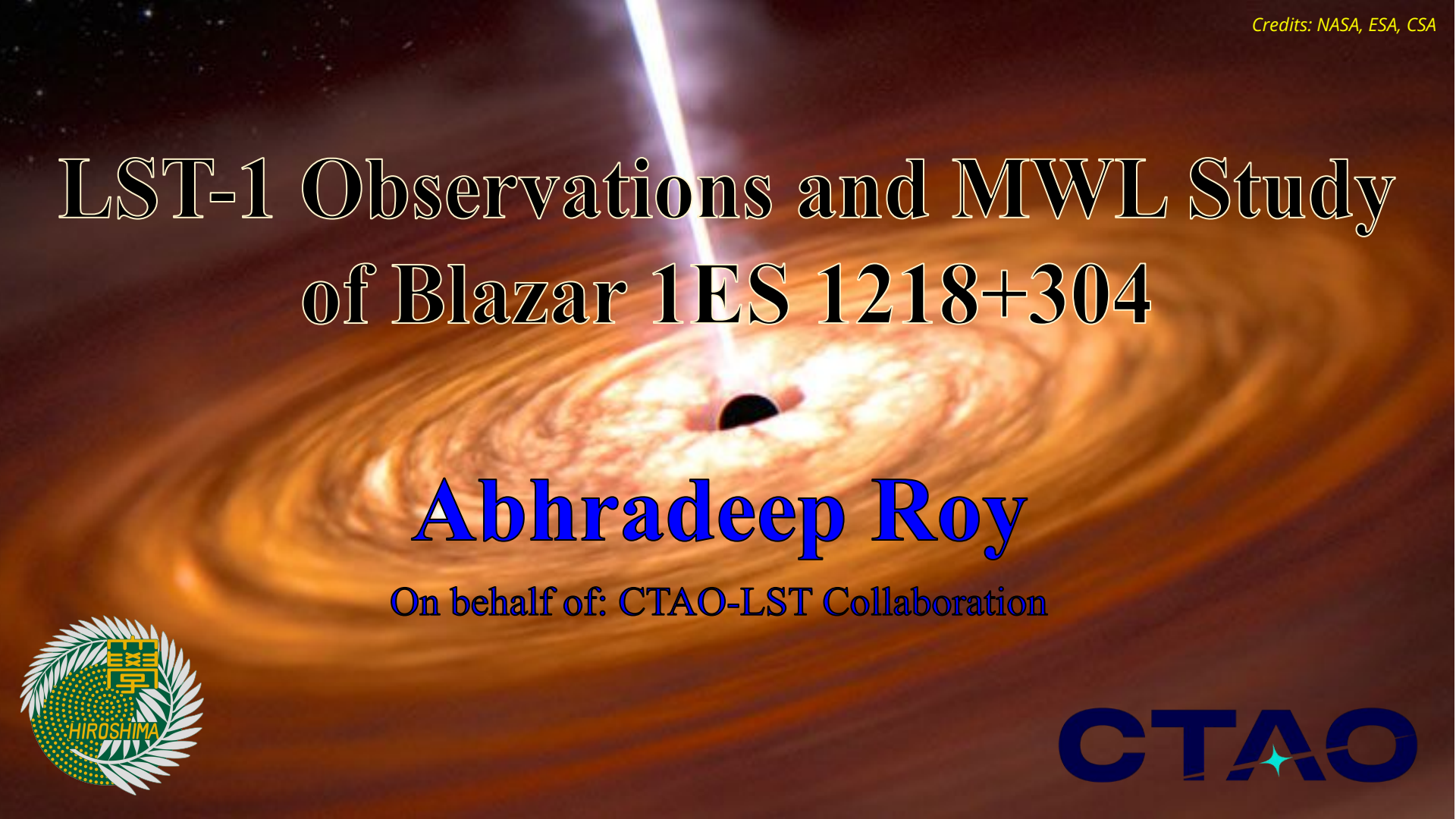


LST-1 Observations and MWL Study of Blazar 1ES 1218+304

Abhradeep Roy

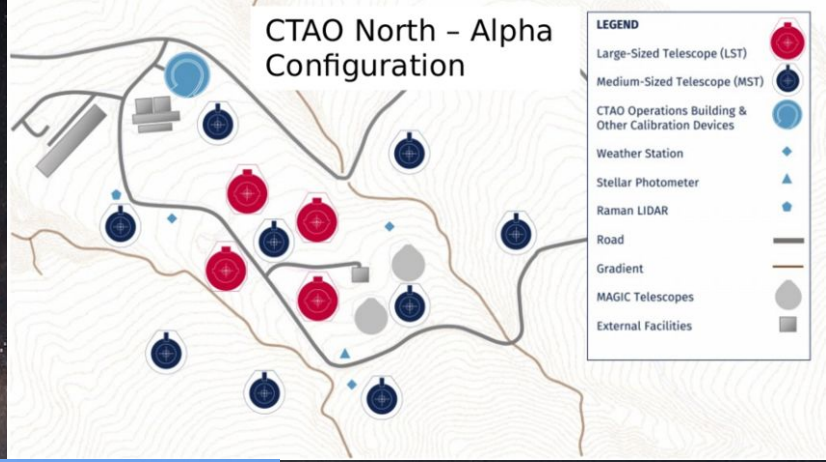
On behalf of: CTAO-LST Collaboration

HIROSHIMA

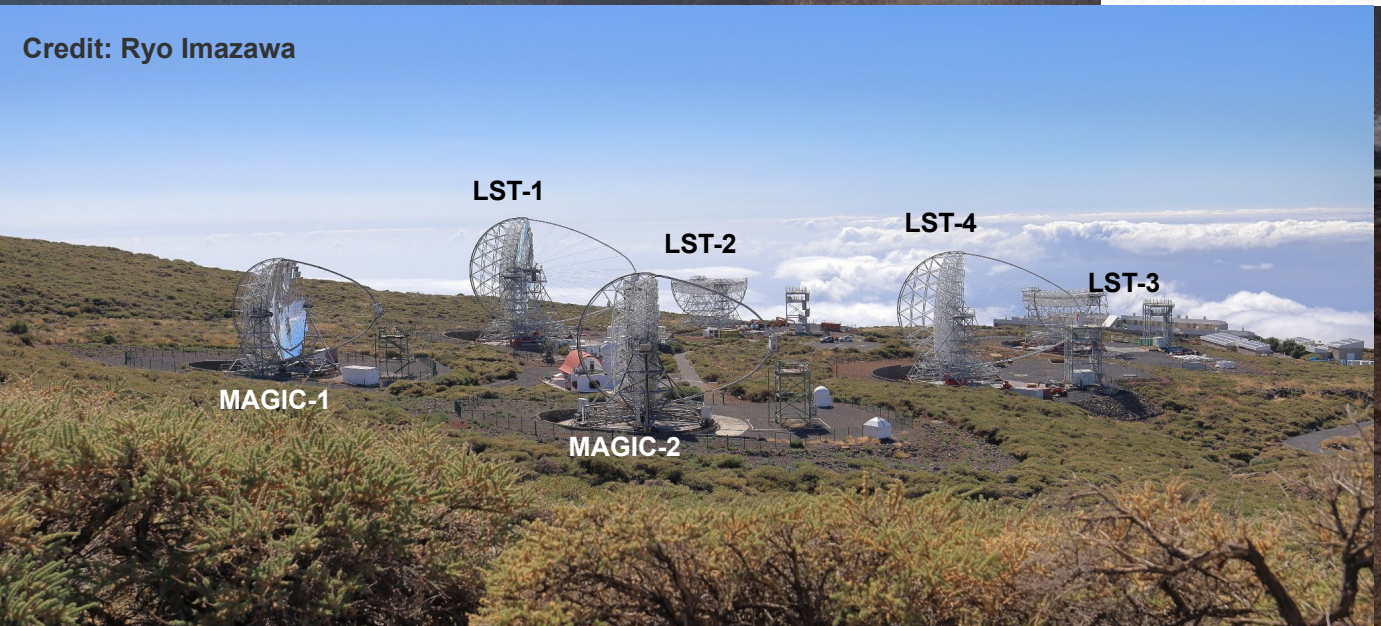
CTAO

