlations

## Physical interpretation

- Near zone possibly linked to plasma blob ejection
- Spectral index changes suggest cooling and injection driving the changes, adiabatic losses or stochastic acceleration in shocks



# Flat Spectrum Radio Quasar OP 313

Upcoming publication on the 2023 flare by the LST and MAGIC Collaborations soon to come (CTAO-LST & MAGIC Collaborations, A&A, accepted, in press)

Proof that CTAO will expand the limits of the known VHE  $\gamma$ -ray Universe



D. Sanchez



J. Otero Santos



L. Heckmann



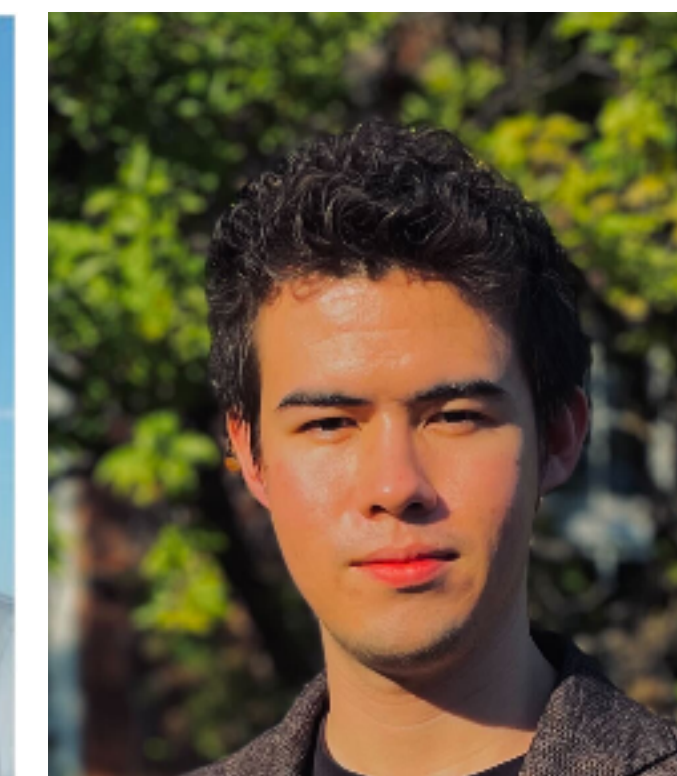
M. Nieves Rosillo



D. Morcuende



A. Arbet-Engels



J. Baxter

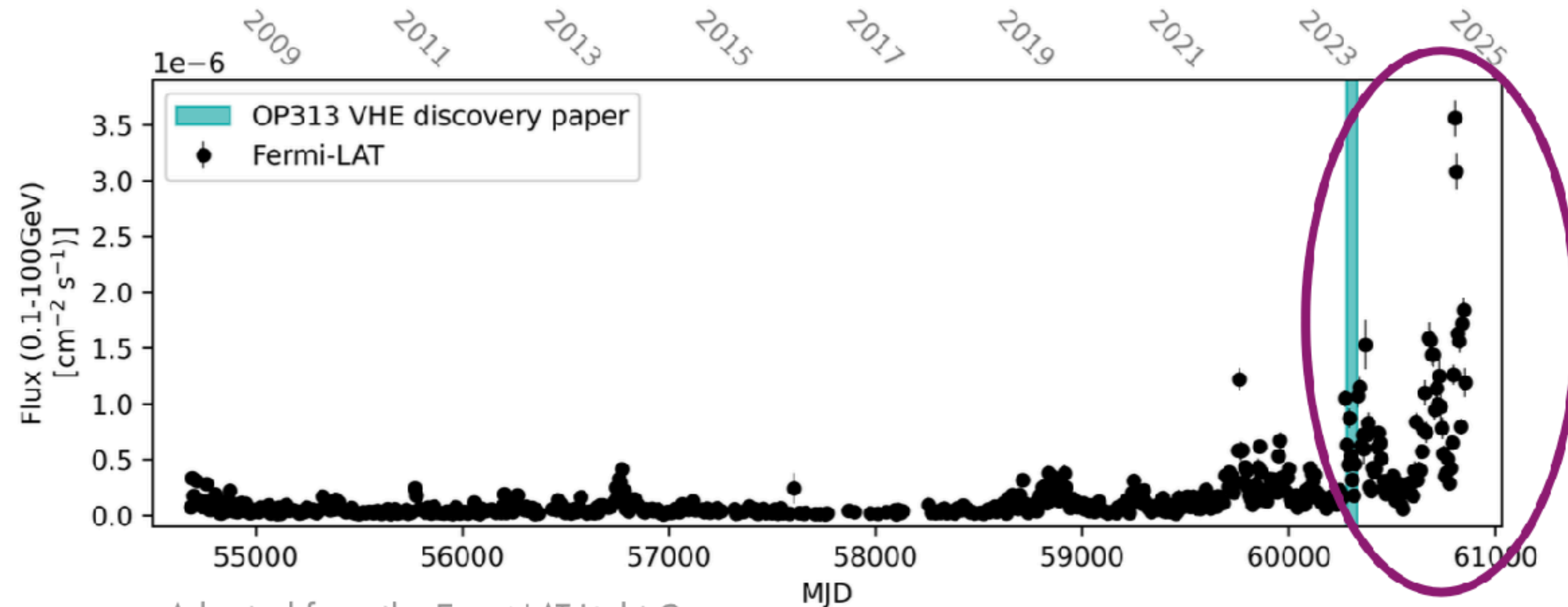
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Proof that CTAO will expand the limits of the known VHE  $\gamma$ -ray Universe

More interesting results on OP 313 are coming!

- Recurrent flares during 2024
- Brightest flare ever in January 2025, and among the brightest ever detected by *Fermi*-LAT from an AGN/blazar



Adapted from the Fermi LAT Light Curve Repository (LCR)

Stay tuned!

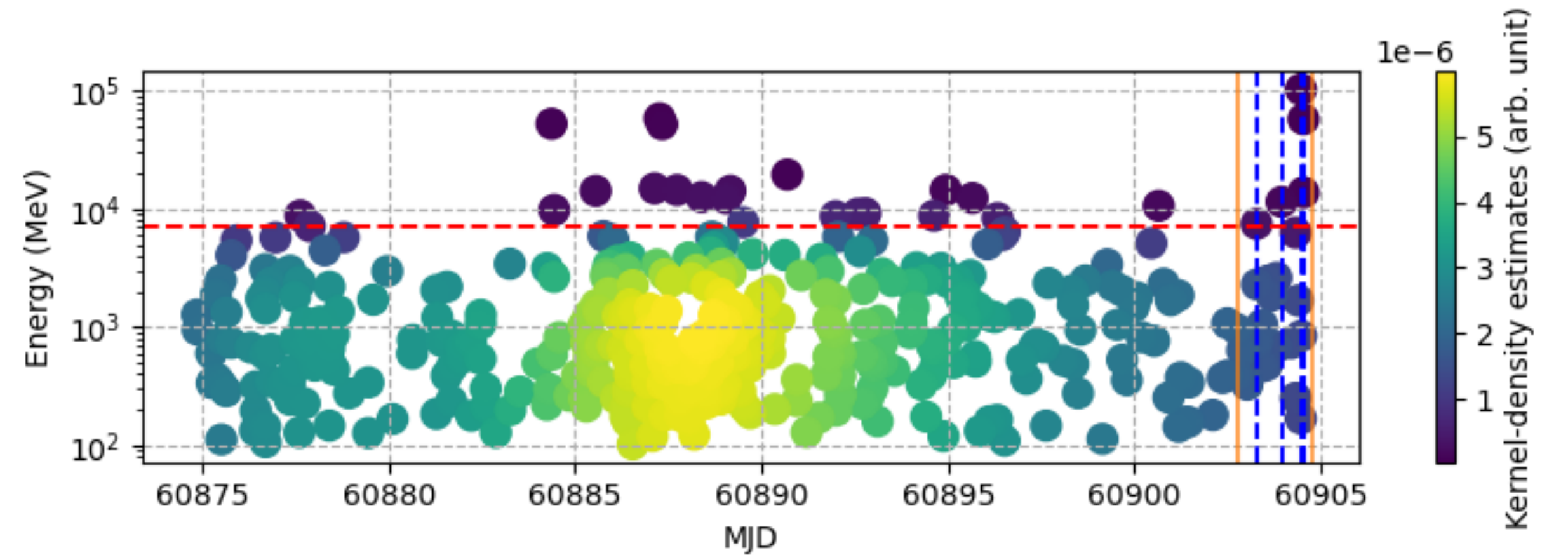
# Flat Spectrum Radio Quasar PKS 1725+123

## More discoveries are coming!

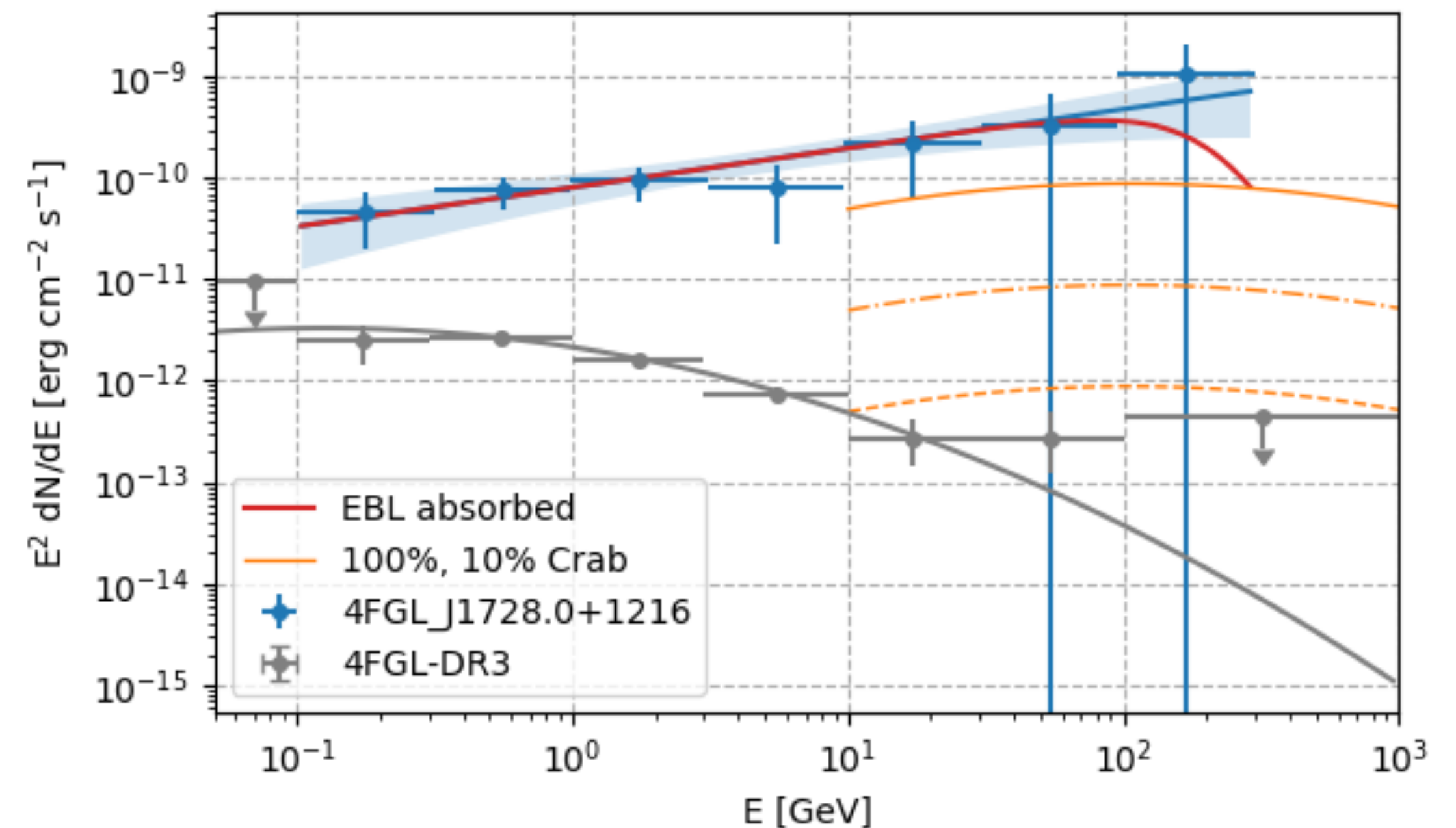
- [Flaschep pipeline](#) detected a cluster of [VHE  \$\gamma\$ -ray photons](#) from FSRQ **PKS 1725+123** ( $z=0.589$ ) in August 2025
- [Very hard spectrum](#) in the HE  $\gamma$ -ray band seen by *Fermi*-LAT ([spectral index 1.61](#))

**LST-1 and MAGIC** observed for 2 hours on the nights of the 18 and 19 of August

Campaign supported by [Swift-XRT/UVOT](#), [Sierra Nevada Observatory](#), [Las Cumbres...](#)



4FGL J1728.0+1216 (PKS 1725+123) [FSRQ, LSP],  $z=0.58$   
index=1.61  $\pm$  0.15



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## First detection of flaring very-high-energy gamma-ray emission from PKS 1725+123 with the MAGIC and LST-1 telescopes

ATel #17344; *David Paneque (Max Planck Institute for Physics), Masahiro Teshima (Max Planck Institute for Physics), Ryuji Takeishi (Institute for Cosmic Ray Research, University of Tokyo), Seiya Nozaki (Institute for Cosmic Ray Research, University of Tokyo), Mathilde Croisssonier (IFAE Barcelona), Yusuke Suda (Hiroshima University), Axel Arbet-Engels (Max Planck Institute for Physics) and Jorge Otero Santos (INFN Padova) on behalf of the MAGIC and LST CTAO collaborations*  
on 19 Aug 2025; 21:31 UT

PKS 1725+123:

- Second scientific discovery made with LST-1
- 12th FSRQ ever detected at VHE  $\gamma$ -ray energies

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# LST-1 and IXPE

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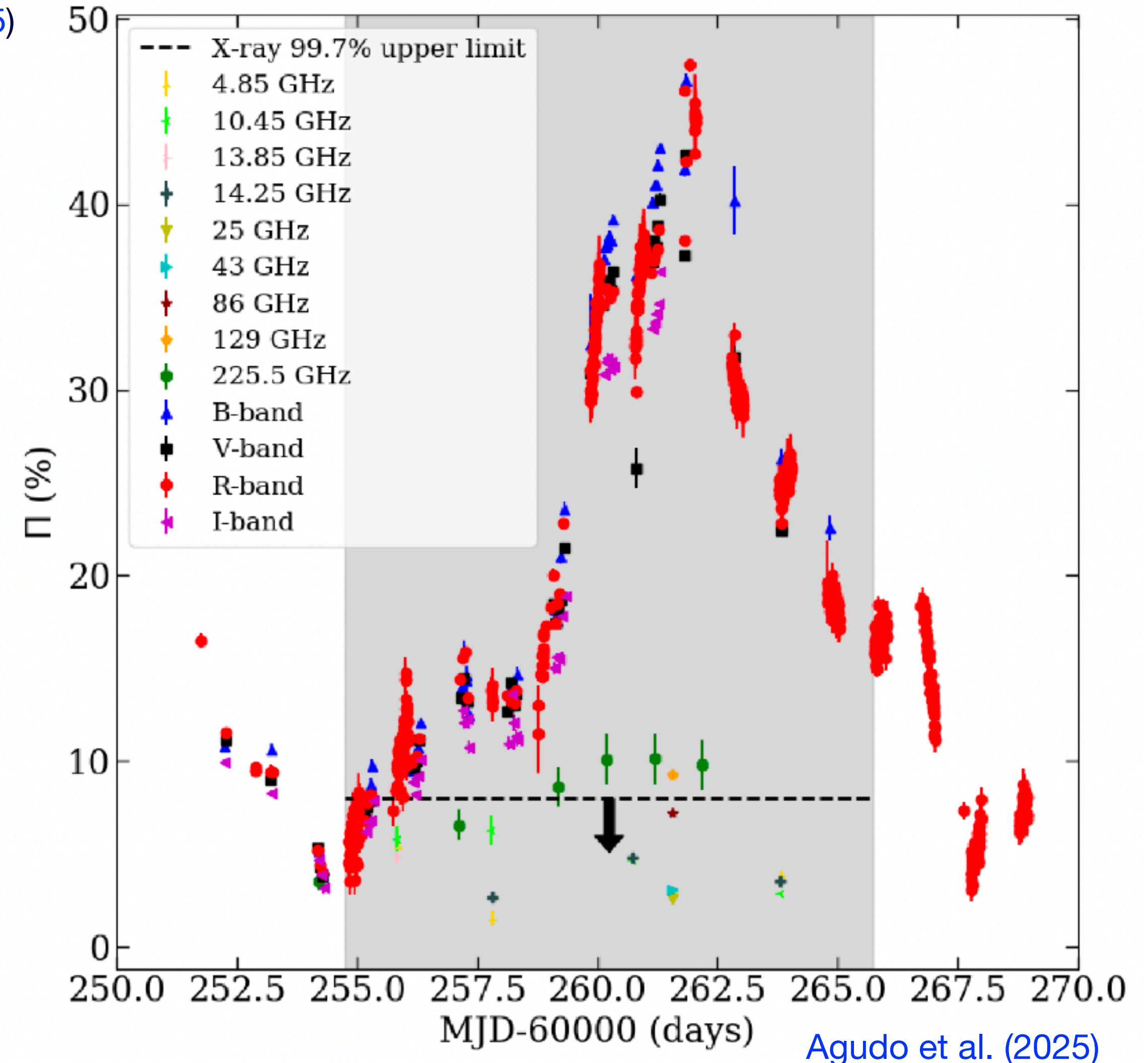
# LST-1 and IXPE: BL Lacertae campaign

IXPE observed BL Lac in November 2023 (Agudo, Liodakis, Otero-Santos et al., 2025)

- **Optical polarization** from ~3-4% up to **47.5%**
  - **Almost perfectly ordered magnetic field**
  - **Most polarized blazar ever observed**
- **High polarization at radio wavelengths (~10%)**
- **X-ray polarization  $3\sigma$  upper limit of <7.4%**

Model	X-ray polarization degree
single-zone leptonic (EC)	Unpolarized
single-zone leptonic (SSC)	$0.5 \times \Pi_O$
energy-stratified/multizone leptonic (SSC)	$\leq 0.3 \times \Pi_O$
single-zone hadronic	$\approx \Pi_O$
energy-stratified/multizone hadronic (flare)	$\approx \Pi_O$
energy-stratified/multizone hadronic (non-flare)	$\approx \Pi_{mm}$

Poutanen et al. (1994), Liodakis et al. (2019), Zhang, Liodakis & Böttcher (2024)



Agudo et al. (2025)