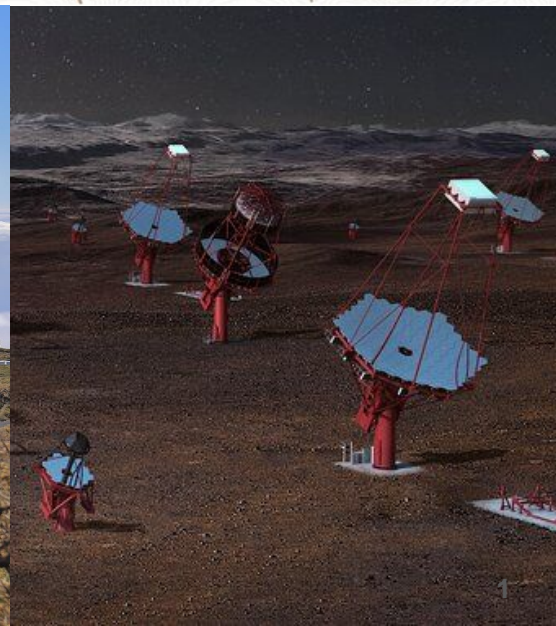
Courtesy: ESO

CTAO

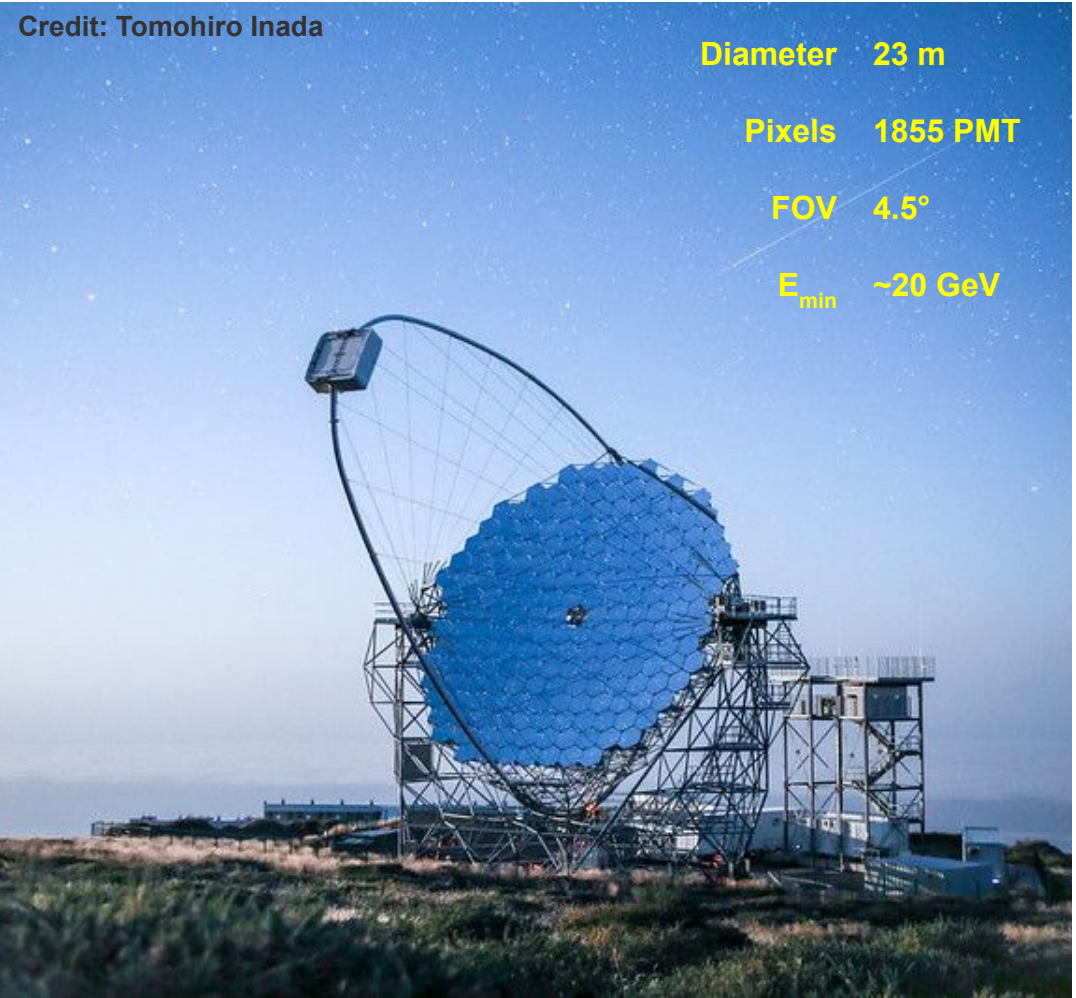


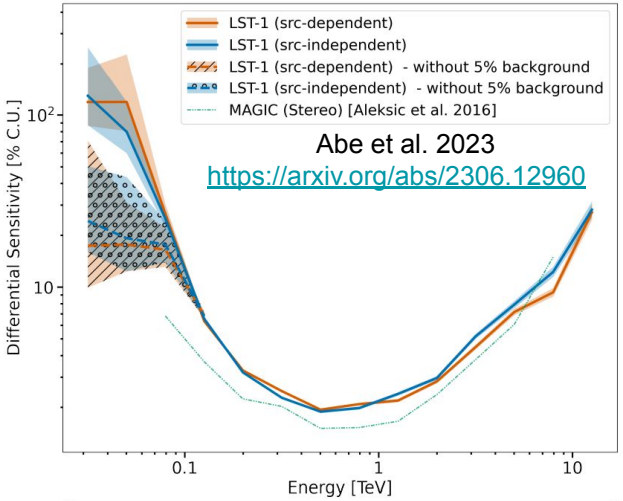
Credit: Ryo Imazawa

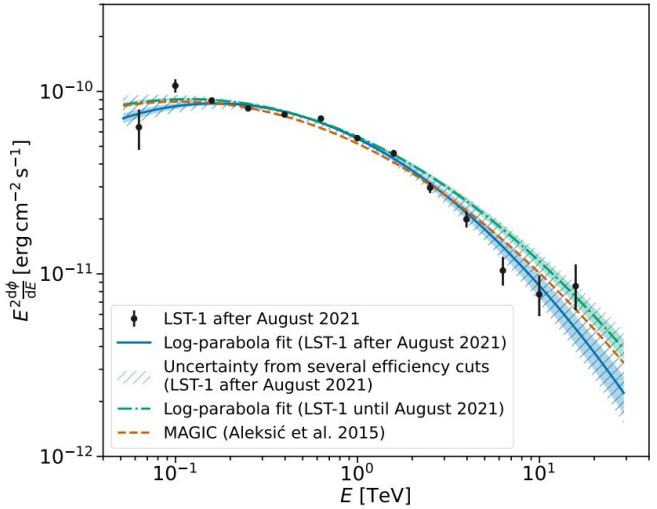




The Large-Sized Telescope-1 (LST-1)







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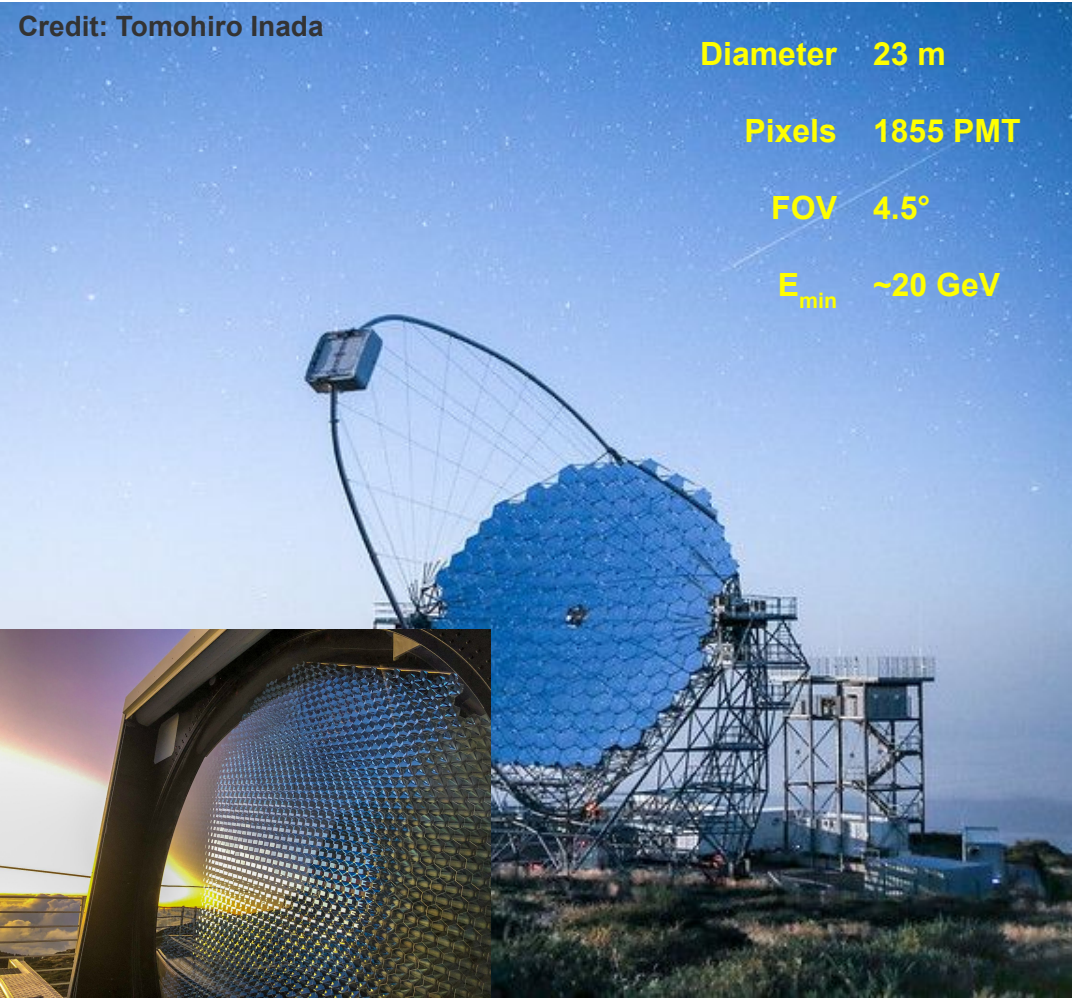
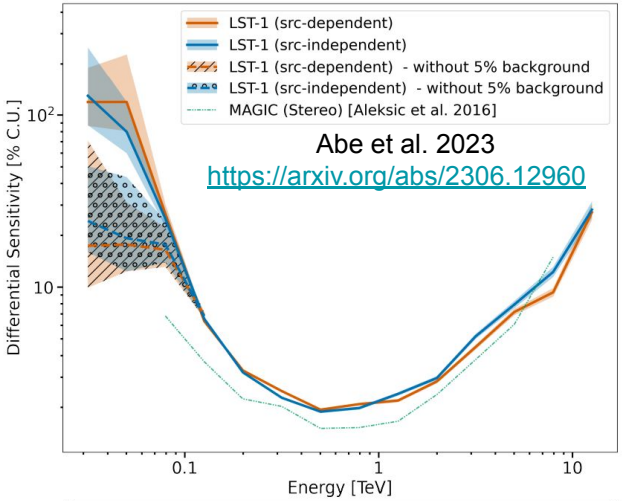
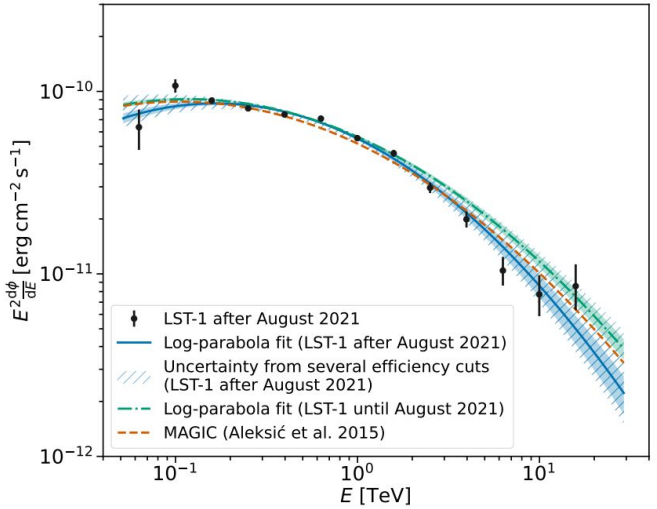
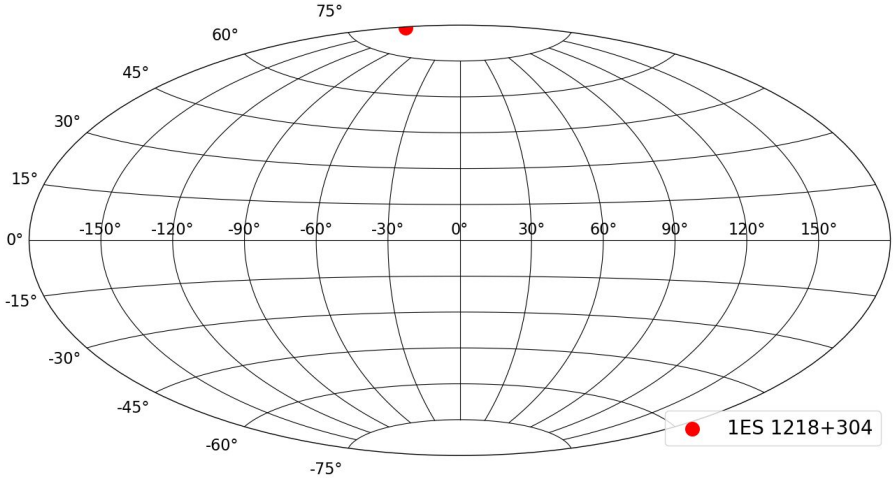






1ES 1218+304: Introduction



More details: [TeVCat Gamma-Ray Source Summary: 1ES 1218+304]

Source details

- High-energy peaked BL Lac (HBL) object (discovered in TeV by MAGIC on 2006-05, [Albert et al. 2006]).
- Later detected by VERITAS ([Acciari et al. 2009]).
- Variable in Very High Energies ([Acciari et al. 2010]).
- VHE spectral index ~3.0.
- Redshift, z = 0.182

LST-1 observation details

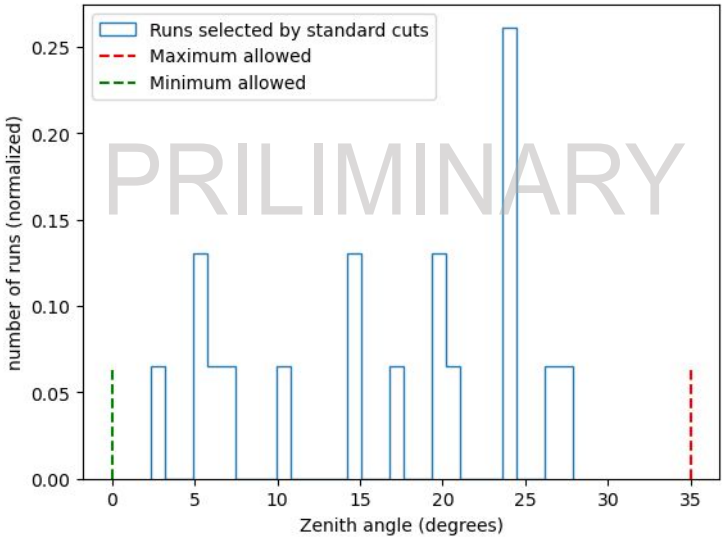
- Observation duration: 2023-02-28 to 2023-04-12
- 64 observations (~18 hours)
- ~40% observations in moonlight condition (rejected by standard data quality cuts).