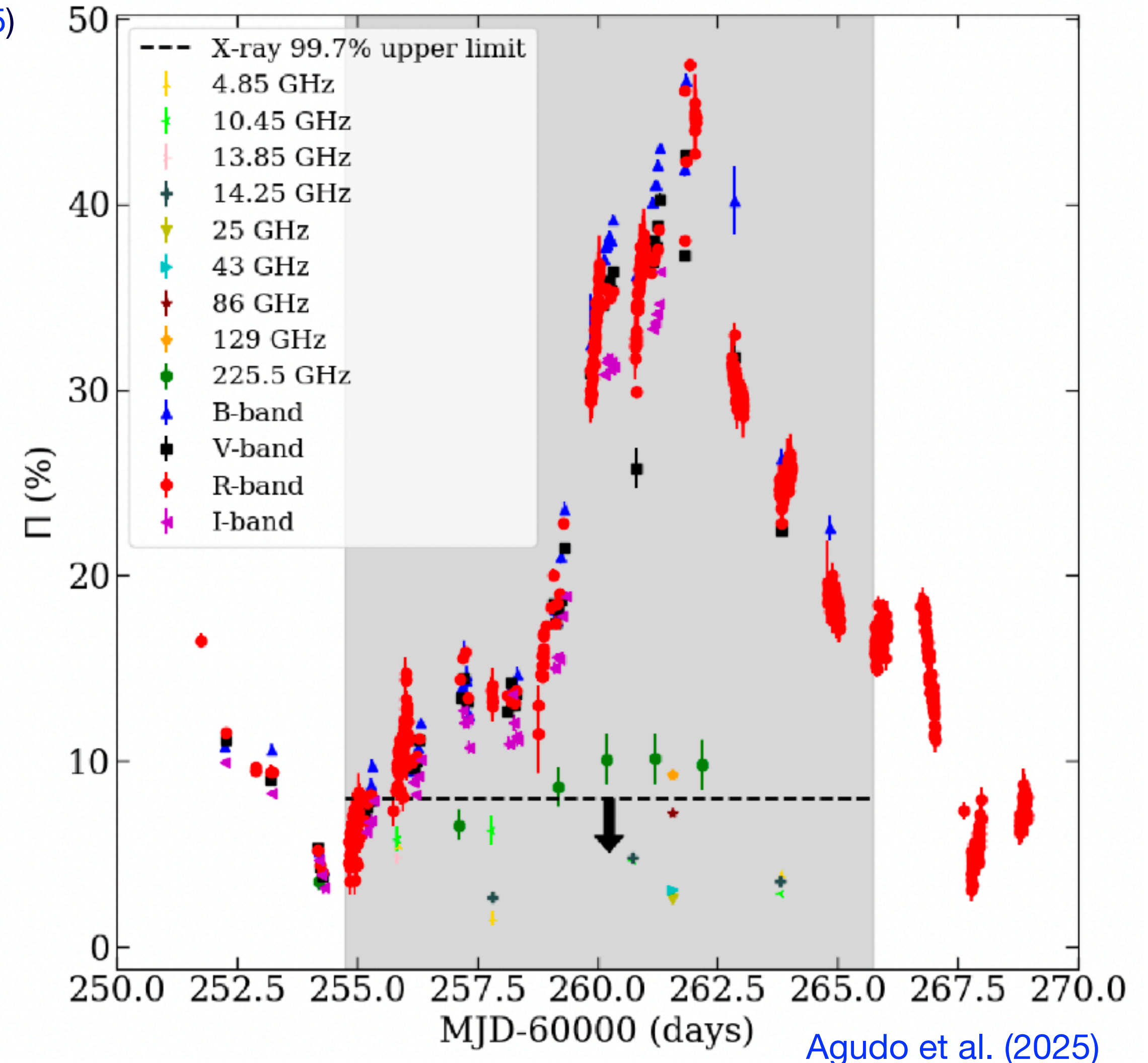
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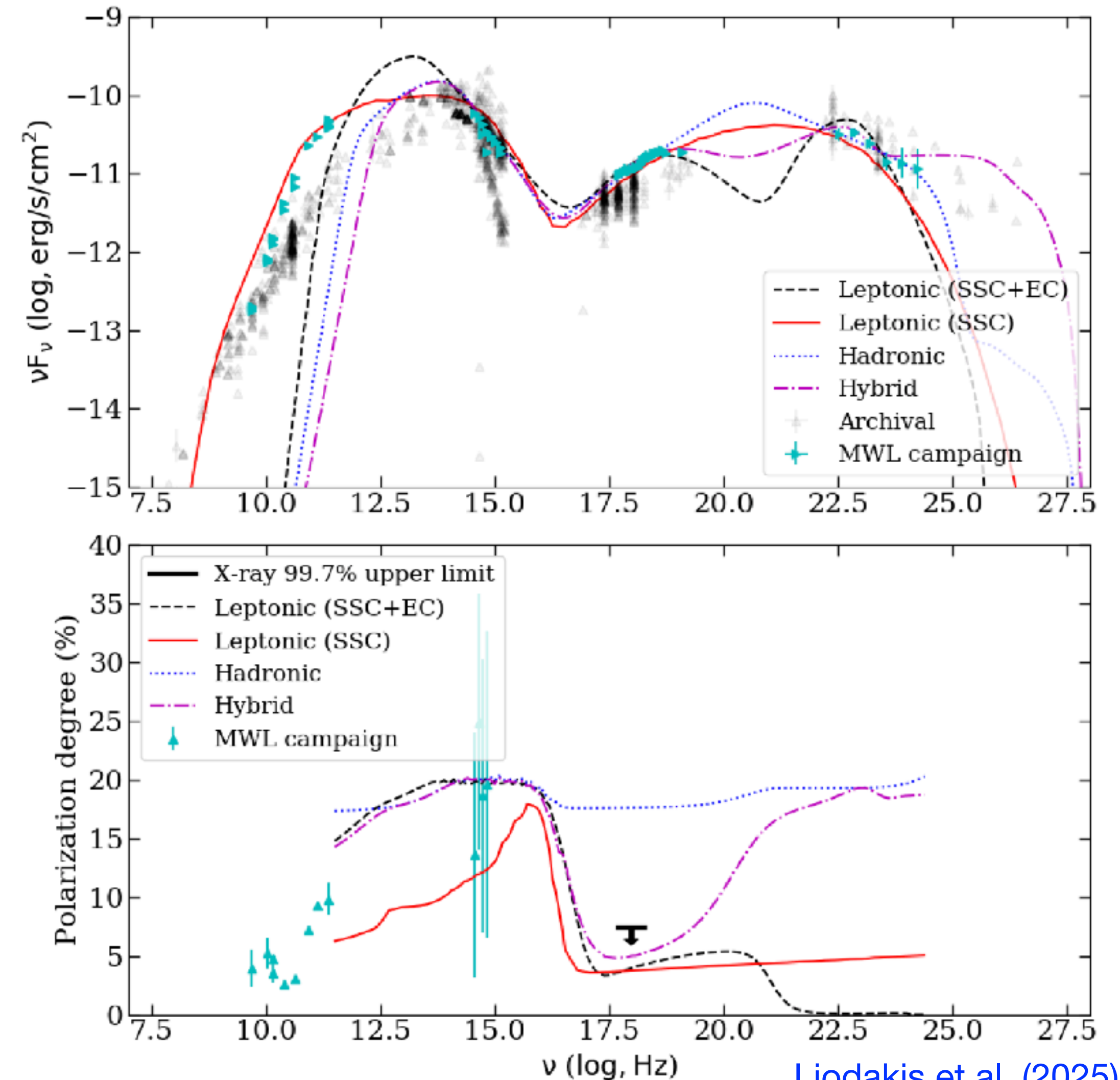


Agudo et al. (2025)

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Complemented analysis with **theoretical modelling** of the multi-wavelength emission **incorporating the polarization** information

- **Leptonic SSC favoured**

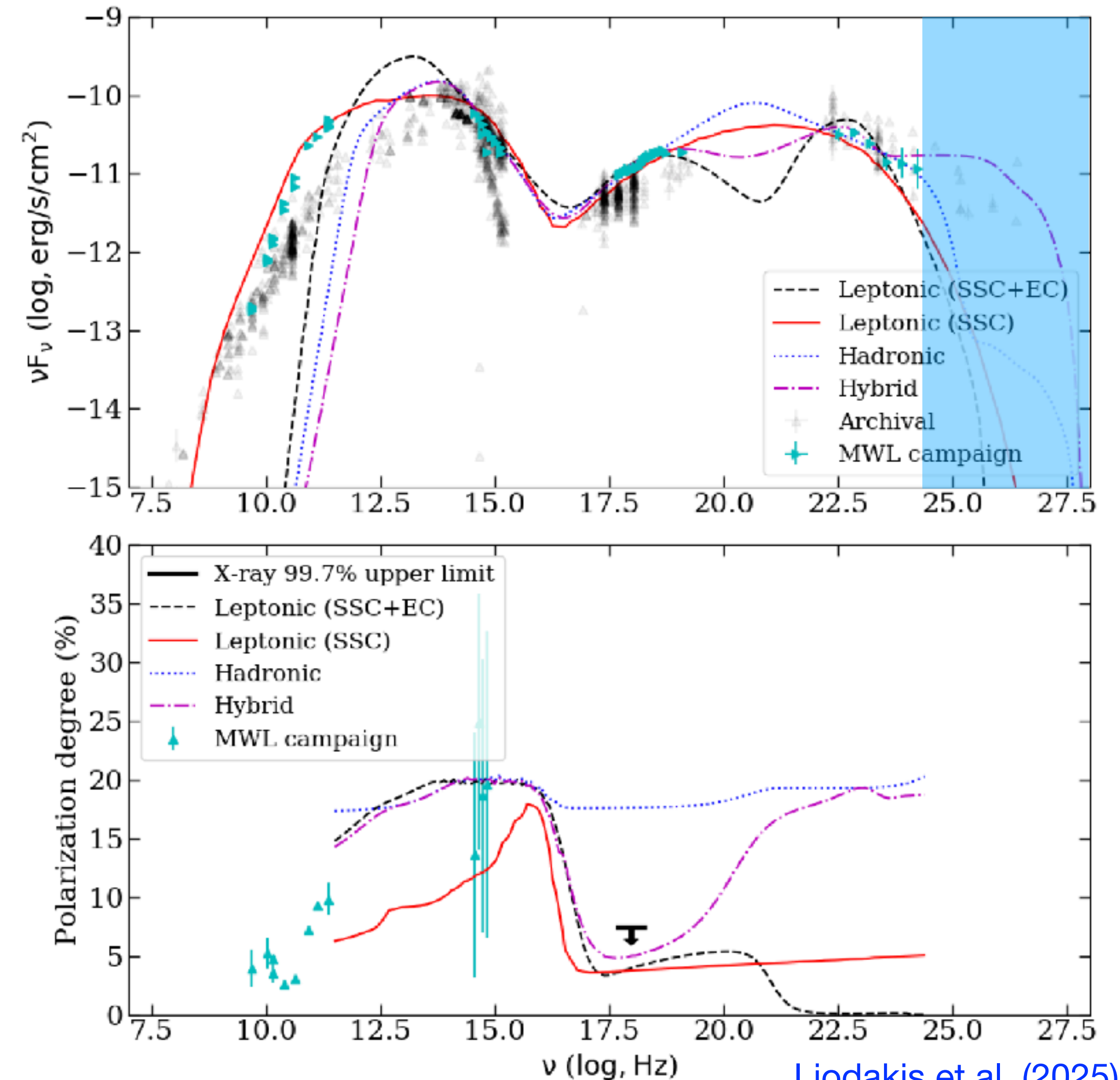


Liodakis et al. (2025)

# LST-1 and IXPE: BL Lacertae campaign

Complemented analysis with **theoretical modelling** of the multi-wavelength emission **incorporating the polarization** information

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- Hybrid **lepto-hadronic models still possible**, but with very different signatures at VHE  $\gamma$  rays



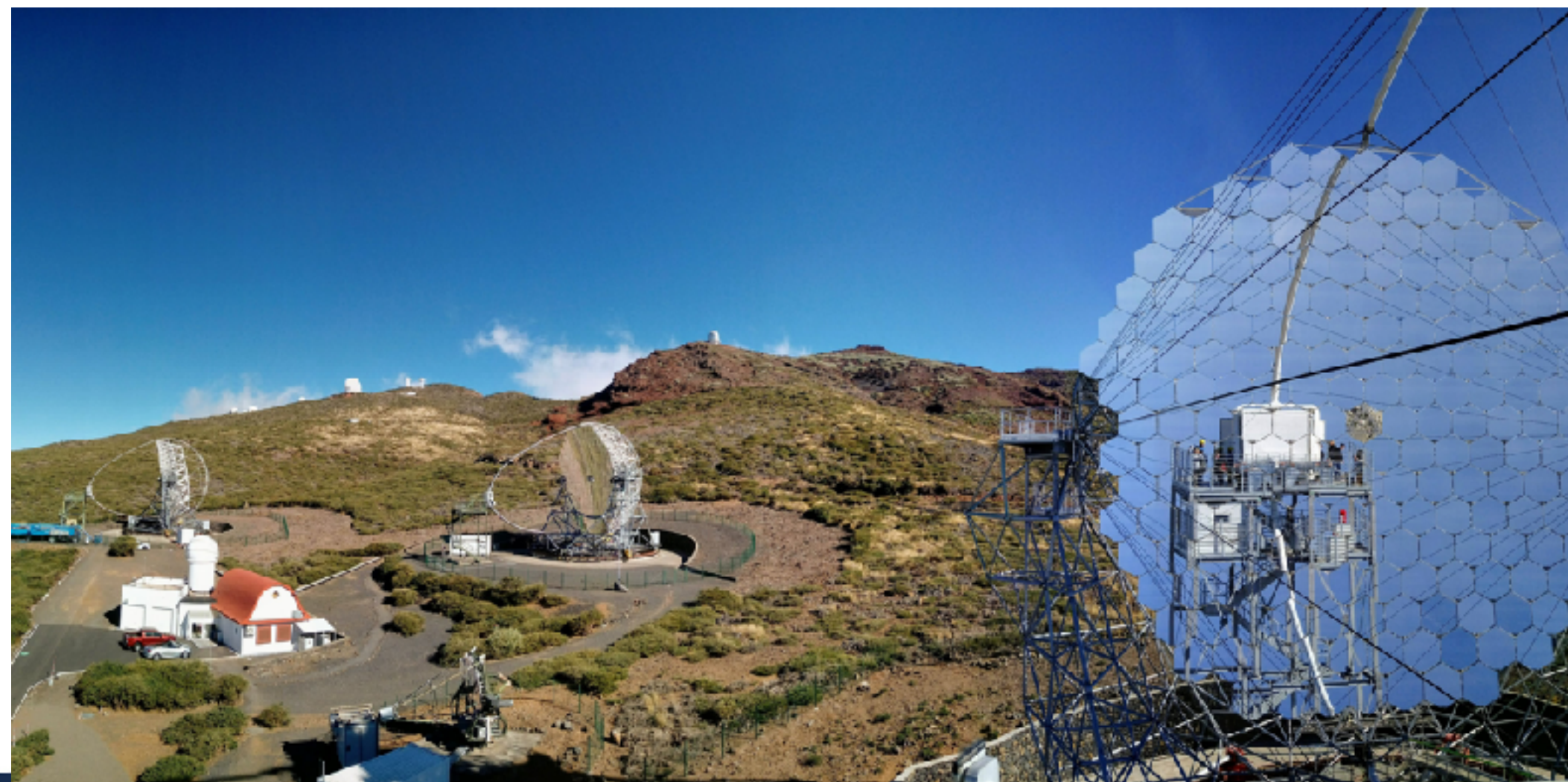
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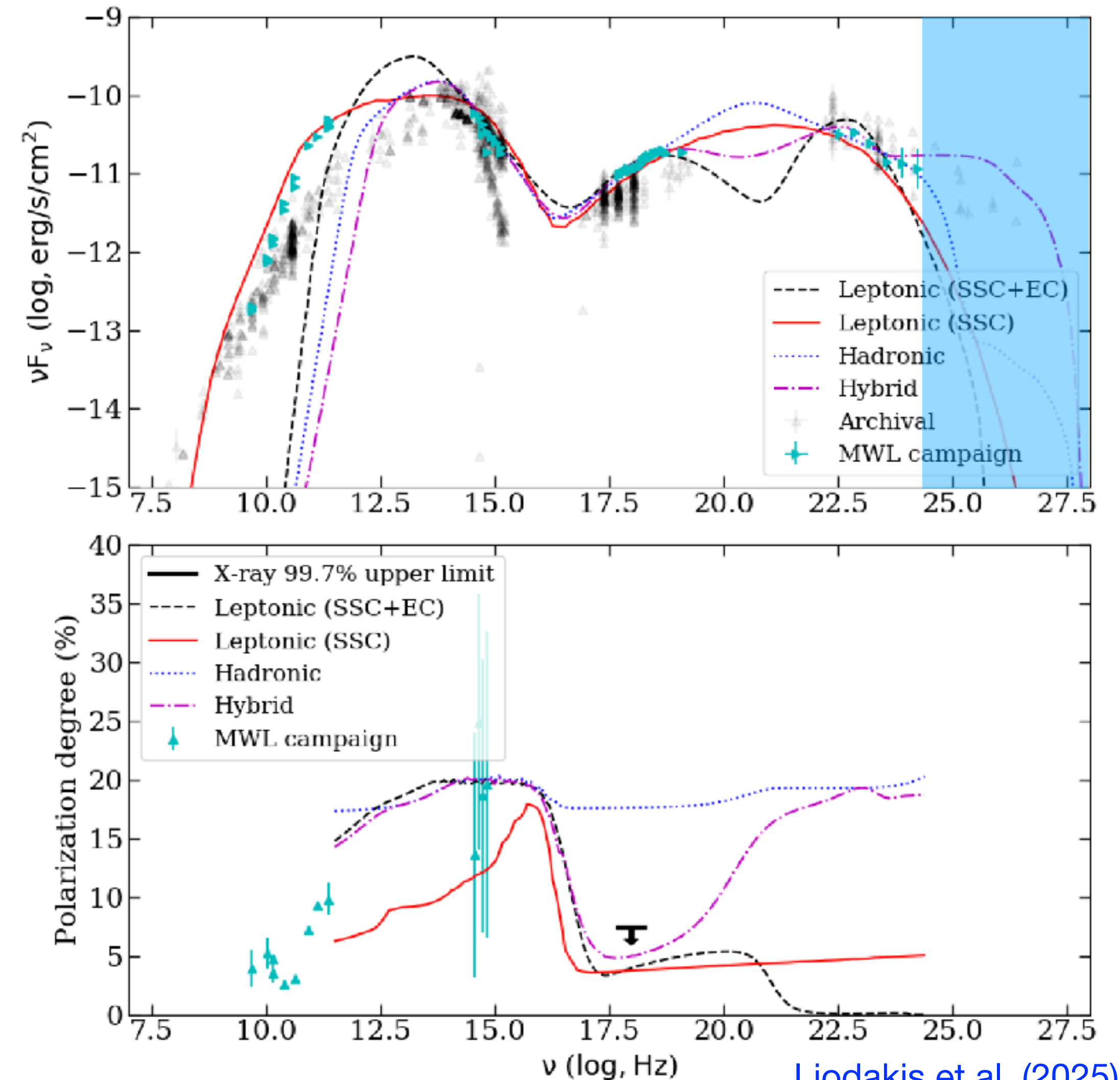
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IXPE campaign followed by **MAGIC and LST-1**



Credit: Alicia López Oramas (IAC)



Lioudakis et al. (2025)

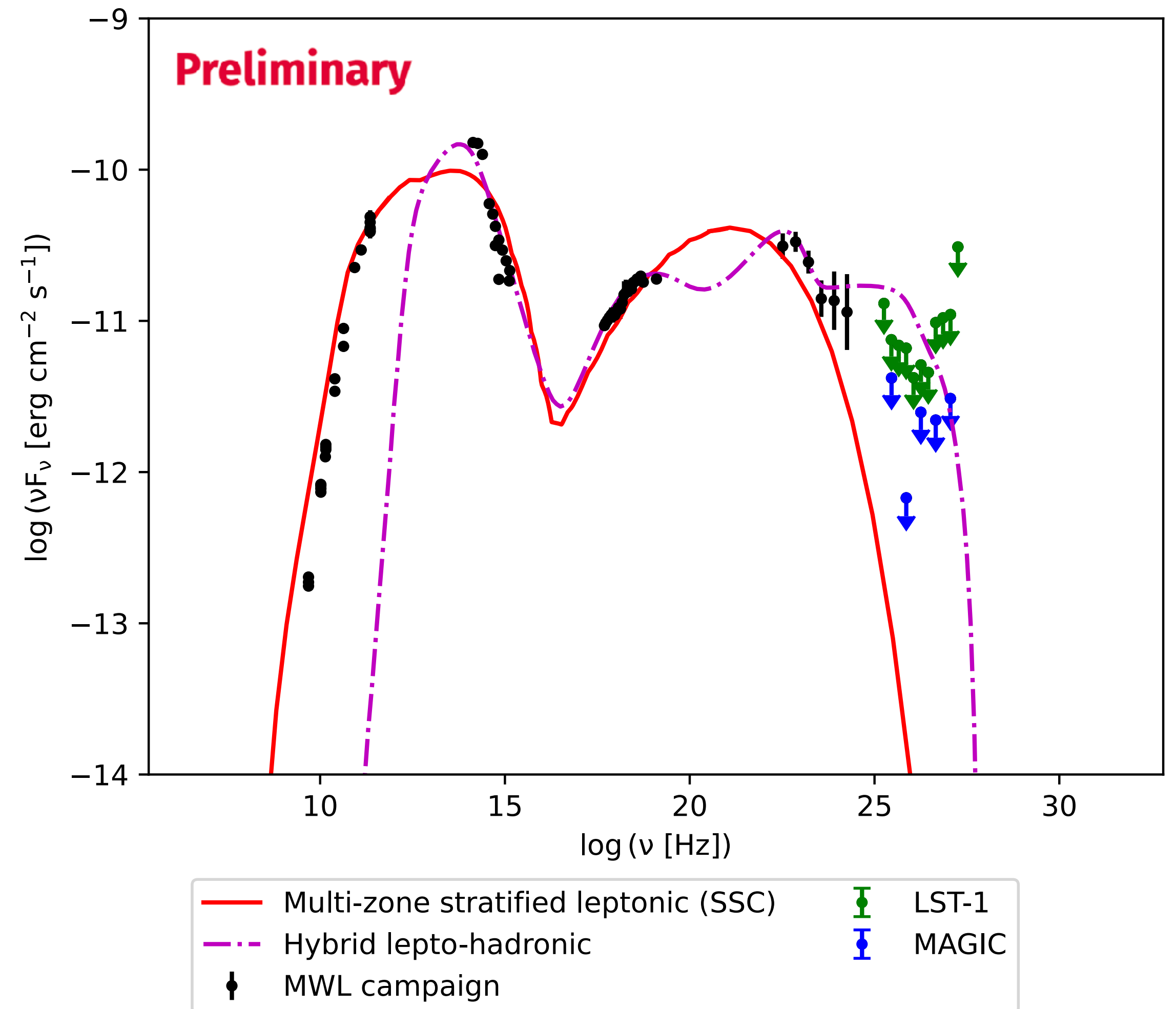
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## Ongoing work within MAGIC and CTAO-LST-1

- Upper limits used to exclude or constrain the possibility of hybrid lepto-hadronic emission
- Parameter scan of the hadronic models considering different hadronic processes
- Joint MAGIC+LST analysis can be even more constraining



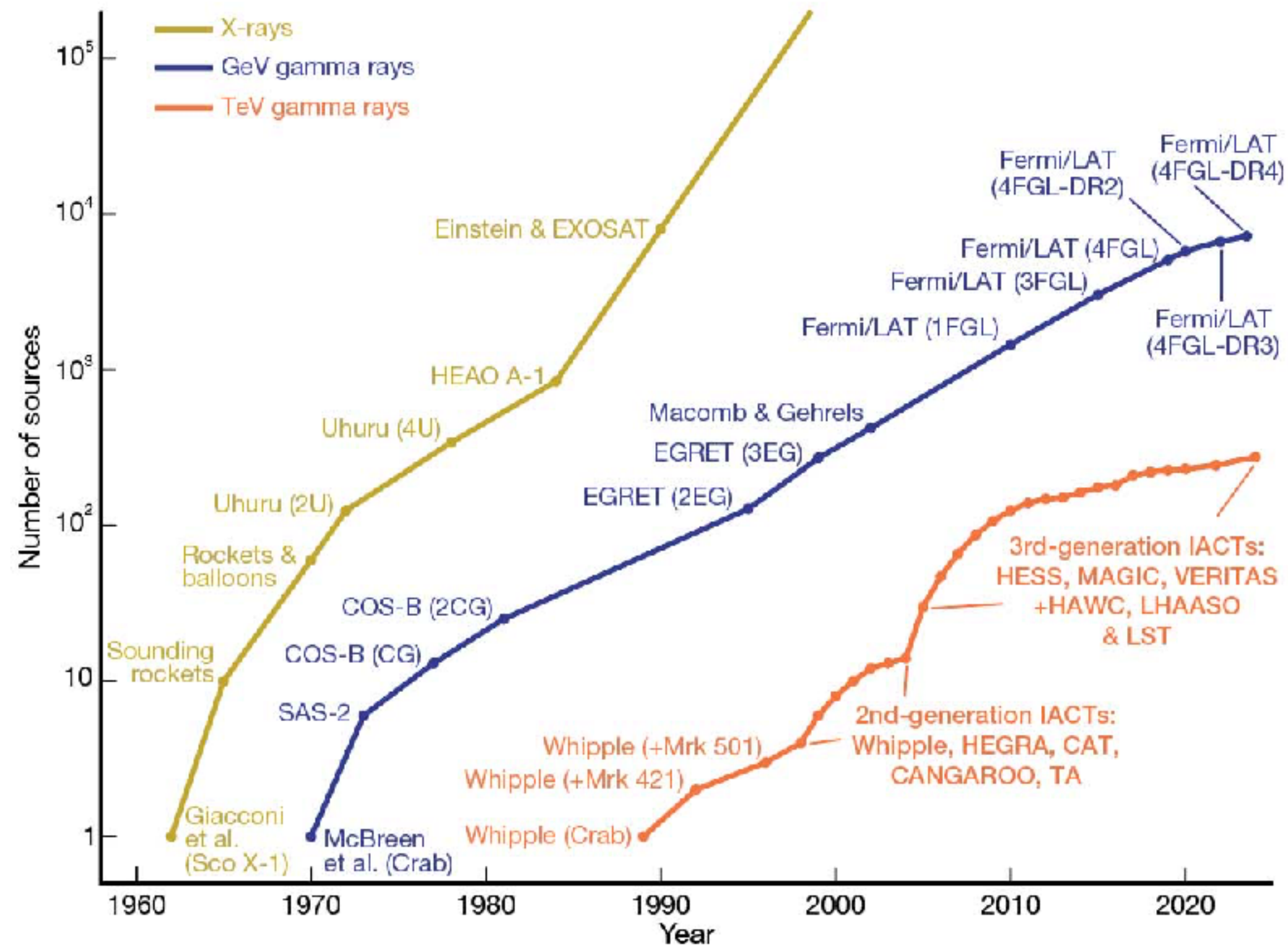
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# Perspectives on extragalactic physics towards CTAO

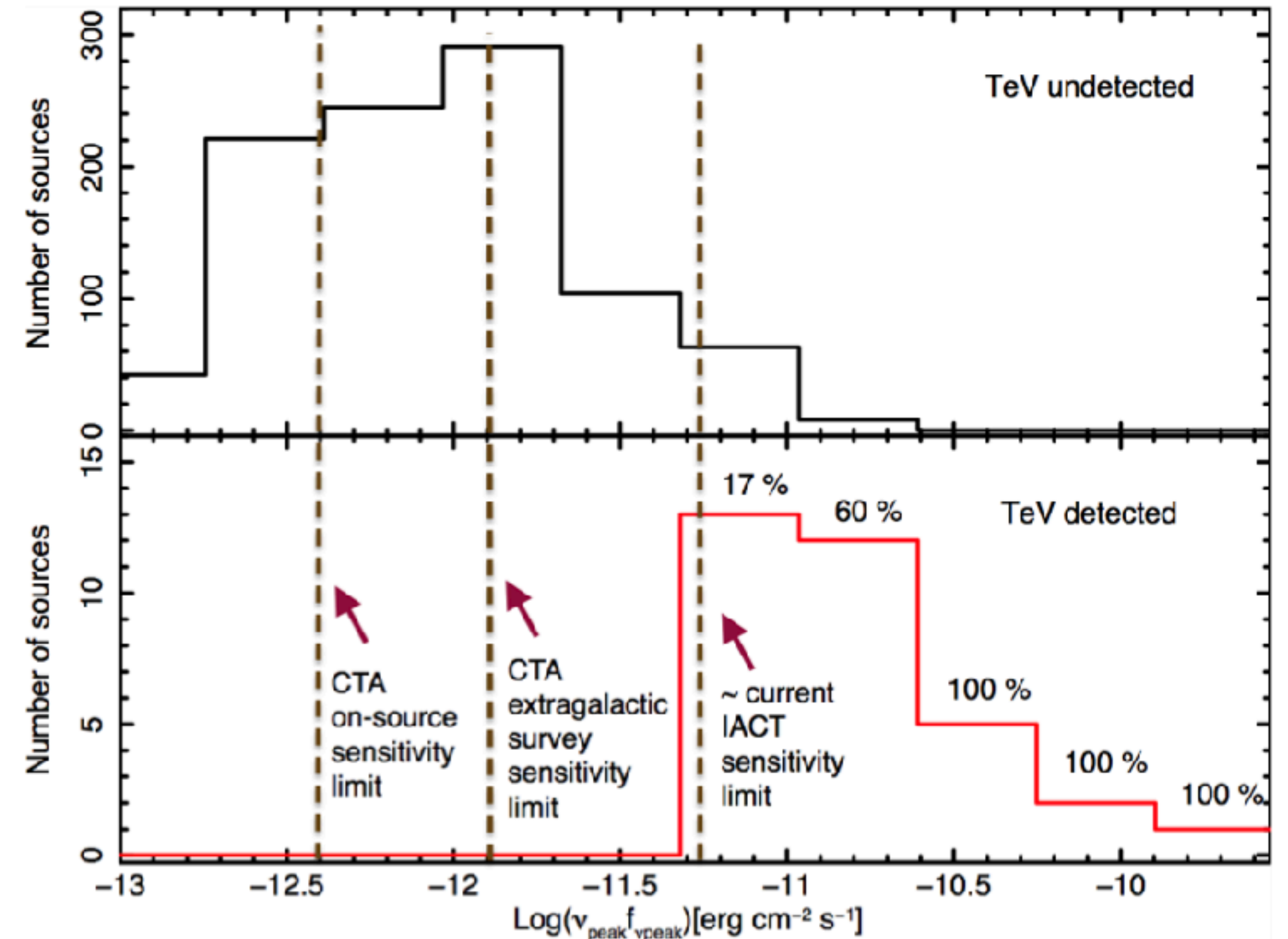
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# Perspectives towards CTAO