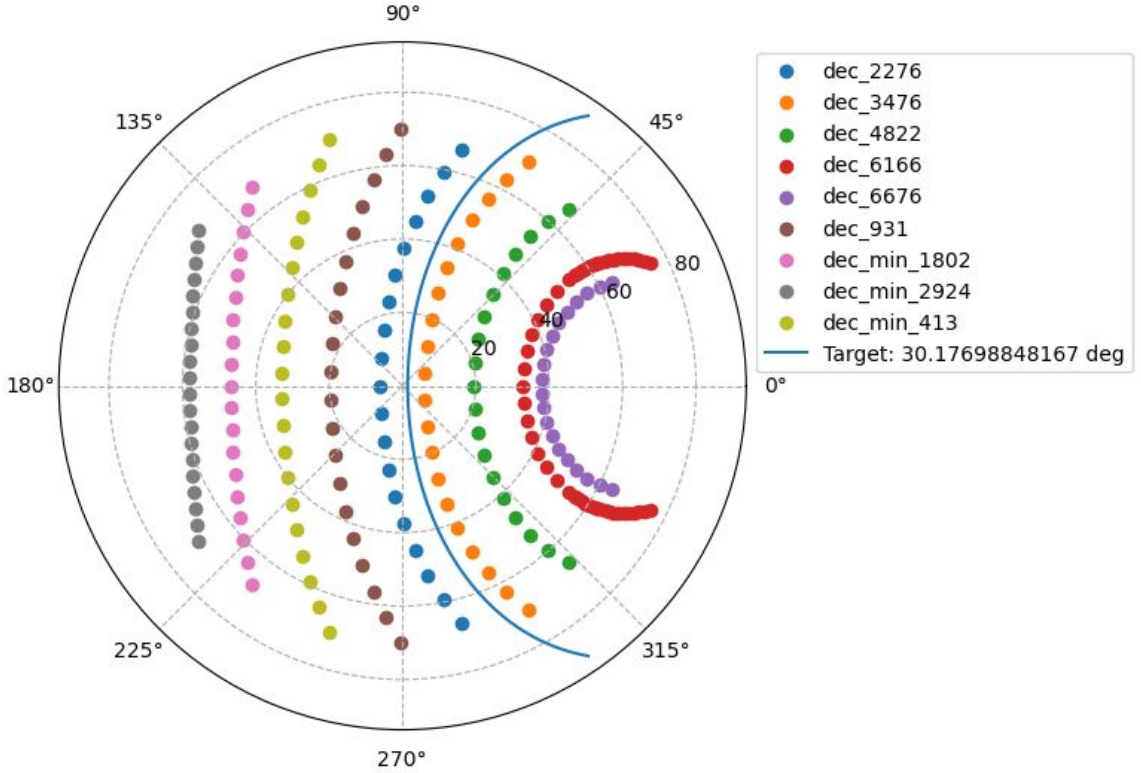
LST-1 Analysis:

- Lstchain-v0.10.11 (DL1 to DL3)
- Gammapy-1.1 (post DL3)

Observed and Monte-Carlo Data

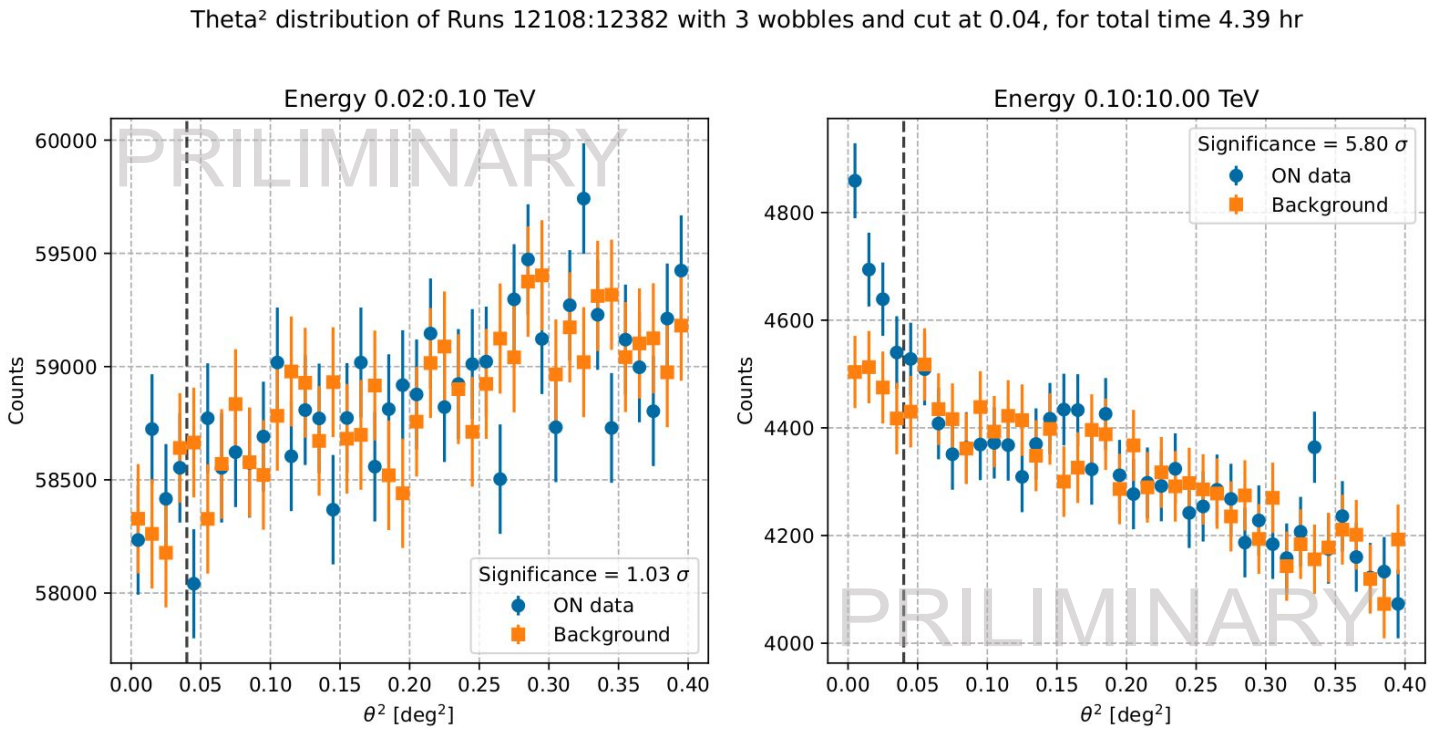
- Duration of selected observations = 2023-02-28 to 2023-04-12 (4.4 hours)
- MC and IRF: dec_2276