CTAO will revolutionize the field of  $\gamma$ -ray astronomy

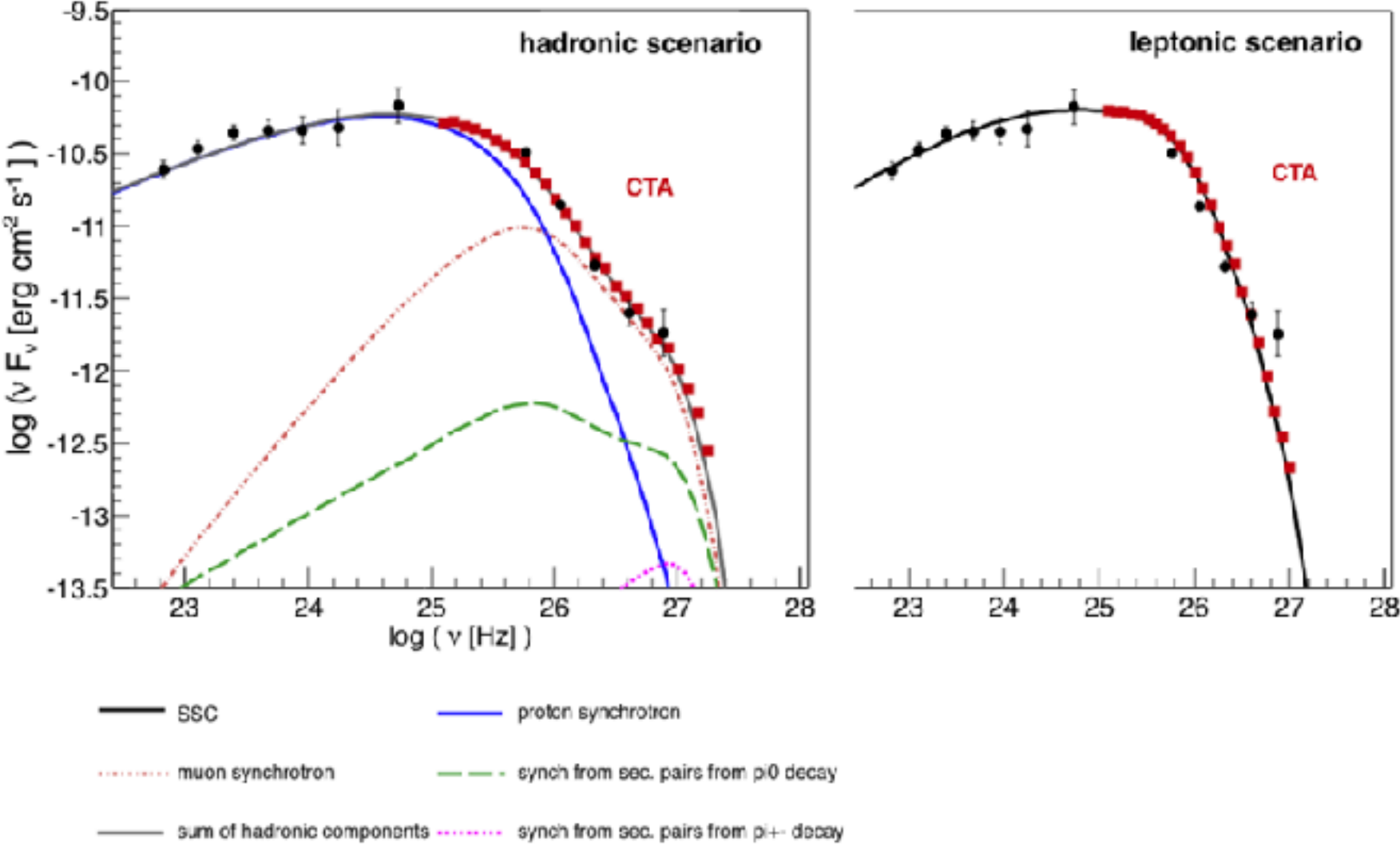


Credit: CTAO



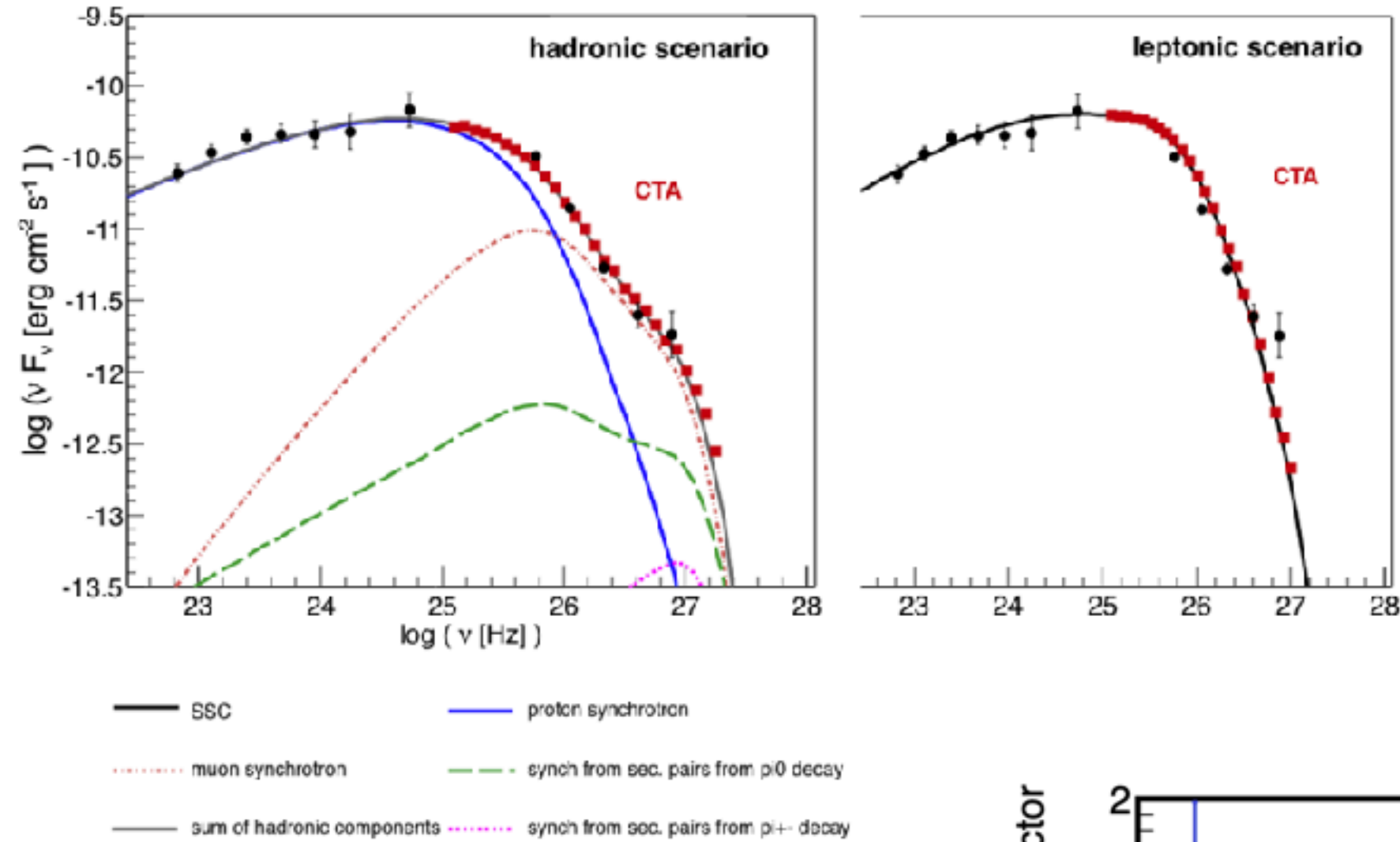
CTAO Science Book

## Origin of the $\gamma$ -ray emission

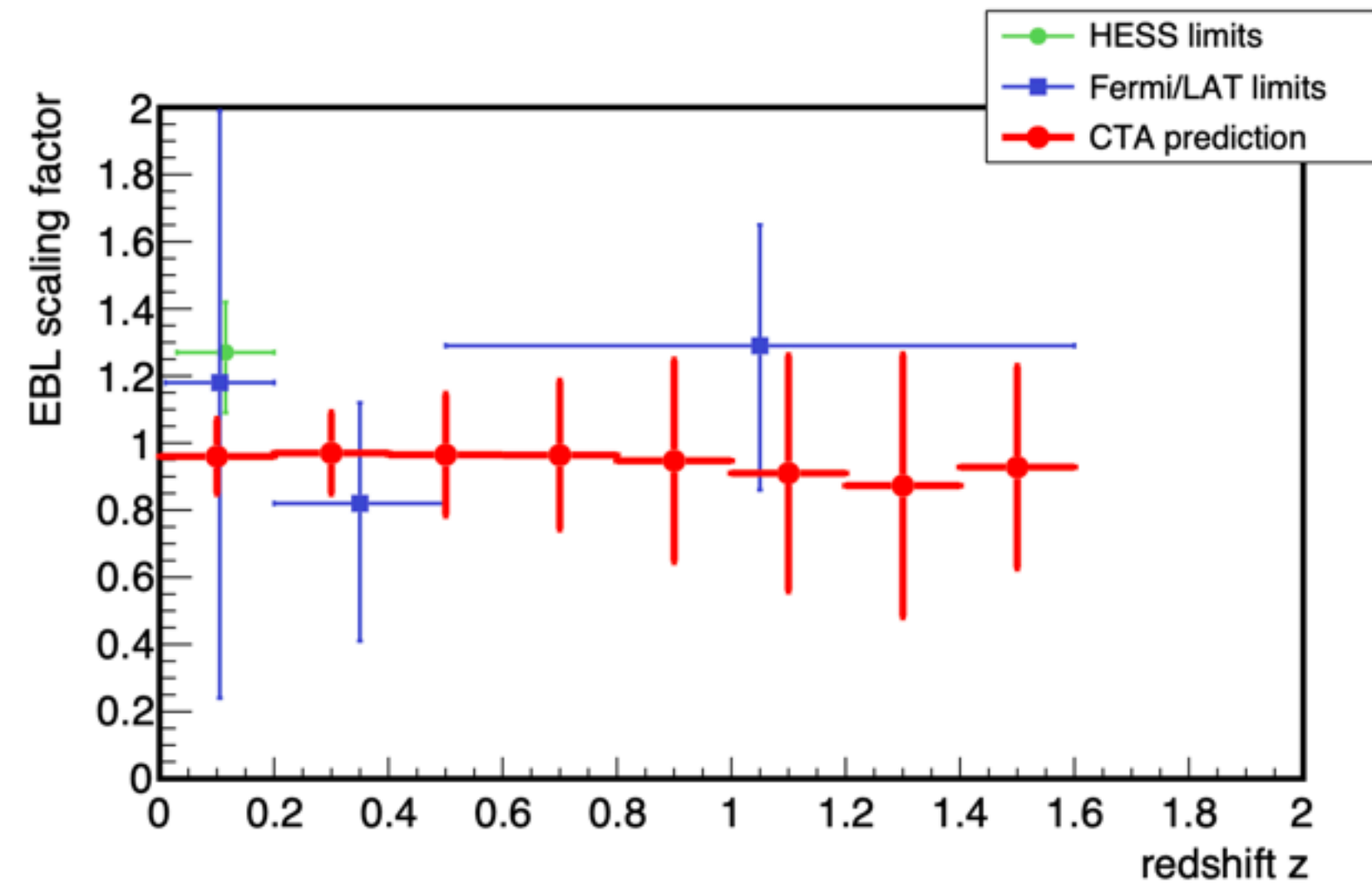


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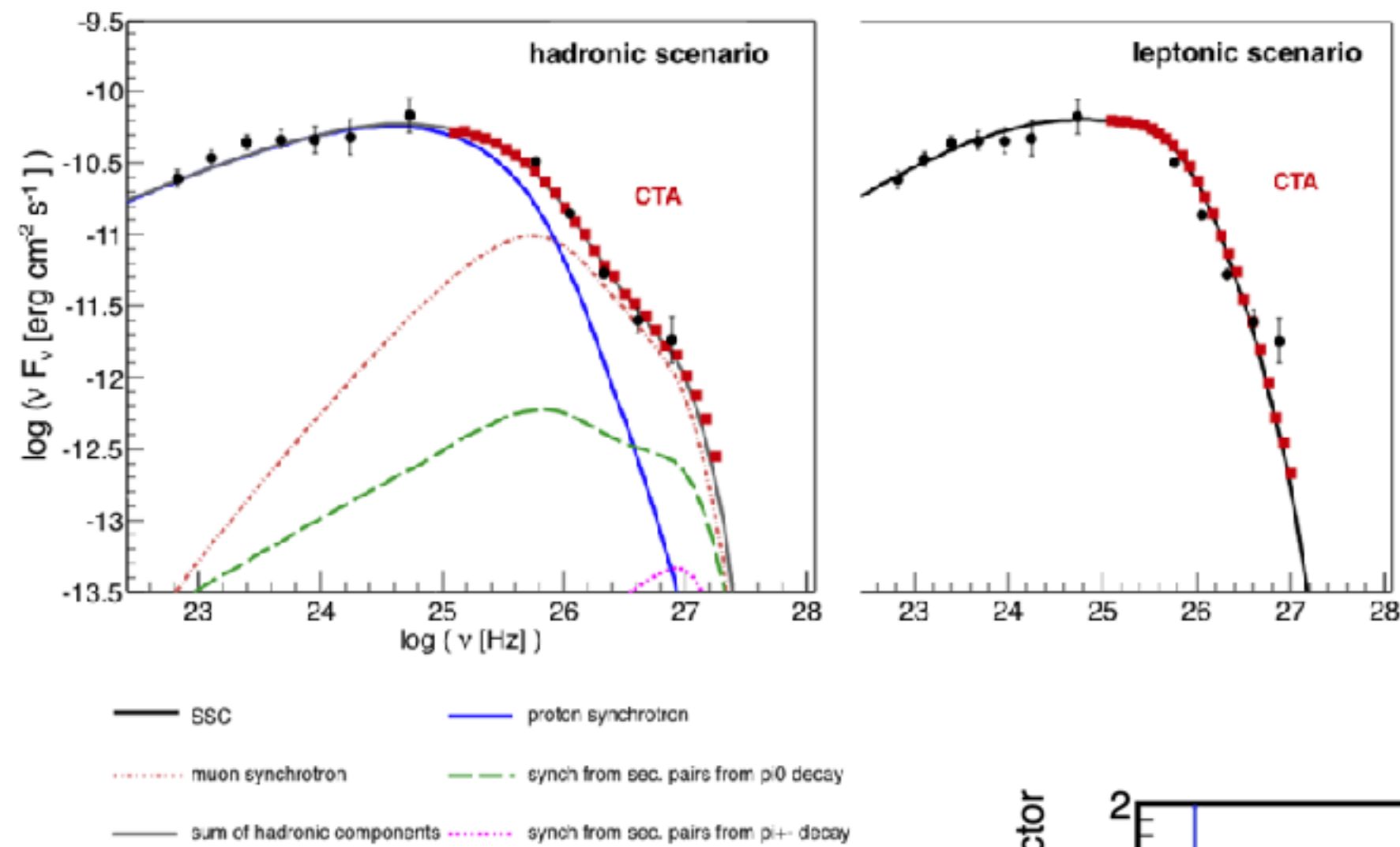


## EBL studies

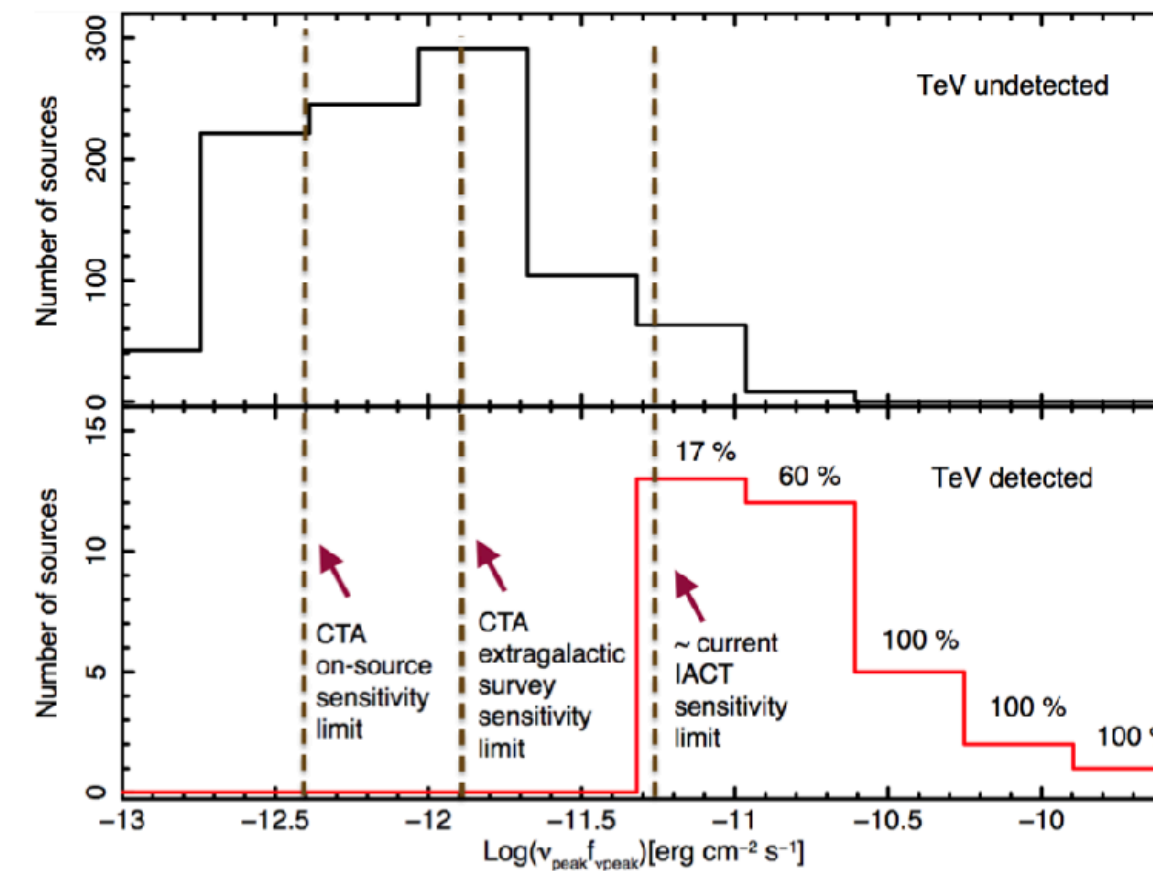


CTAO Science Book

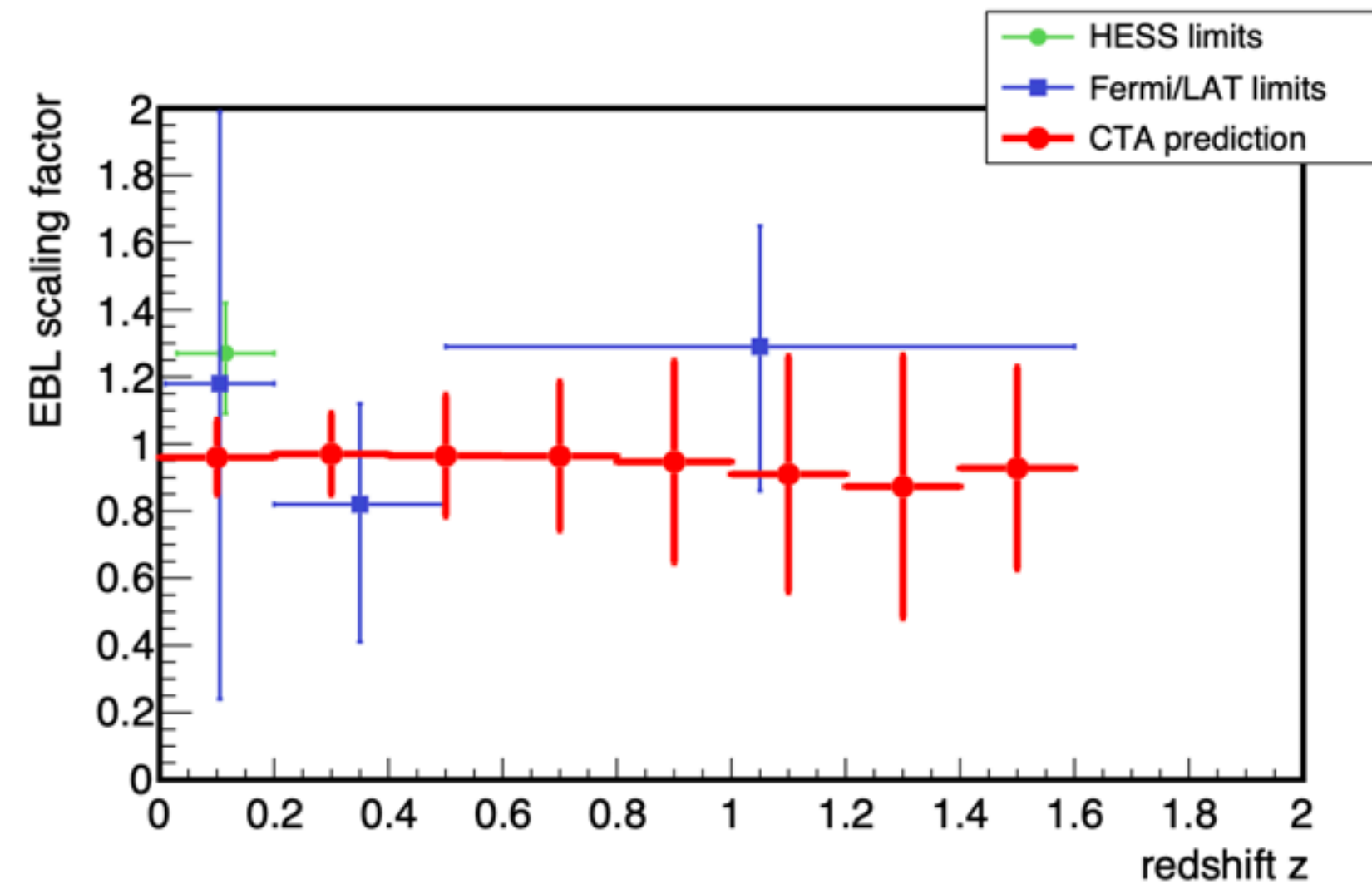
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## Population studies

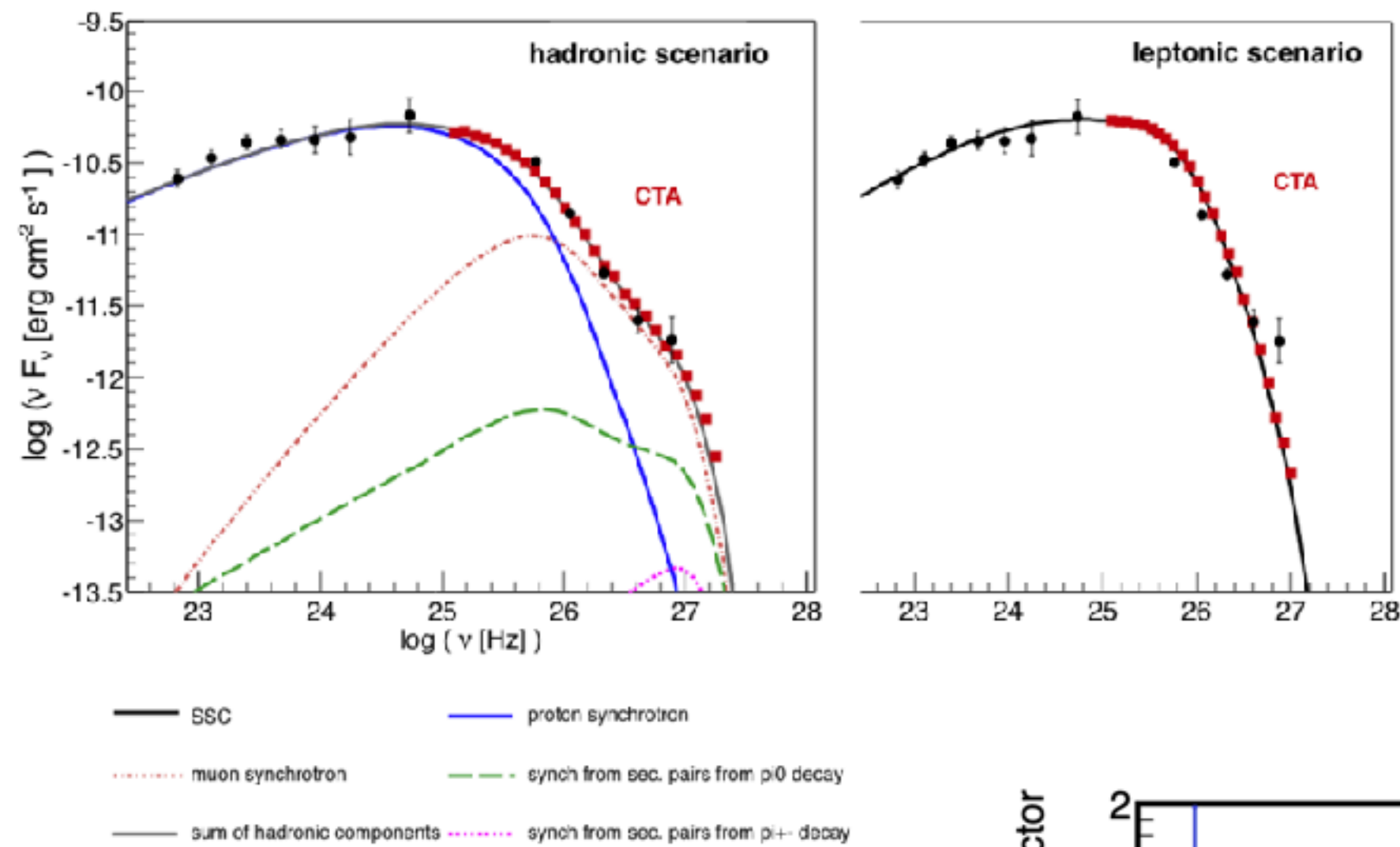


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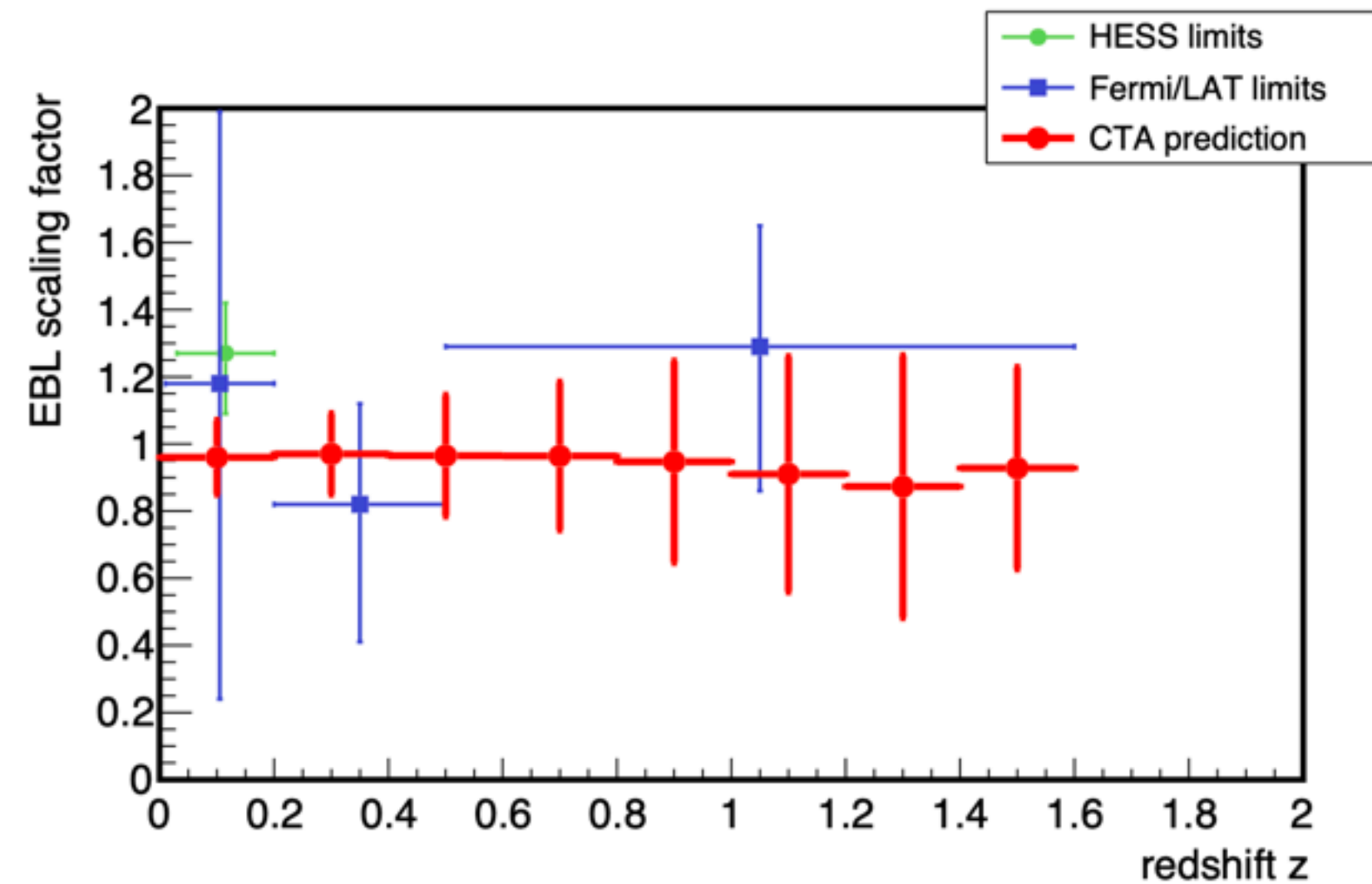
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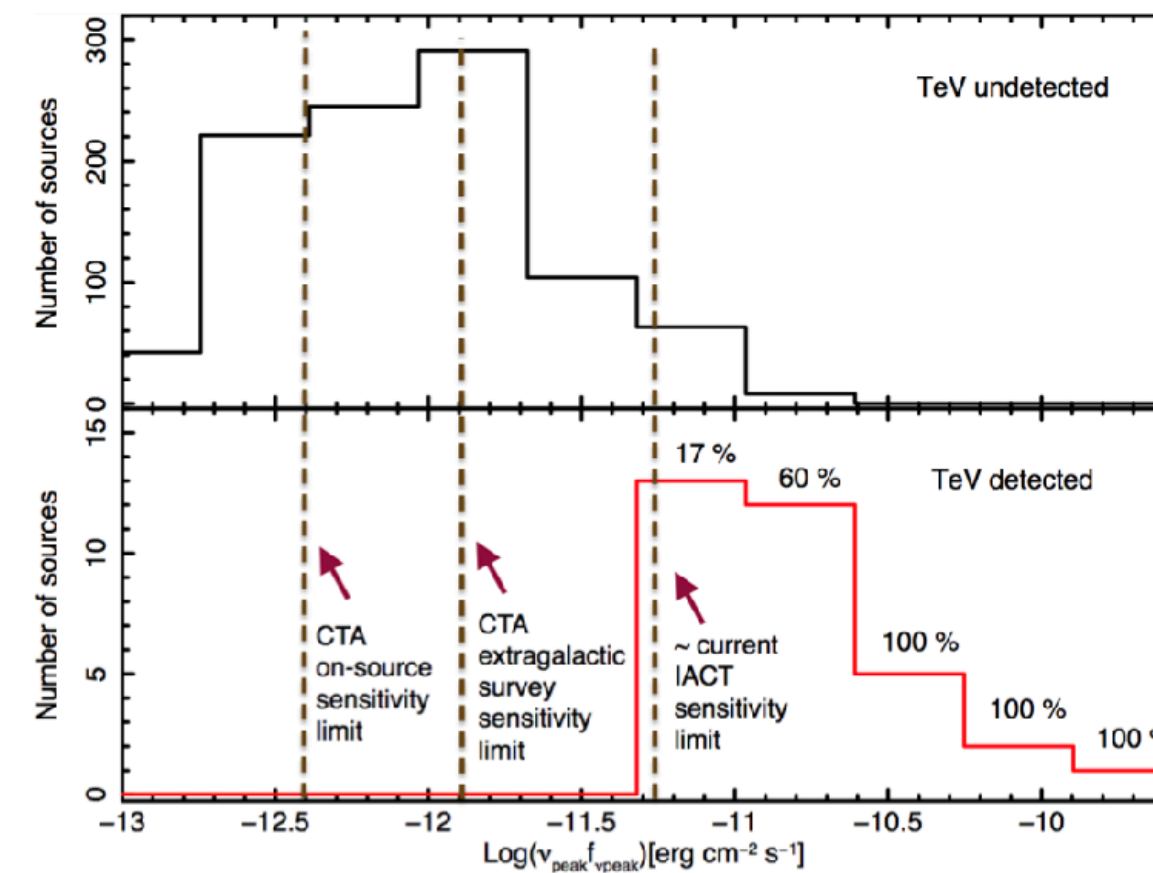


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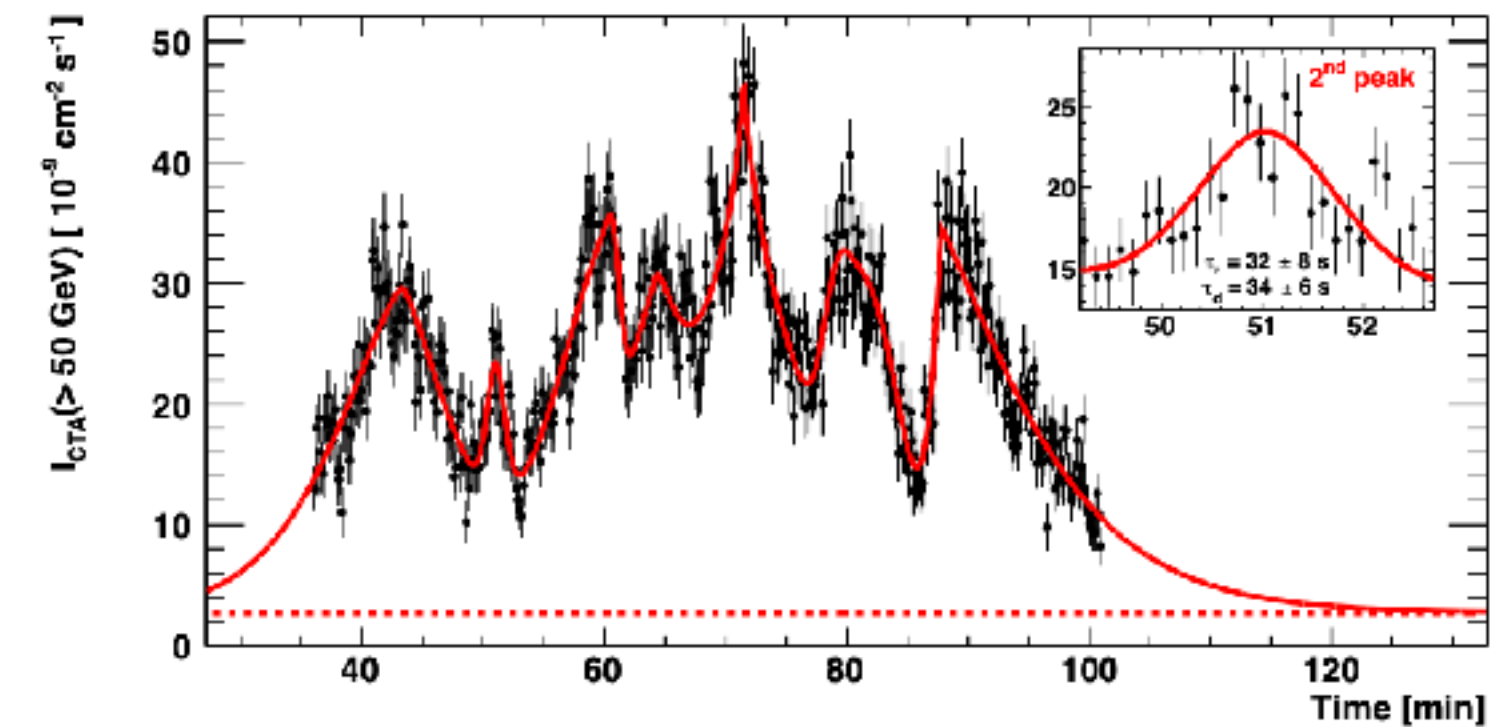
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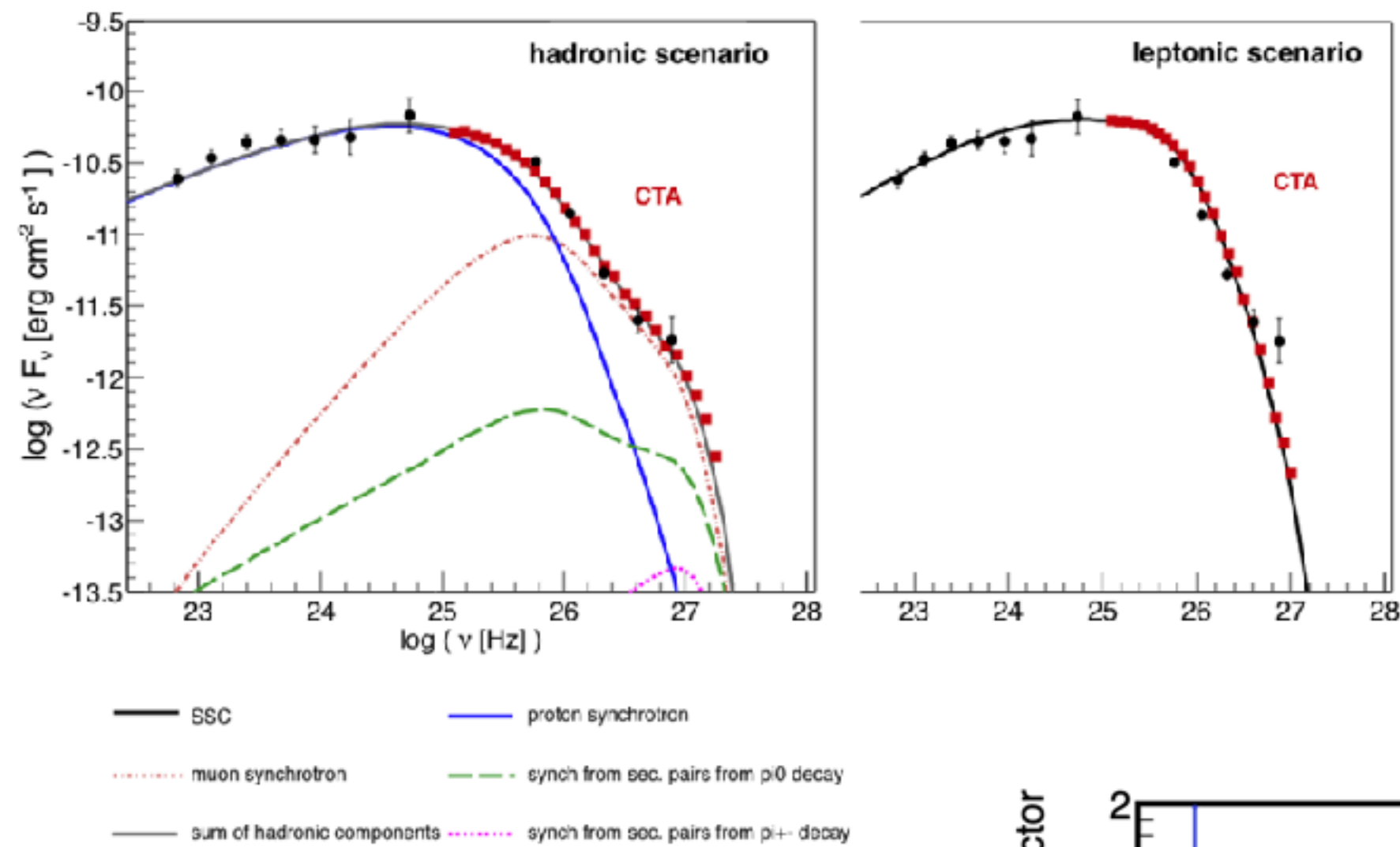
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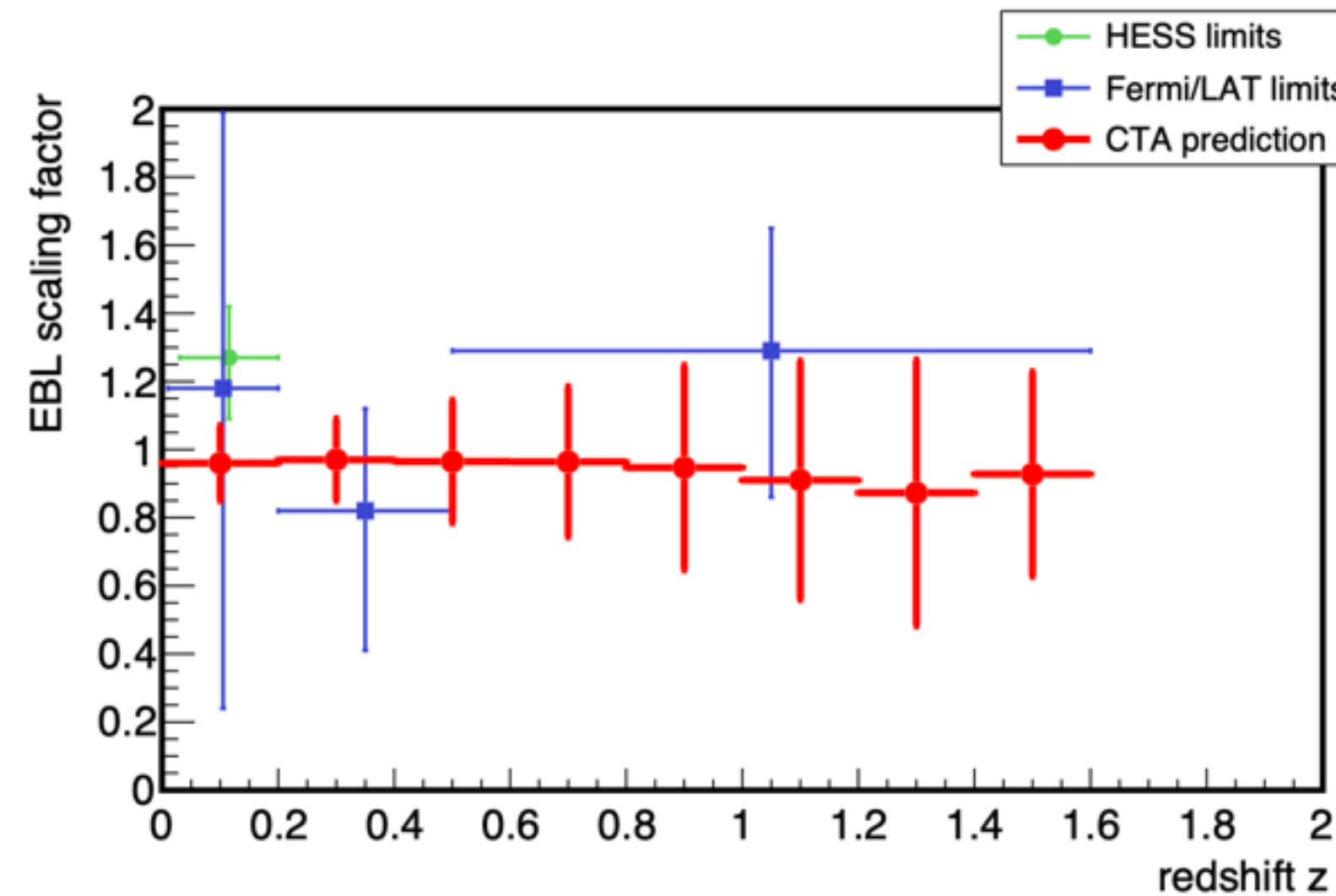
## Fast variability



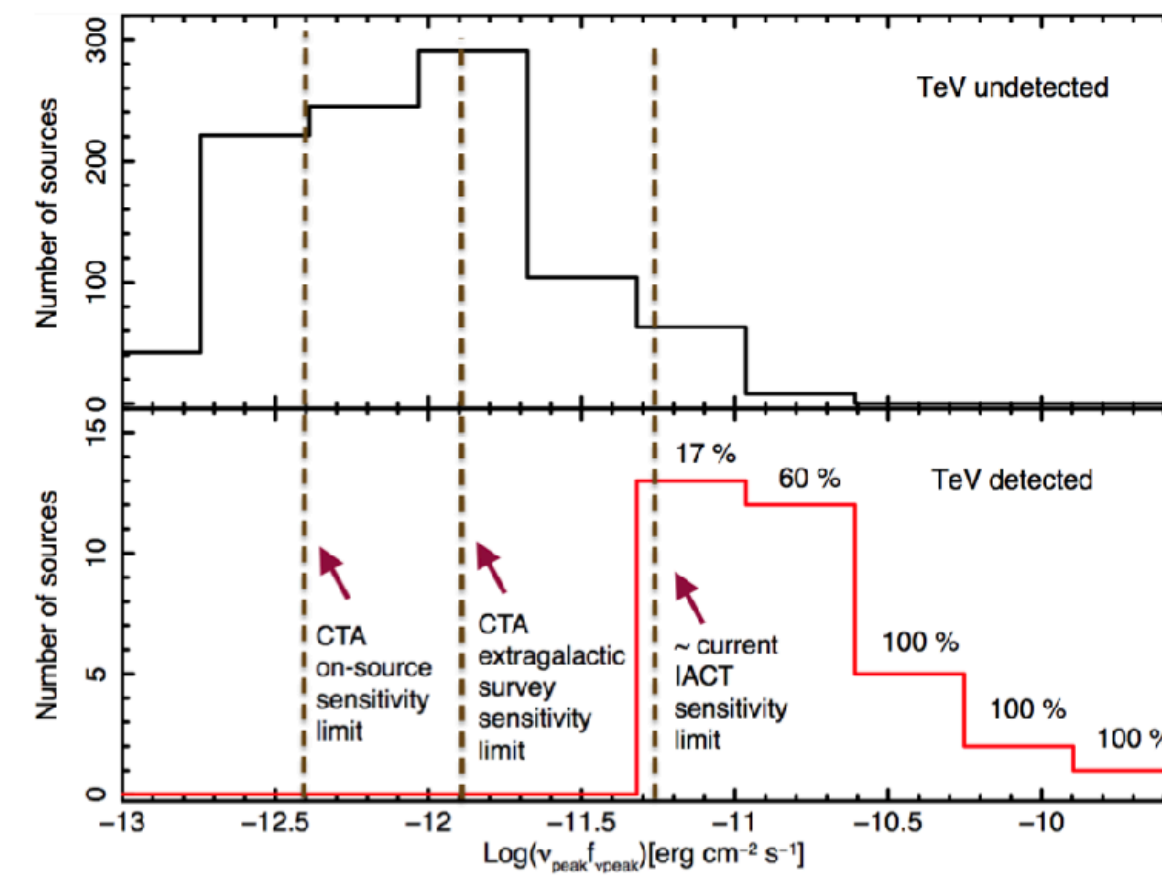
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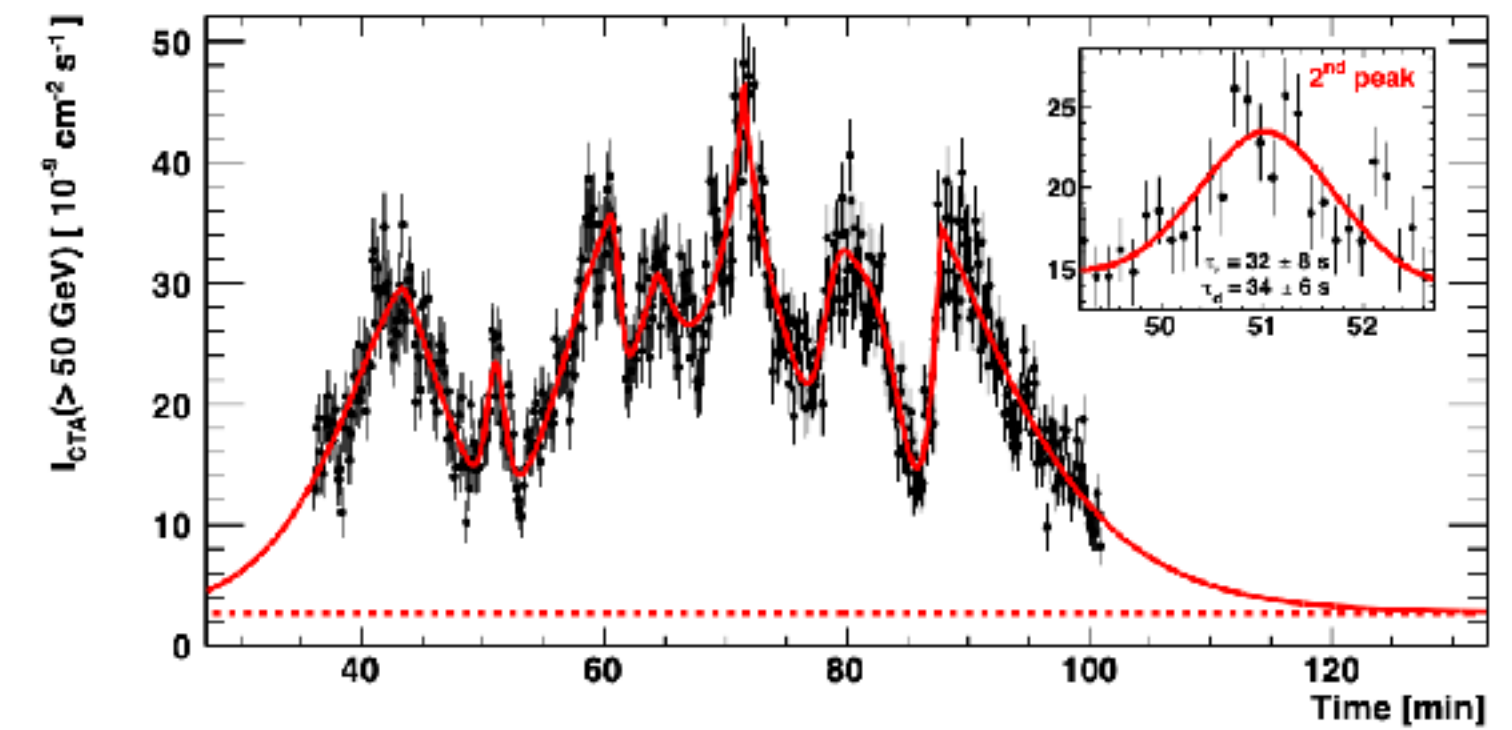
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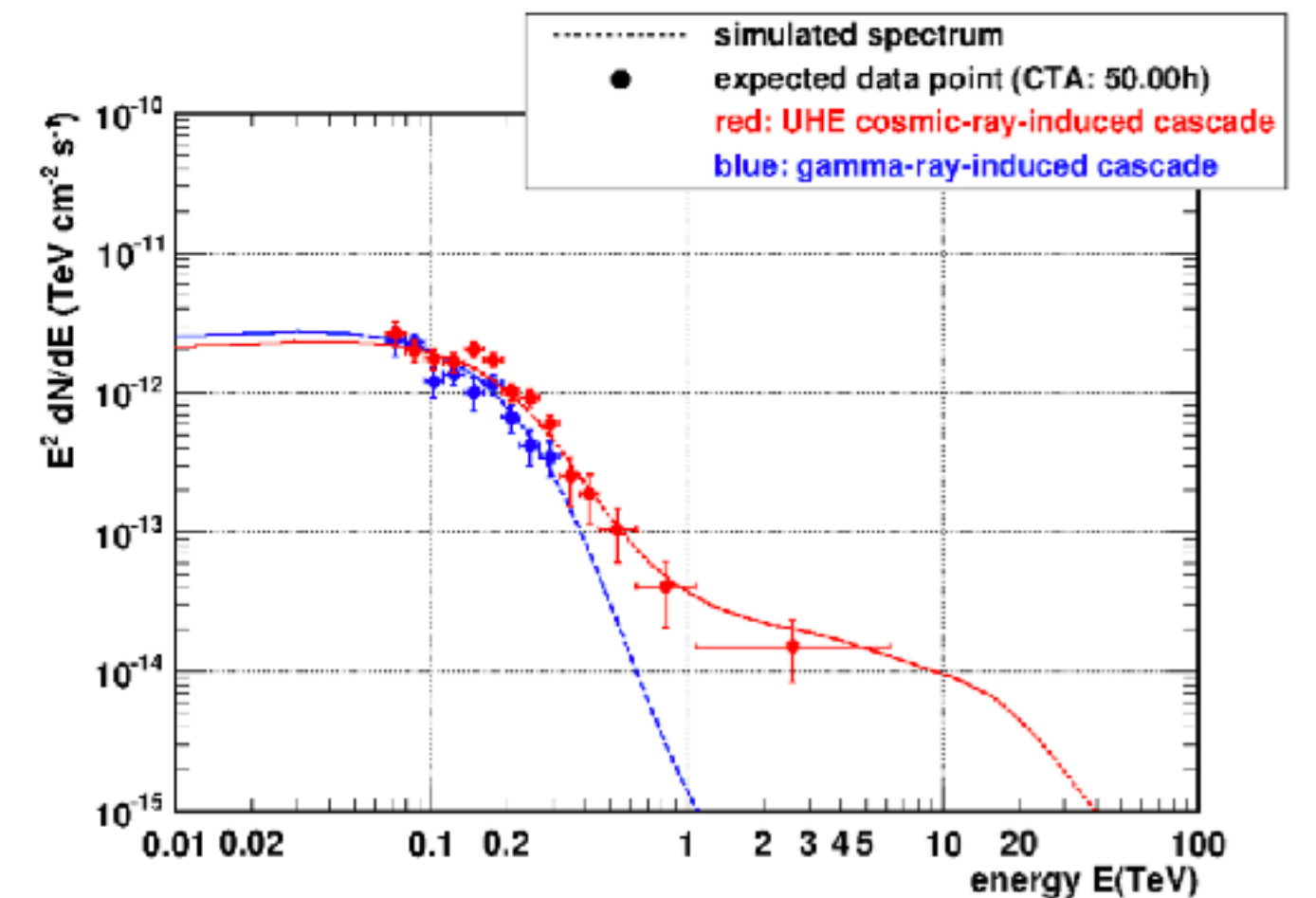
## Population studies