Applying Standard Cuts (θ^2 distribution)

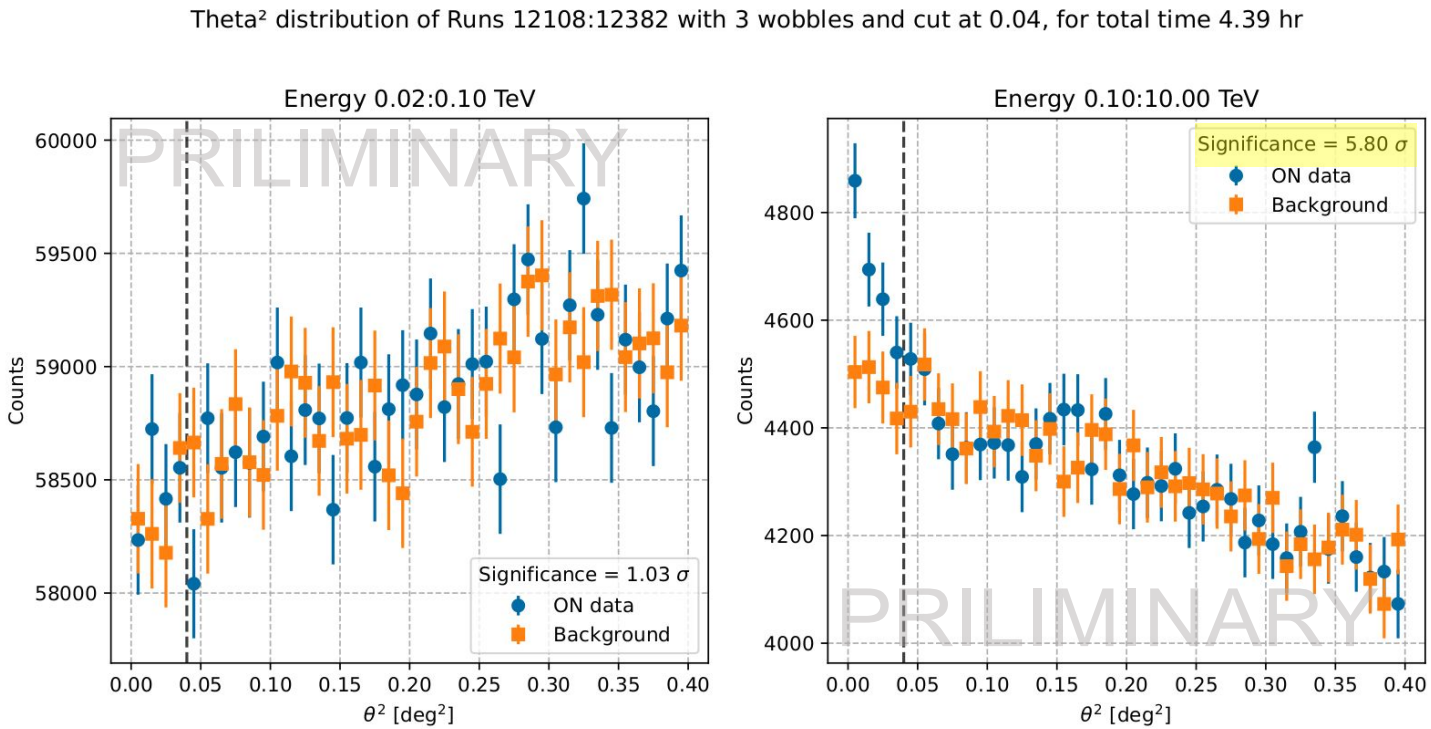
- Duration of selected observations = 2023-02-28 to 2023-04-12 (4.4 hours)
- MC and IRF: dec_2276
- Energy-dependent gammaness cut with 0.7 efficiency.



***Source-independent analysis**

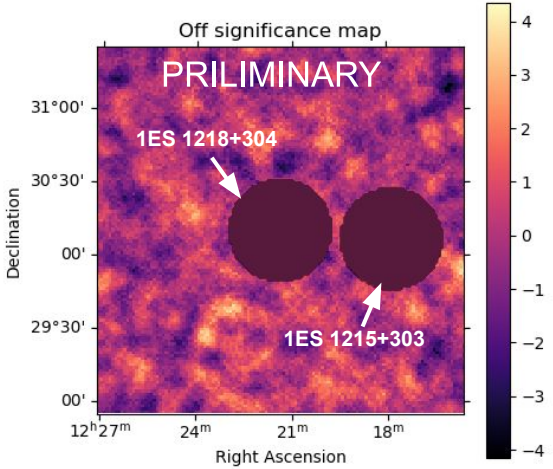
Applying Standard Cuts (θ^2 distribution)

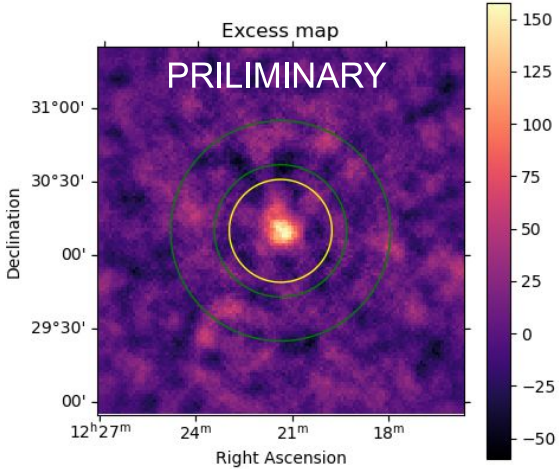
- Duration of selected observations = 2023-02-28 to 2023-04-12 (4.4 hours)
- MC and IRF: dec_2276
- Energy-dependent gammaness cut with 0.7 efficiency. Significance of >5 sigma.

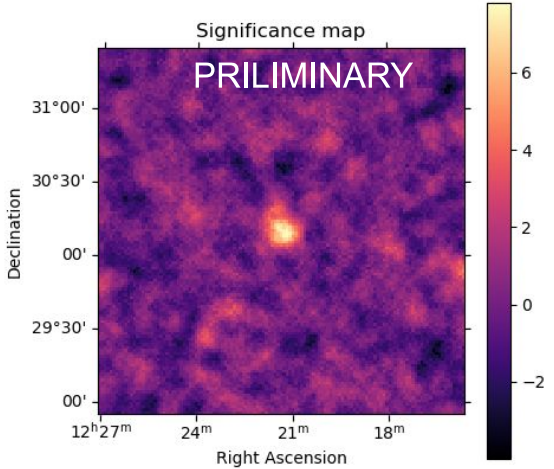


***Source-independent analysis**

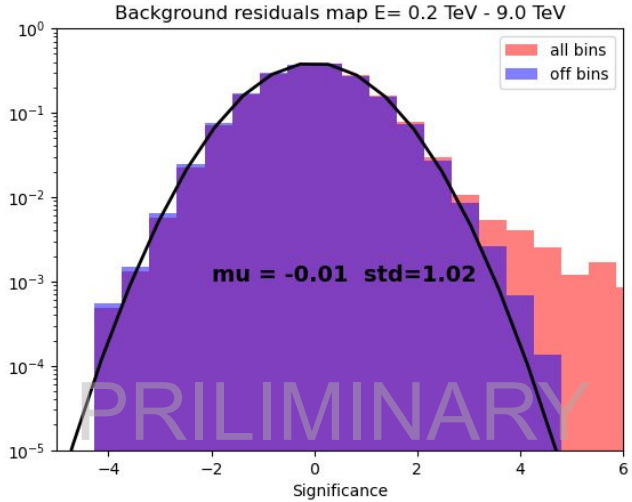
The Skymap





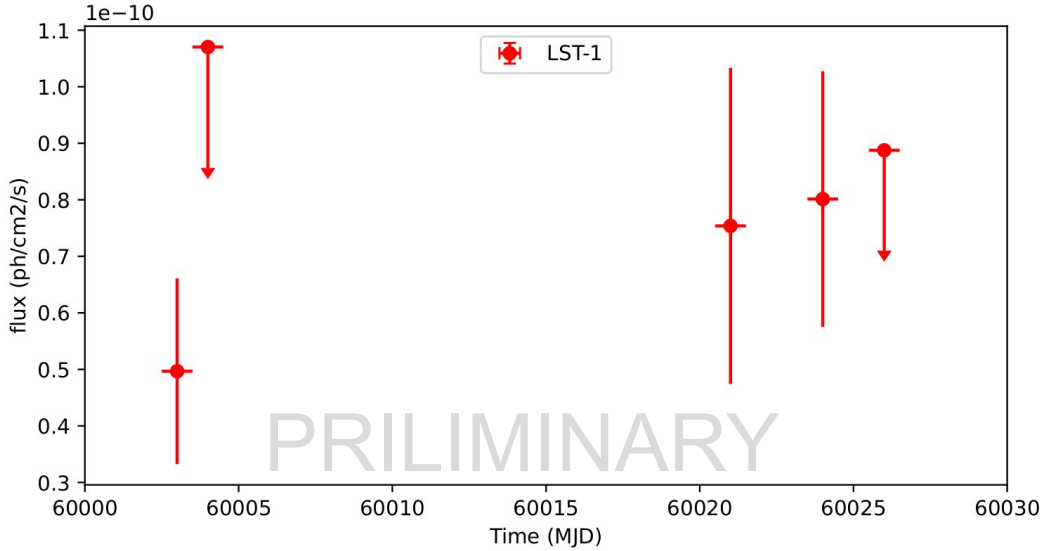


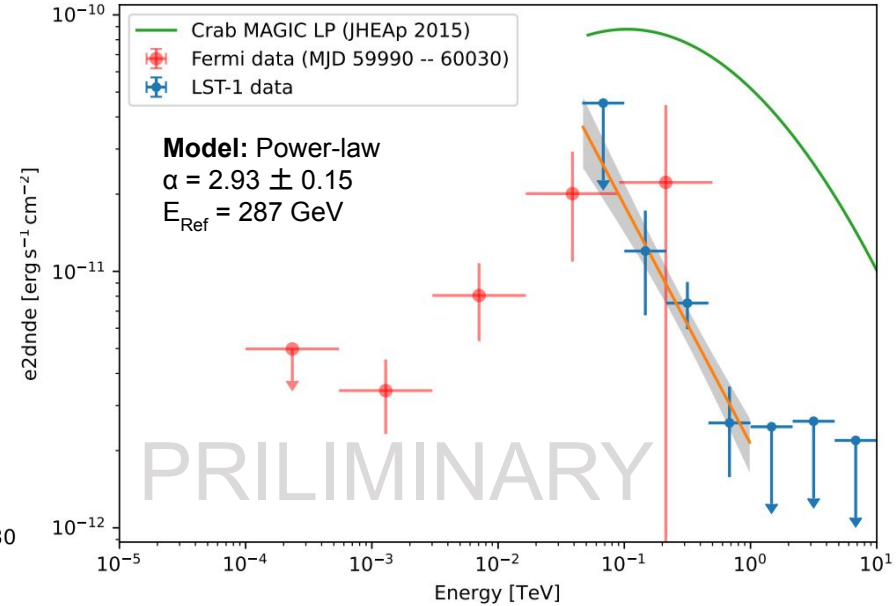
★ Masked sources in FOV : 1ES 1215+303



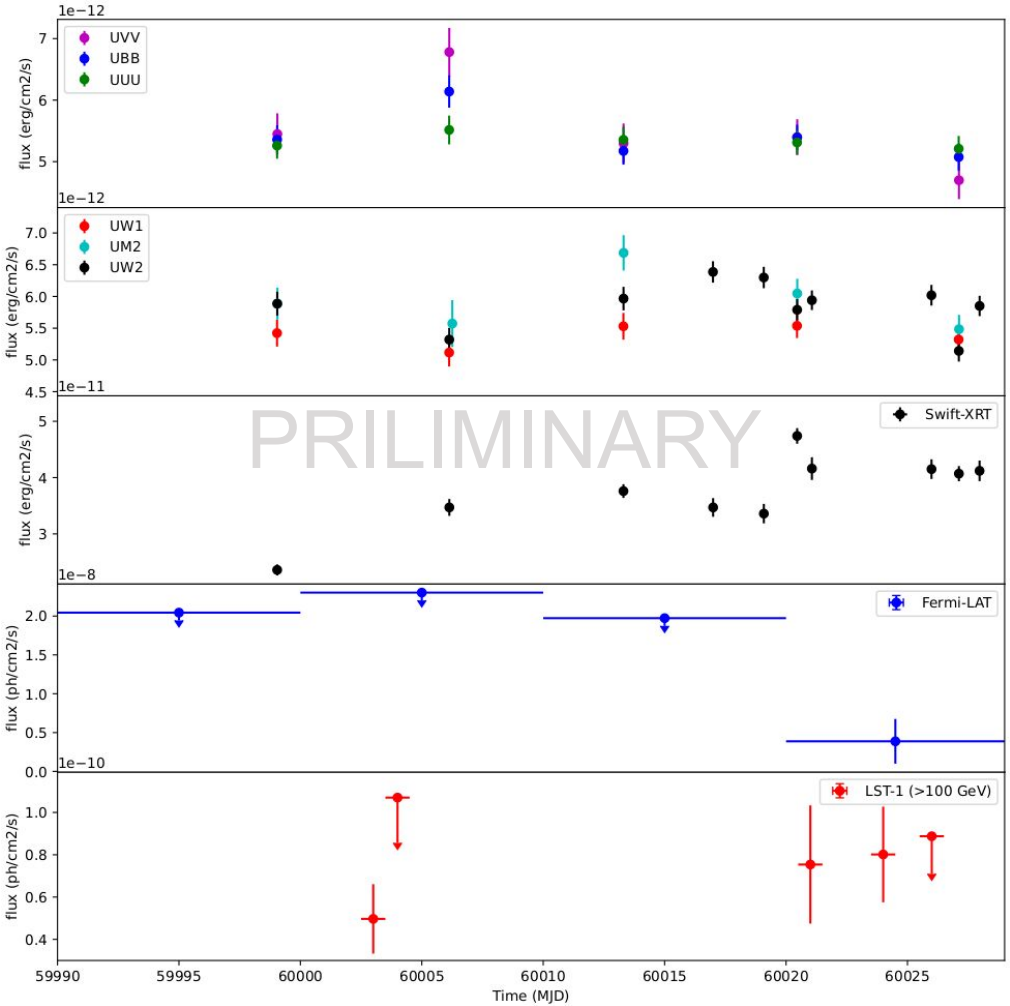
LST-1 Light curve and Spectrum

LST-1 light curve (night-wise) at E > 100 GeV





Multiwavelength Data



- 10 Swift observations.
- Optical-UV data from Swift-UVOT filters.
  - Galactic reddening and extinction correction
- Swift-XRT (0.3 to 10 keV)
  - Corrected for pile-up effect.
  - Correction for neutral Hydrogen column density during modelling.
- Fermi-LAT (100 MeV to 500 GeV)
  - Low emission state
  - Kept 1ES 1215+303 free during modelling
  - Spectral index ~1.59
- No significant variability observed in gamma-rays
  - No time-resolved SED study
  - One overall average SED