## Fast variability



## Ultra-high-energy cosmic-ray origin



CTAO Science Book

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# Final remarks

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# Final remarks

CTAO will revolutionize the  $\gamma$ -ray astronomy field

LST-1 already operating and obtaining interesting results, 3 more LSTs to come

Several AGN already detected, nearby and distant

Possible to break the redshift  $z = 1$  limit

Successful ToO campaigns with flares showing remarkably fast variability (e.g. BL Lacertae)

Already discovering new sources!

- OP 313, furthest ever observed blazar and 10th FSRQ at VHE  $\gamma$  rays
- PKS 1725+123, 12th FSRQ at VHE  $\gamma$  rays

Very interesting synergies with other major facilities with common goals (e.g. IXPE)



Credit: LST Collaboration/Moritz Hutten

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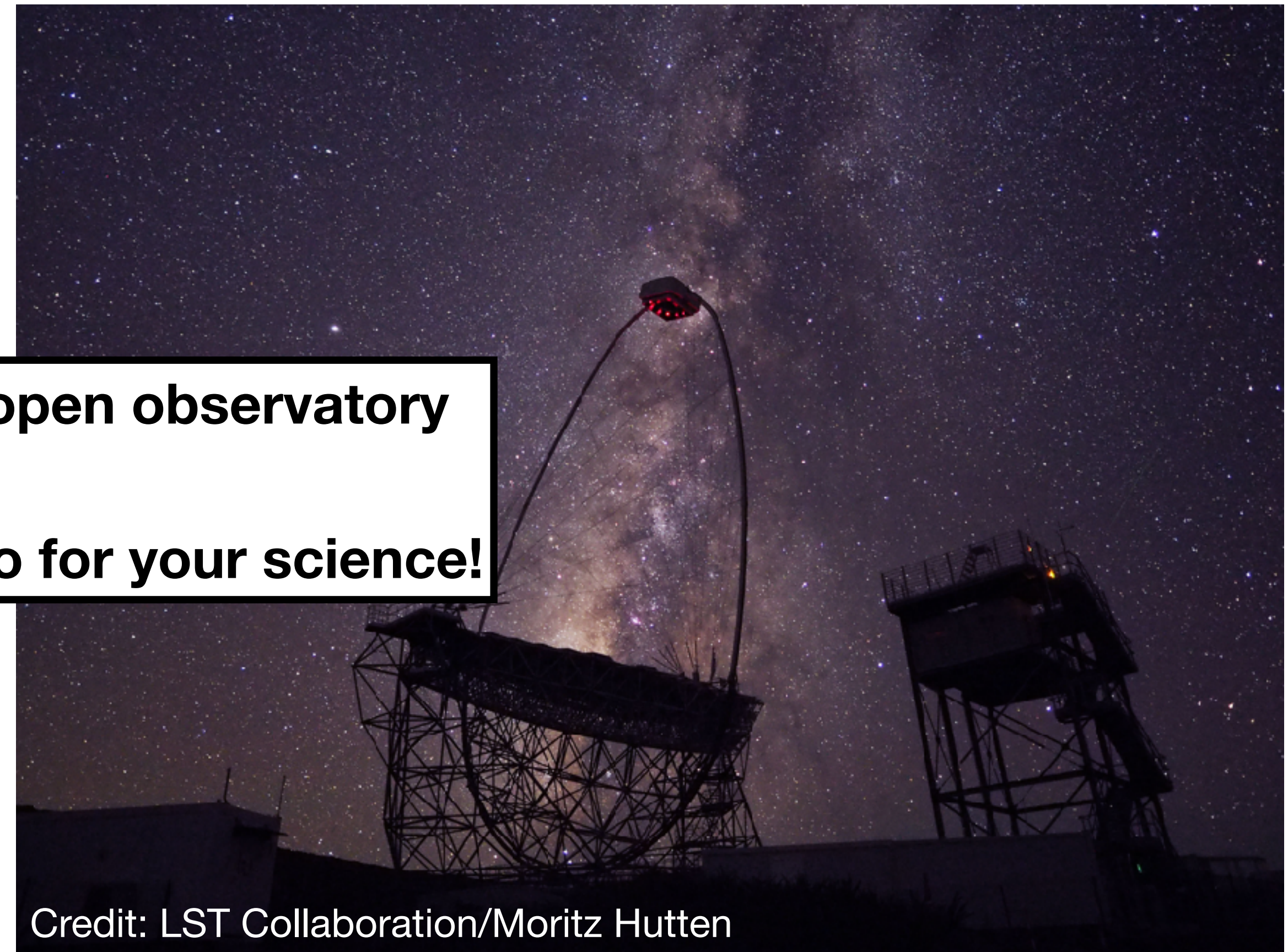
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**CTAO will soon be an open observatory**

**Think what can CTAO do for your science!**



Credit: LST Collaboration/Moritz Hutten



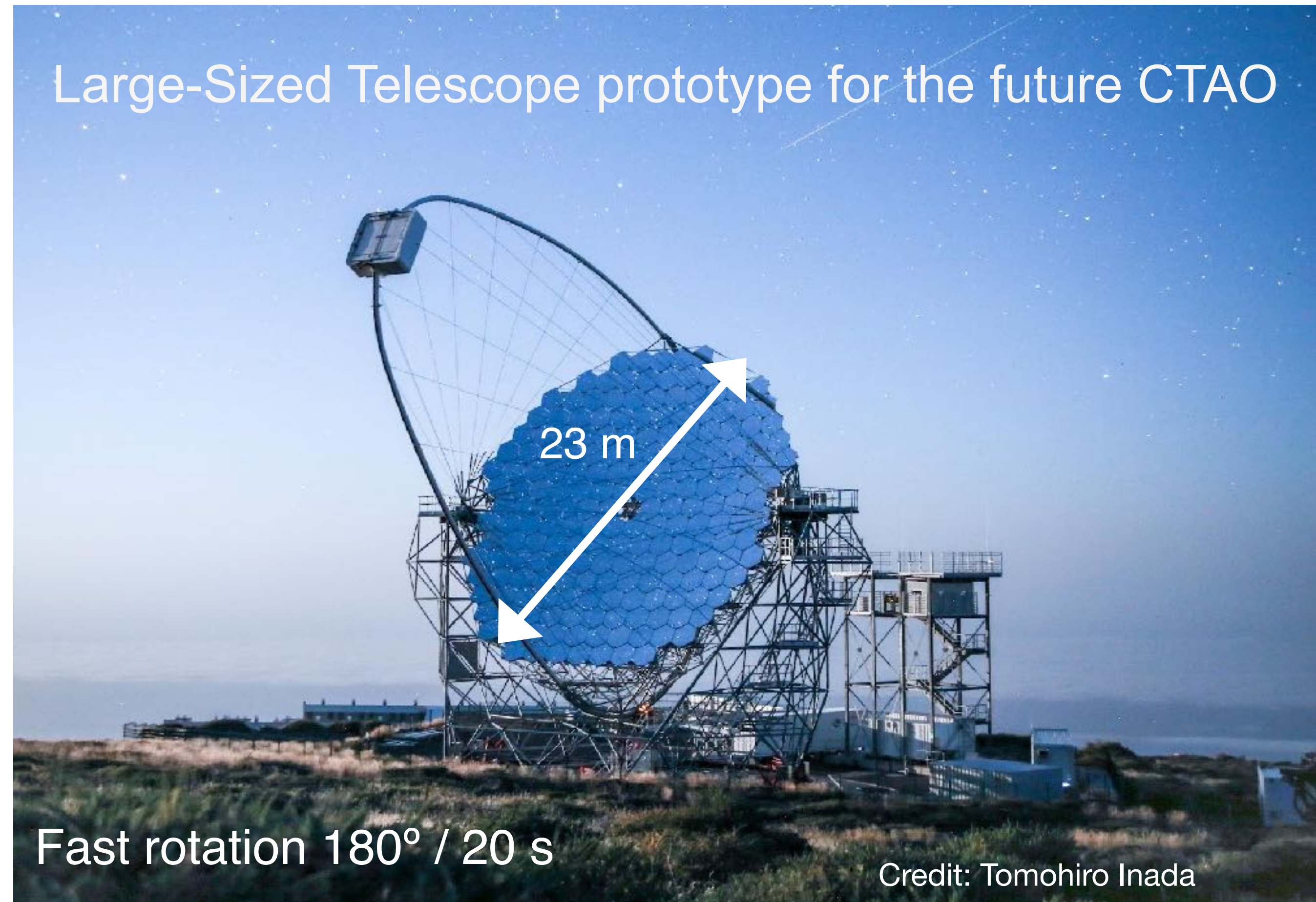
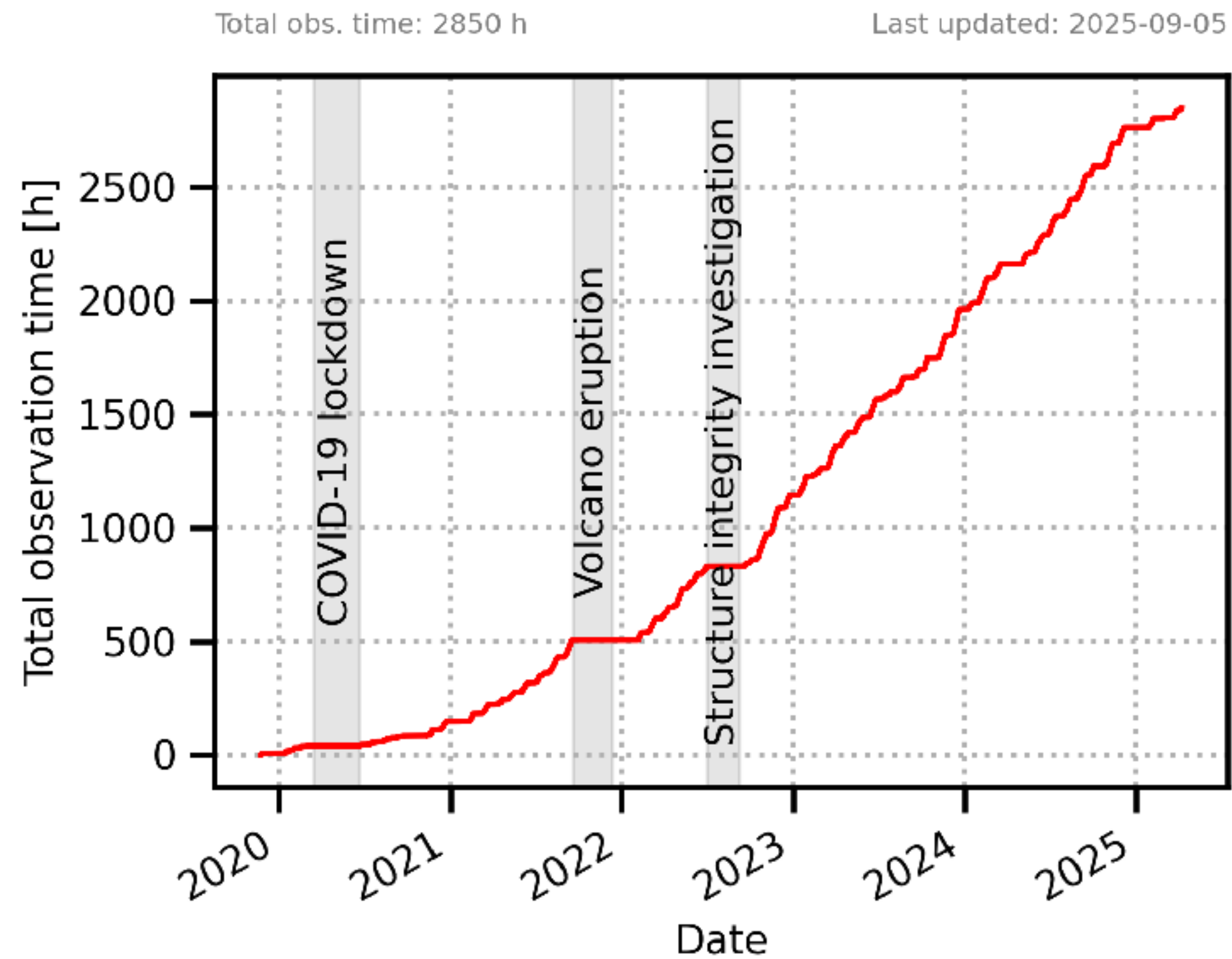
LST  
COLLABORATION

# Thank you for your attention!

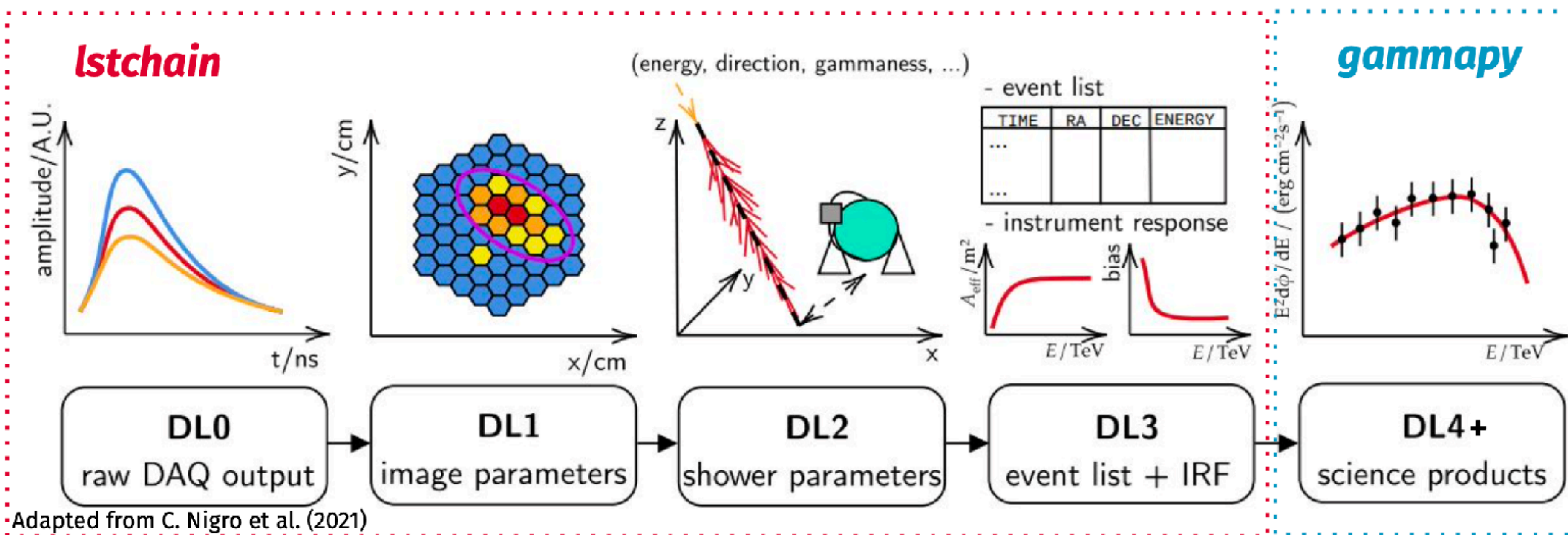
I gratefully acknowledge financial support from the agencies and organizations listed here:  
[http://www.cta-observatory.org/consortium\\_acknowledgments](http://www.cta-observatory.org/consortium_acknowledgments)