The Broadband Spectral Energy Distribution

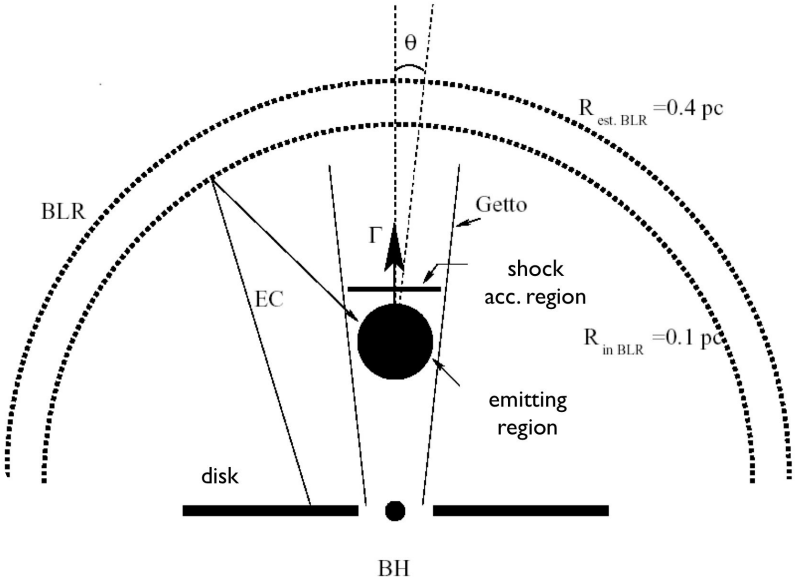
The Model:

- Leptonic one-zone Synchrotron Self-Compton (SSC) model.
- Spherical emission zone relativistically moving down the jet.
- Isotropic magnetic field inside emission region.
- Variability timescale (t_{var}) ≲ 1 day (typical) [Sato et al. 2008, Acciari et al. 2010]
  - Constrain region size

$$R \leq \frac{c\delta t_{var}}{(1+z)} = 2.5 \times 10^{16}\mathrm{cm}$$

- Log parabolic particle spectrum-
  - Probability for a particle to accelerate is a decreasing function of the energy (Massaro et al. 2004)

$$f(\gamma) = (\gamma/\gamma_0)^{-(s+r\log(\gamma/\gamma_0))}$$

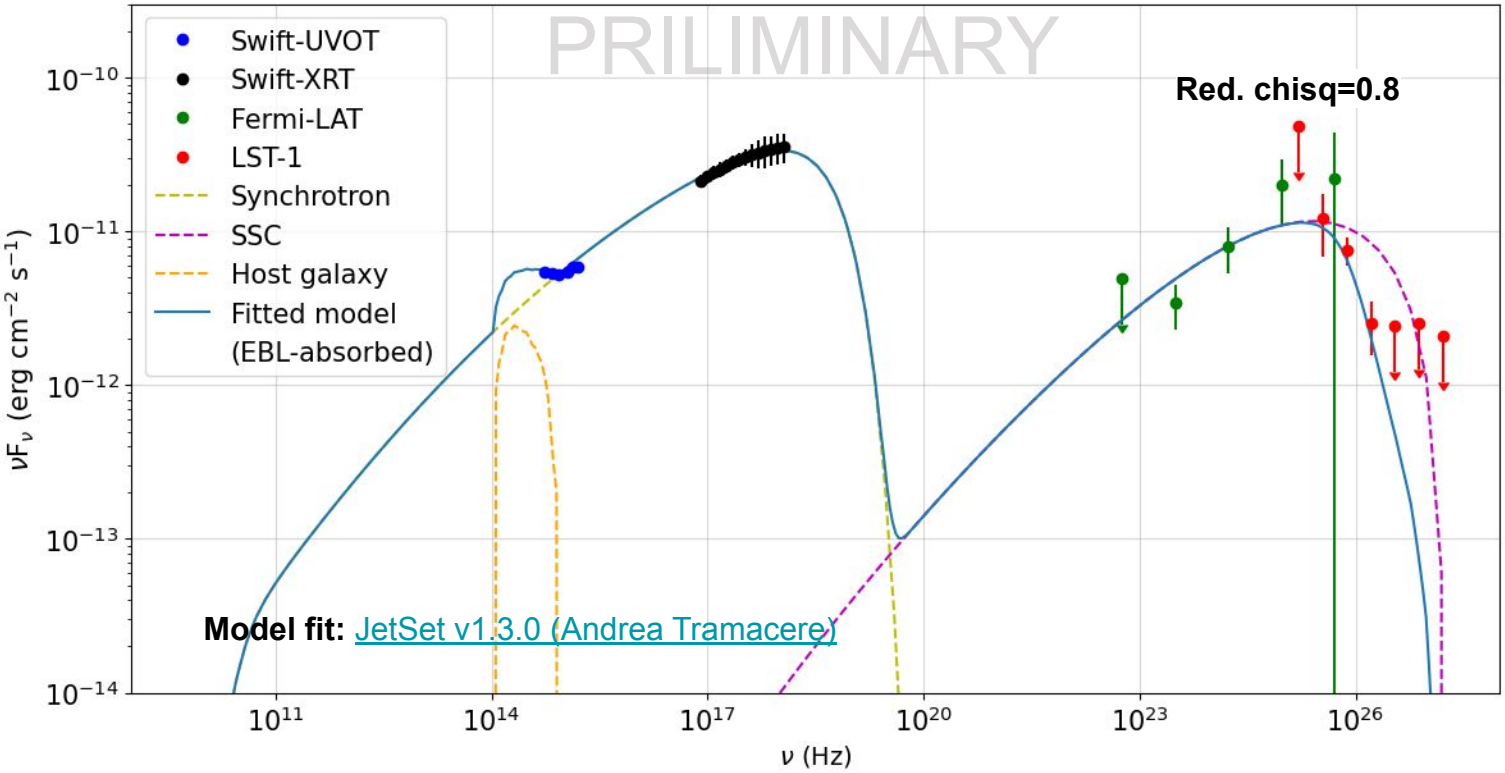


Credit: Andrea Tramacere

Fixed parameters:

- Region size (R) = 2.5 × 10^{16} cm
- Bulk Lorentz factor (Γ) ≃ Doppler boosting (δ) = 20 (typical)
- EBL absorption model: Franceschini et al. 2008