**Back up**

## More than 2500 h of data since 2020

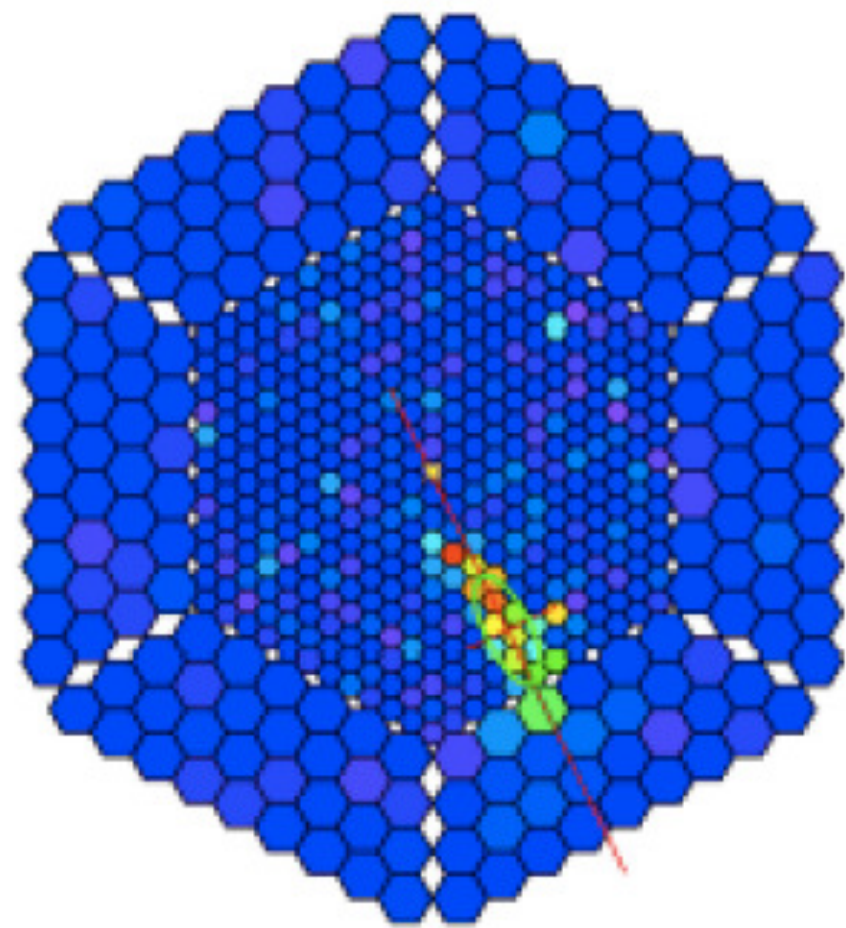


- LST standard data processing (*lstchain*)
  - likelihood method for image parameterization [Emery et al. (2021)]
  - source-dependent approach assuming the expected source position
- Binned likelihood to reconstruct spectrum & light curve (*gammapy*)

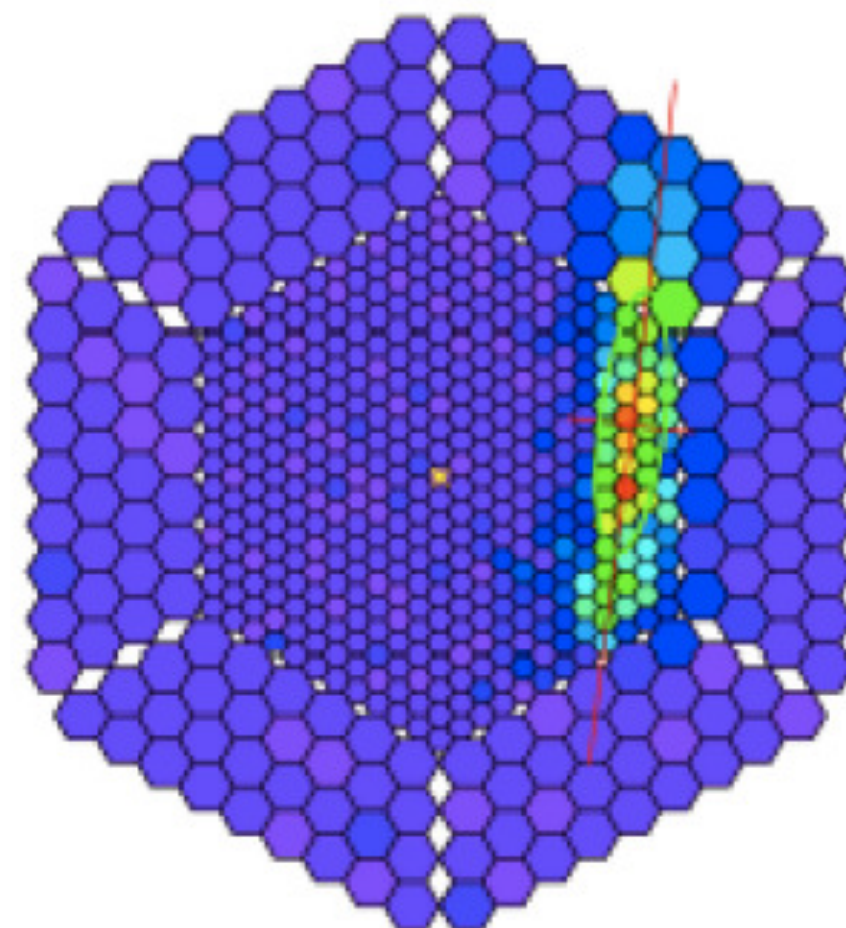


Adapted from C. Nigro et al. (2021)

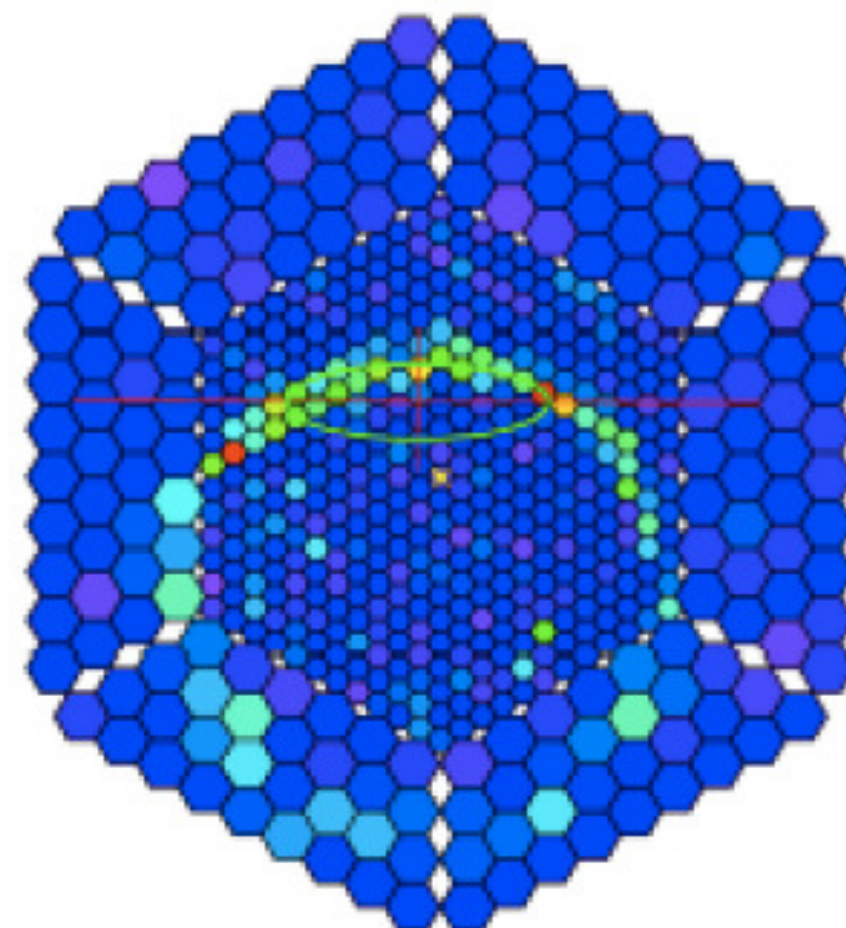
## Event selection and cleaning



**Gamma rays: compact and elliptical shape**



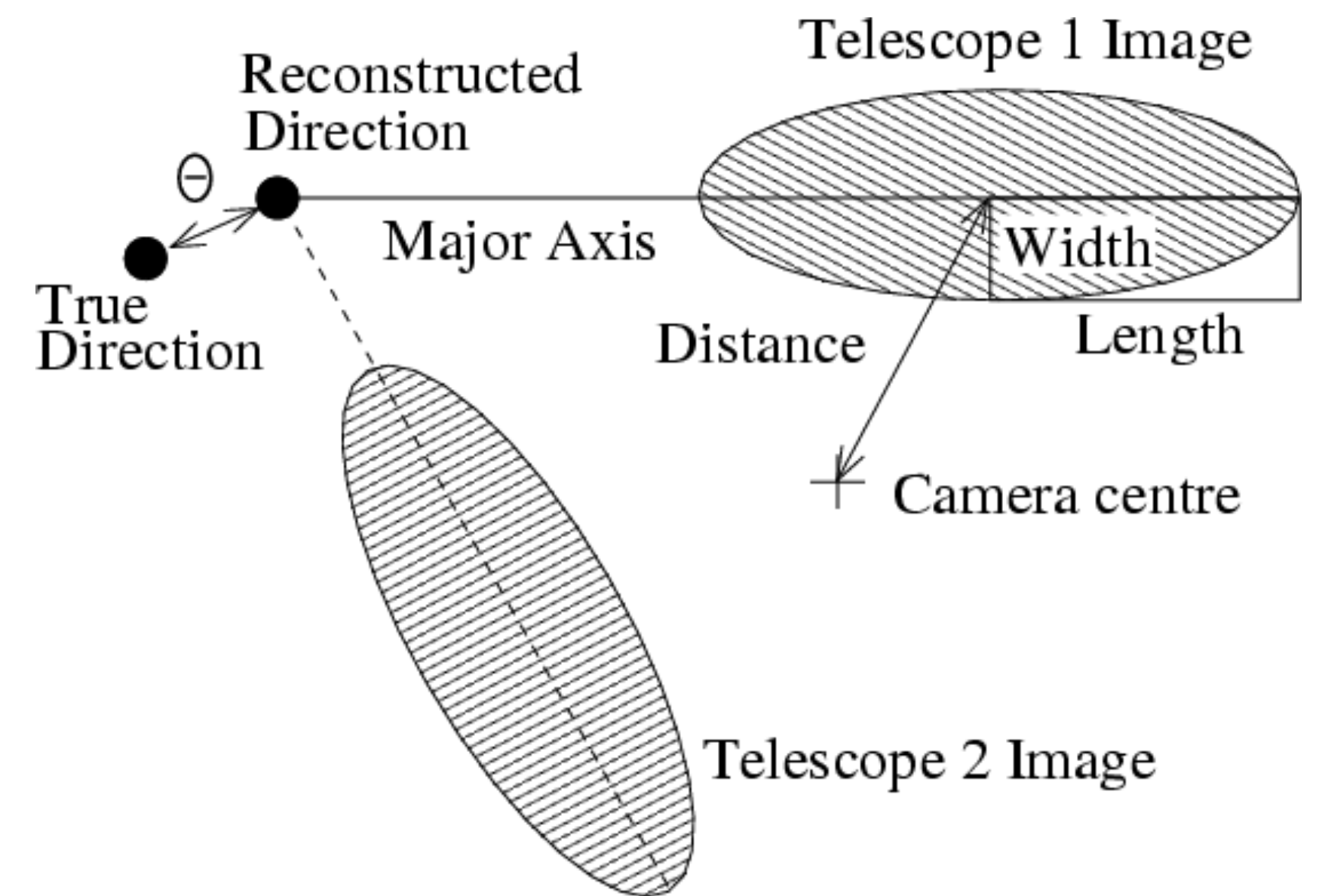
**Cosmic rays: broader and more irregular shape**



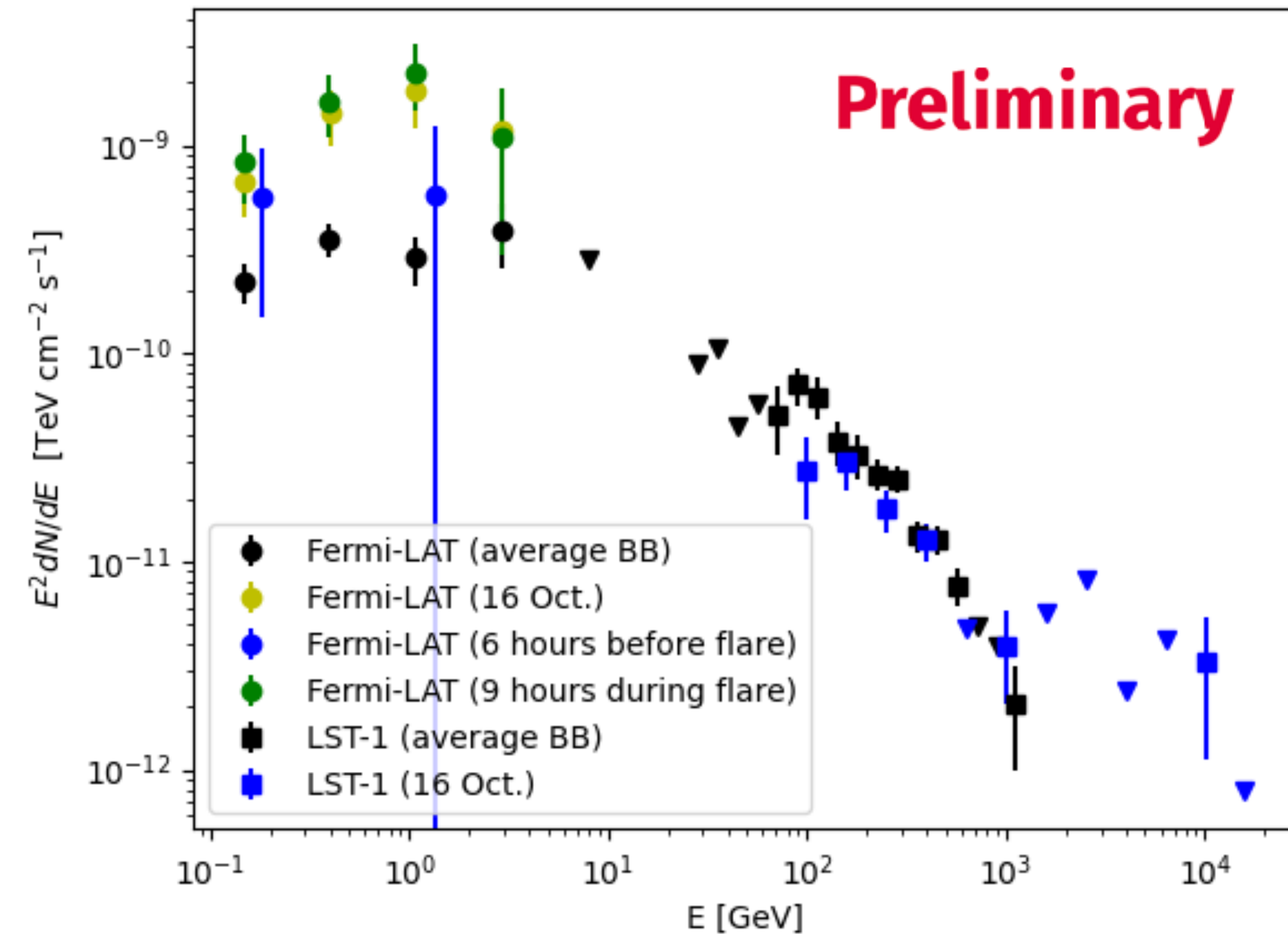
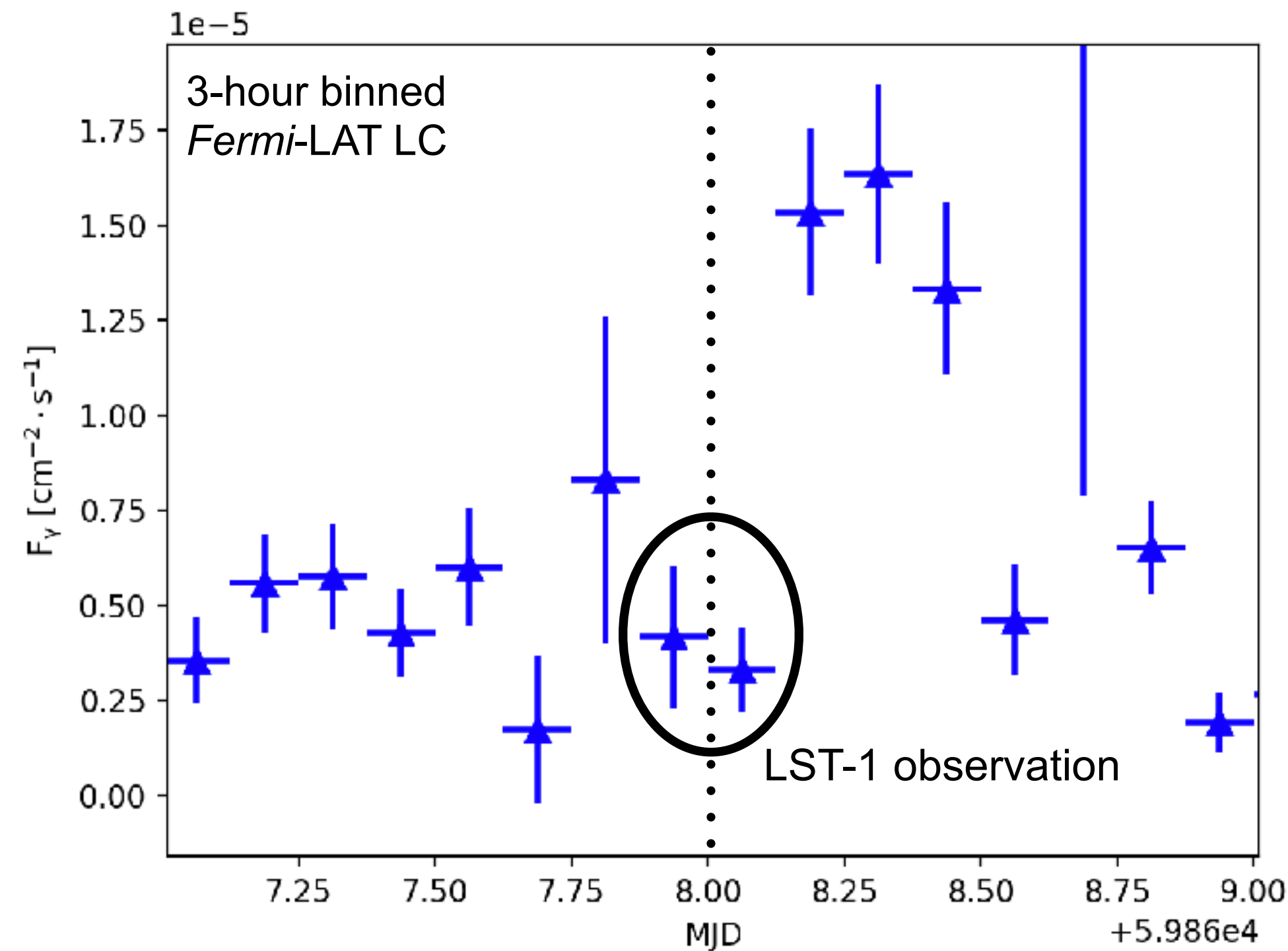
**Muons: ring-like shape**

Trained MonteCarlo to differentiate between gamma-ray and cosmic-ray events

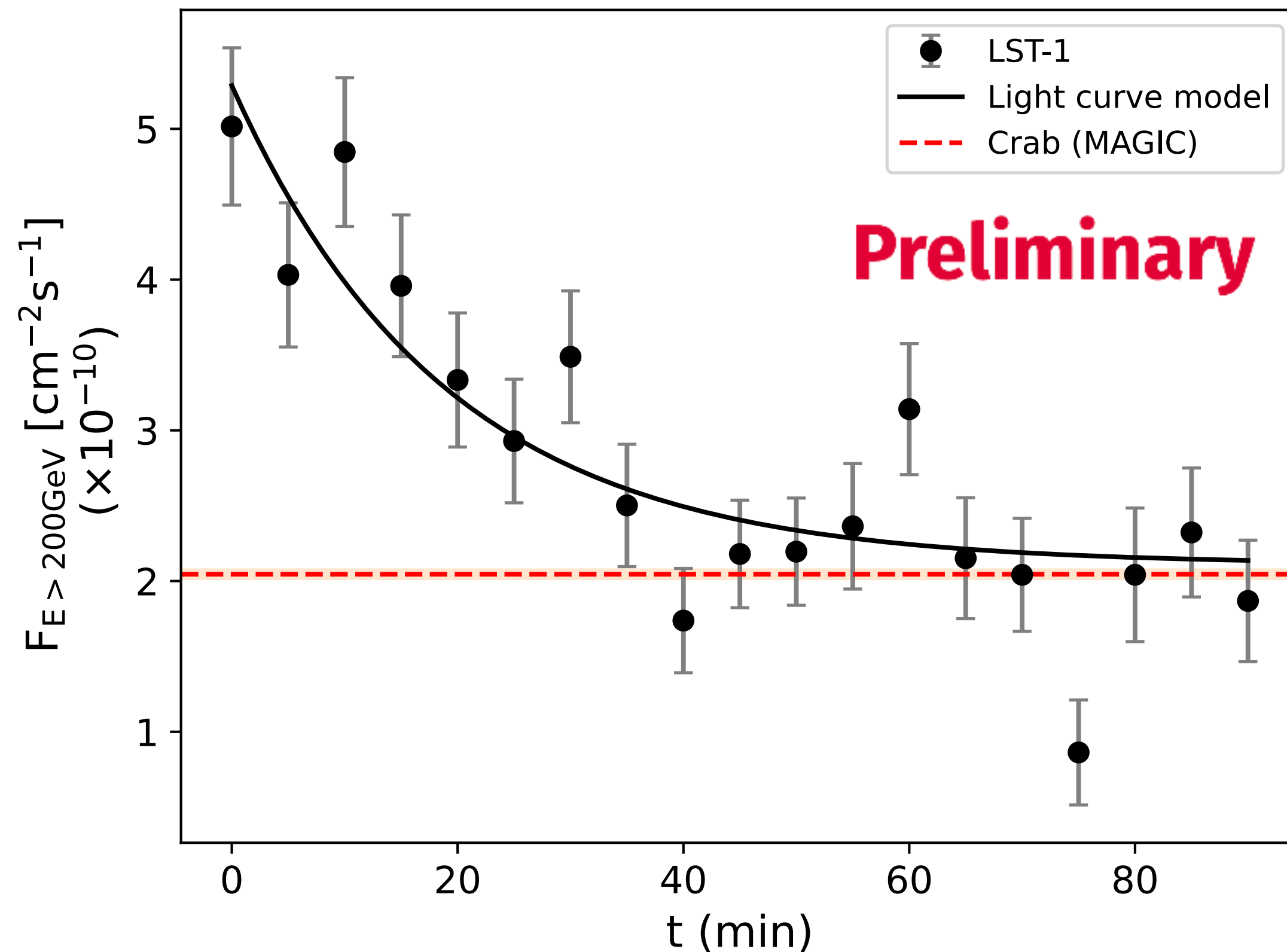
Parametrize the images: Hillas parameters  
Information about the incident  $\gamma$  ray



- *Fermi*-LAT brightest night not coincident with the brightest optical/VHE emission
- Most of the signal comes after MJD~59868.12 (~3 hours after midnight), almost all LST-1's observations before midnight
- Very fast flare (~9 hours), possibly missed by LST-1



- 13 Nov: only decay of the flare, average  $\sim 1.3$  C.U. above 200 GeV
- Maximum emission  $\sim 2.5$  C.U. above 200 GeV, variations from  $\sim 1$  C.U. to 2.5 C.U. in less than 1 hour



Exponential rise and decay and doubling flux timescale as (see [MAGIC Collaboration+2010](#))

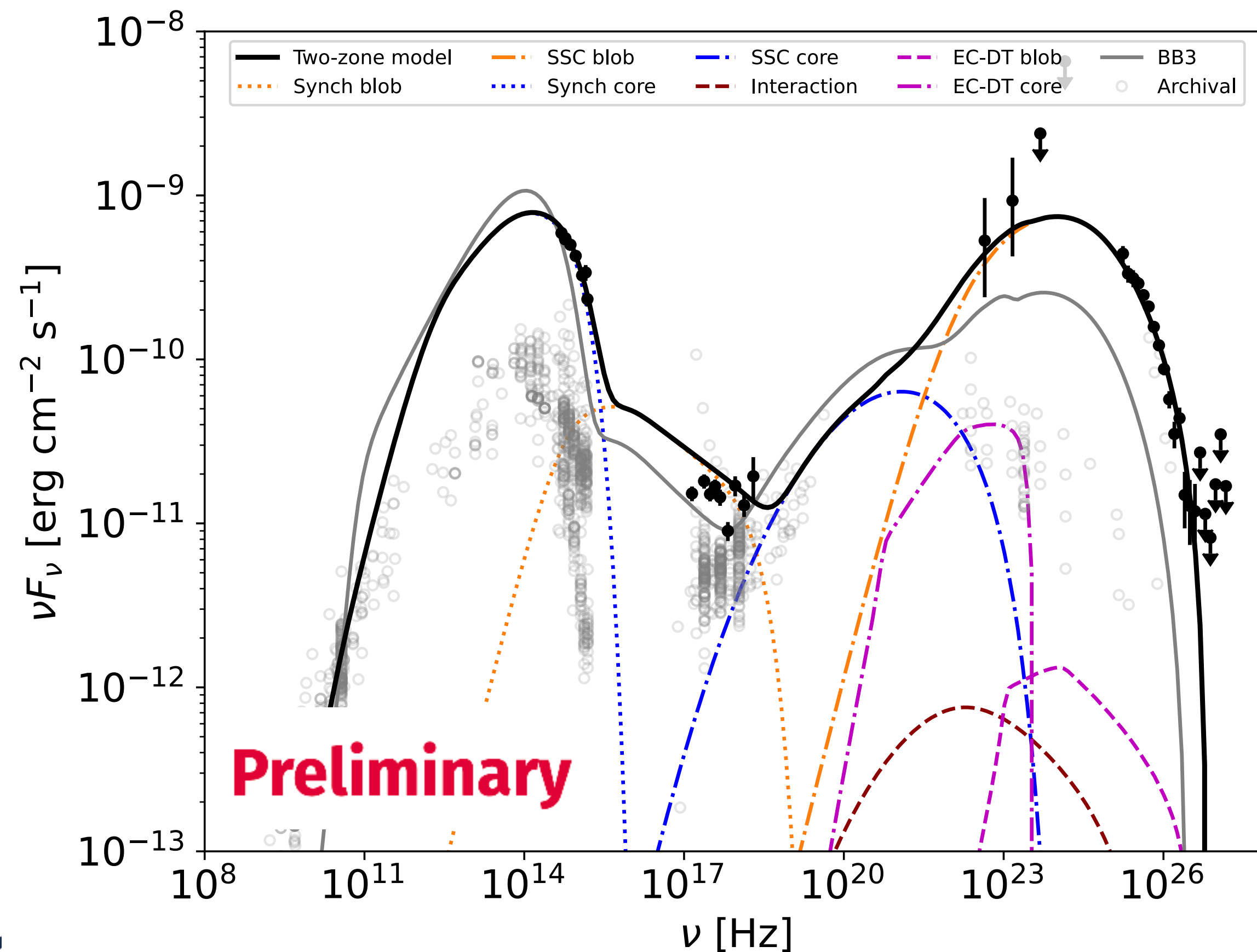
$$t_{\text{doubling, rise/decay}} = t_{\text{rise/decay}} \cdot \ln(2)$$

- $t_{\text{decay}} = 19 \pm 3$  min
- $t_{\text{doubling}} = 13 \pm 2$  min

Constraint on the size of the emitting region (causality, see [Tavecchio+2010](#))

$$R \leq c \cdot t_{\text{var}} \cdot \delta / (1 + z) \sim 2.2 - 11.0 \cdot 10^{-14} \text{ cm for } \delta \sim 10 - 50$$

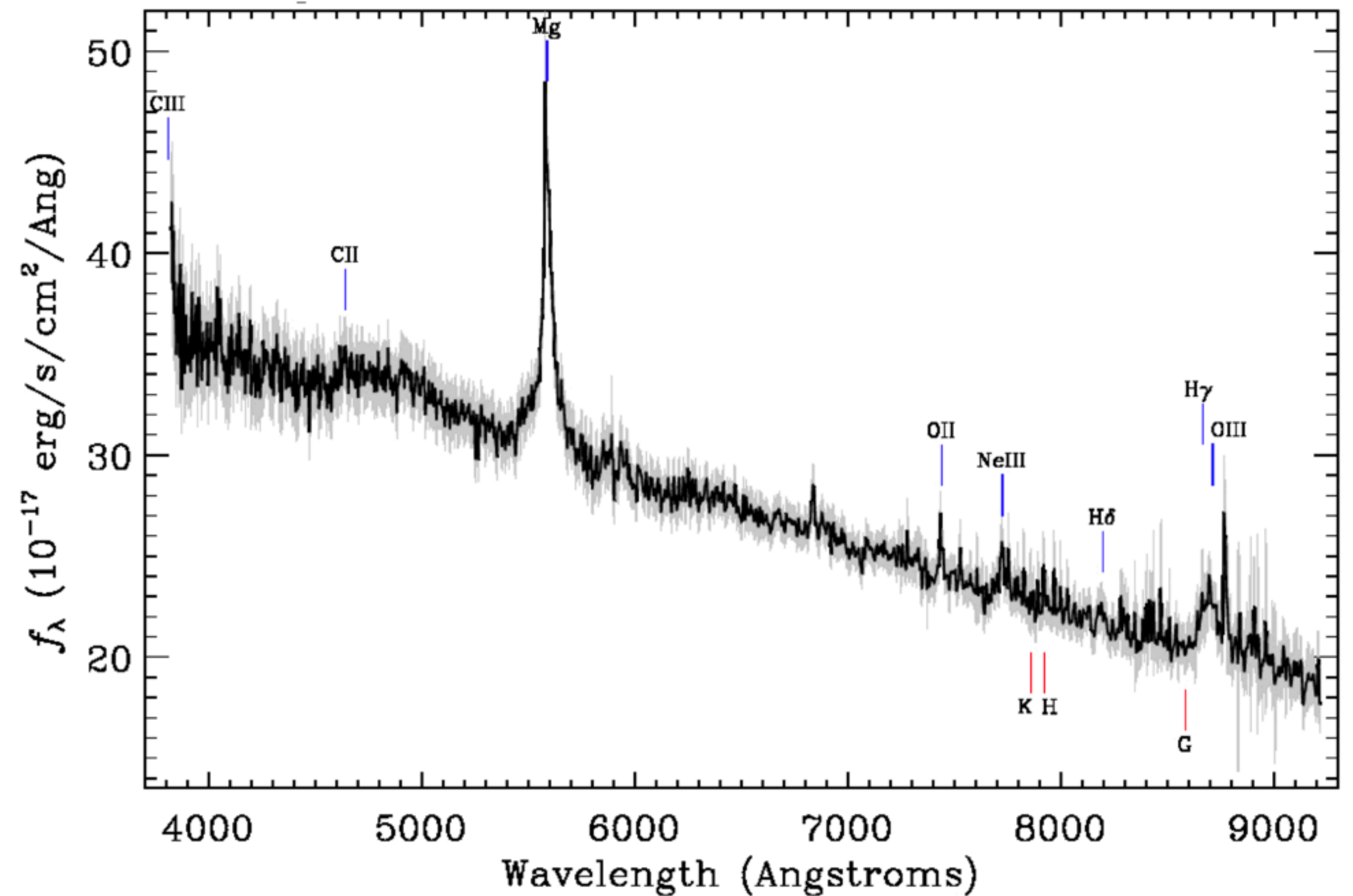
- “Time-dependent” modeling of the broad-band flare SEDs is currently ongoing
- Aim: trace back the MWL emissions evolution during the flare by evaluating a temporal series of SEDs

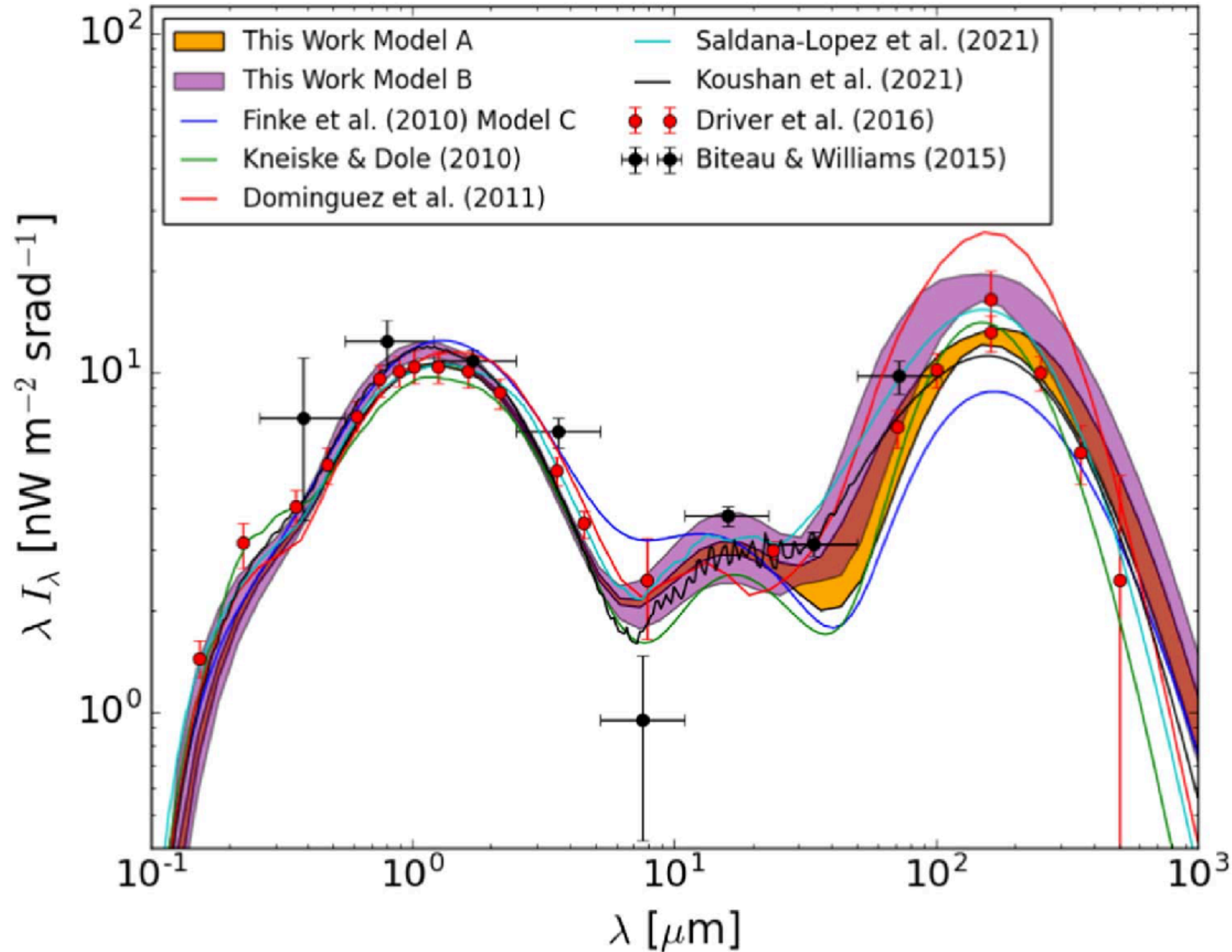


- Leptonic emission favoured (IXPE results, see Peirson+23; Middei+23; Agudo, Liodakis, Otero-Santos+24 in prep.)
- One-zone leptonic synchrotron self-Compton (SSC) models do not reproduce the emission
- Possibilities:
  1. One-zone + external Compton, possible if the emitting region is very close to the BH, but needs very large Doppler factors and does not work for all SEDs
  2. Two-zone model (core + blob)

# Flat Spectrum Radio Quasar OP 313

- Distant ( $z = 0.9973$ ) flat-spectrum radio quasar (FSRQ)
  - Only 9 known at VHE before
- Not detected at VHE before
  - Several attempts by MAGIC (2014 & 2019)
  - Also observed by LST-1 in 2022 (no detection)
- Strong attenuation at VHE due to EBL
- Possible internal absorption of its gamma-ray emission



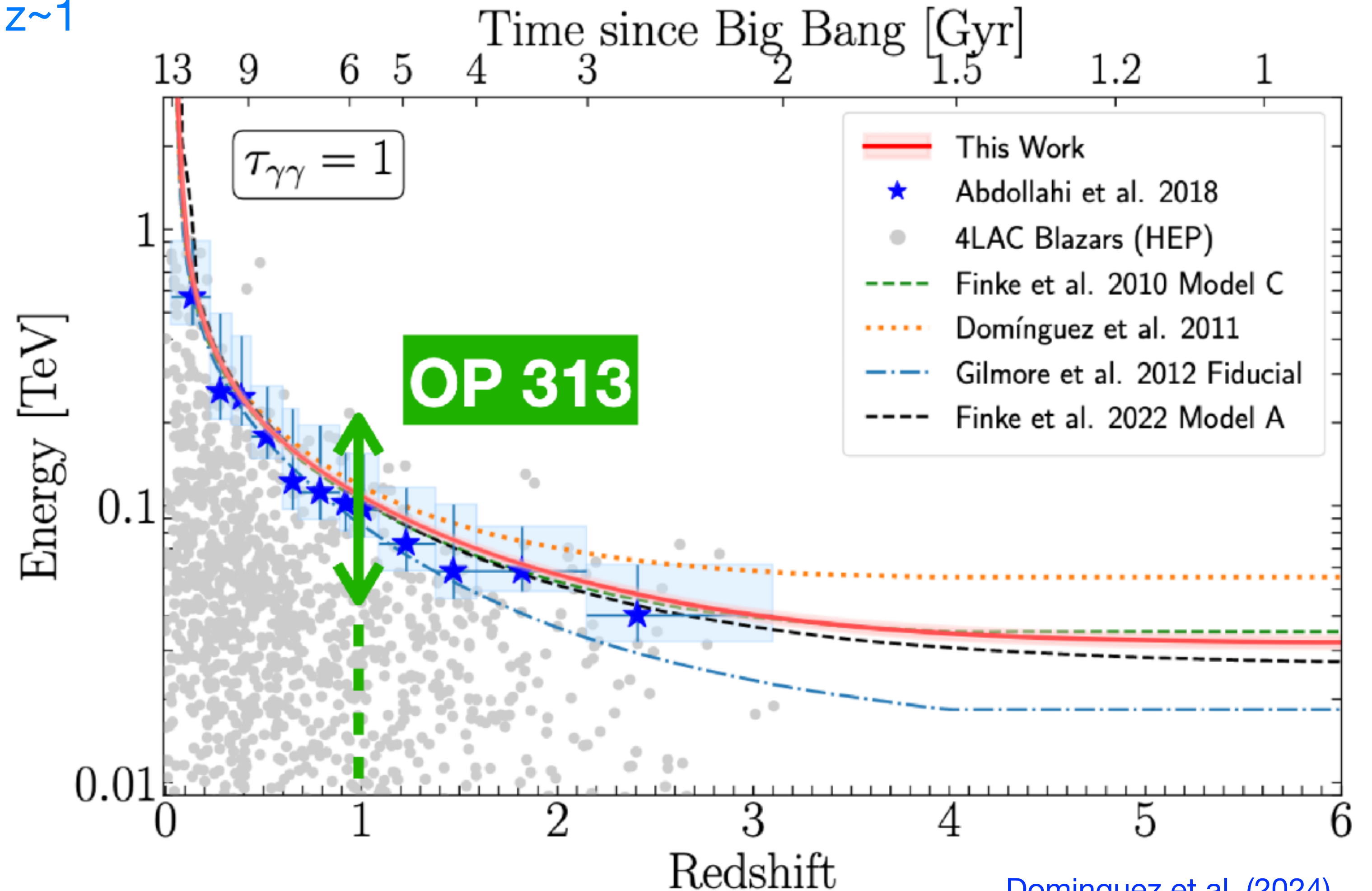


# Flat Spectrum Radio Quasar OP 313

Excellent source to test EBL models at  $z \sim 1$

Source	Redshift	Type
GRB 201216C	1.1	GRB
<b>OP 313</b>	<b>0.9973</b>	<b>FSRQ</b>
PKS 0346-27	0.991	FSRQ
S3 0218+35	0.954	FSRQ
PKS 1441+25	0.939	FSRQ
Ton 599	0.7247	FSRQ
PKS 0903-57	0.695	IBL
B2 1420+32	0.682	FSRQ

Most distant VHE sources (TeVCat)



Domínguez et al. (2024)