The Broadband Spectral Energy Distribution



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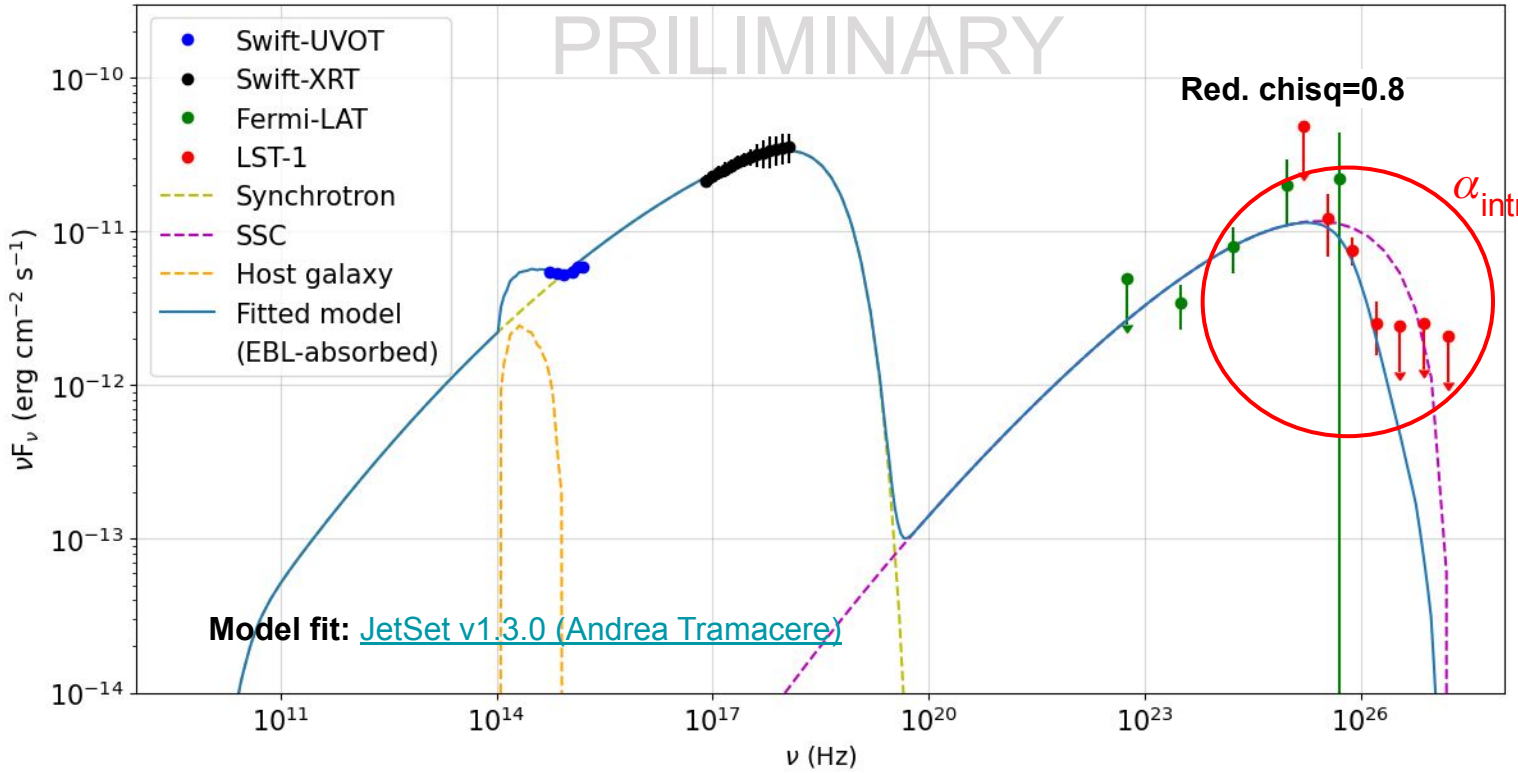
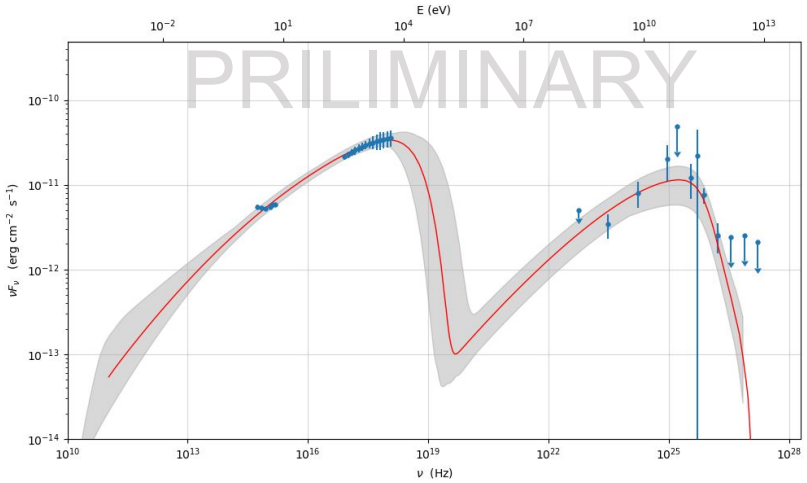
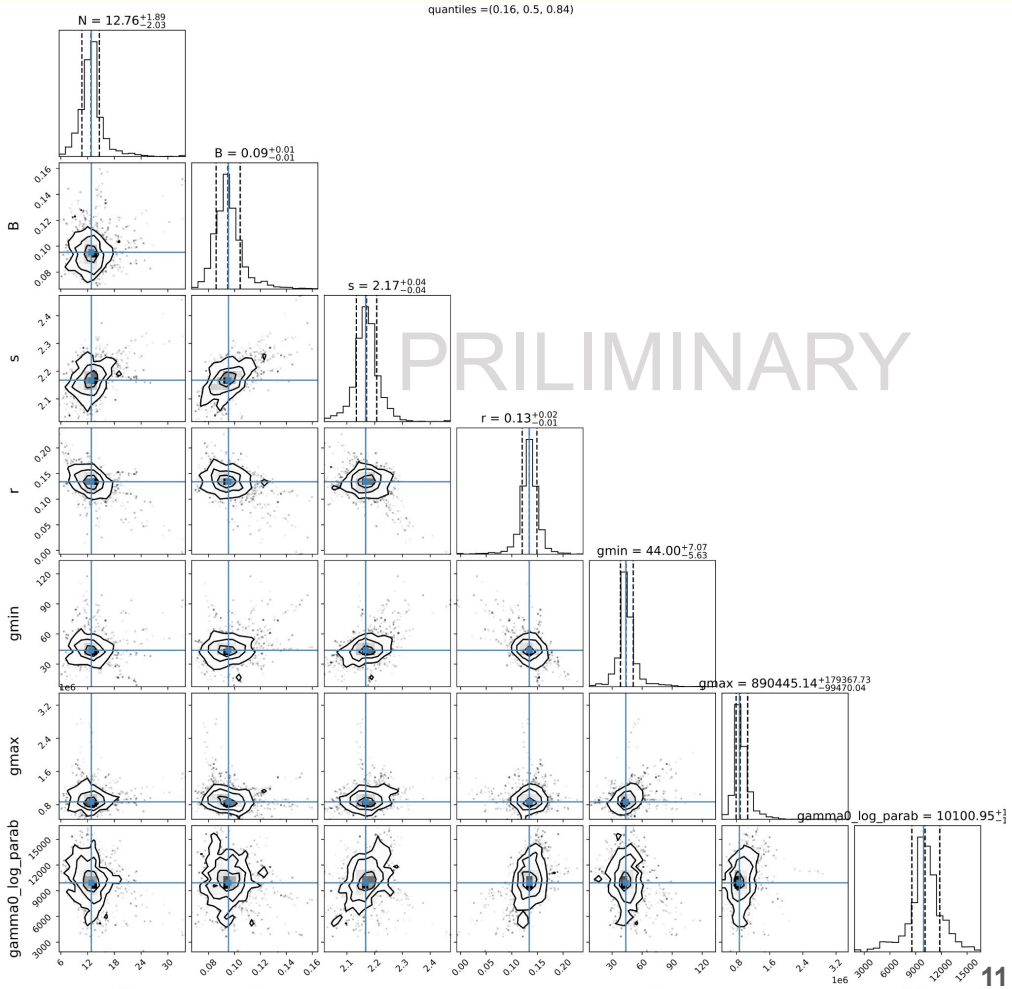


The Broadband Spectral Energy Distribution





Particle density, N = 12.7 ± 1.9 cm^{-3}
Magnetic field, B = 0.09 ± 0.01 G
Index, s = 2.17 ± 0.04
Curvature parameter, r = 0.13 ± 0.02
Minimum Lorentz factor, γ_{min} = 44 ± 7
Maximum Lorentz factor, γ_{max} = (9 ± 1) × 10^5
Reference Lorentz factor, γ_0 = (1.0 ± 0.1) × 10^4

Summary

- Only ~4.4 hours of data got selected by the standard quality cuts.
- Detection significance > 5σ. Flux variability study was not possible.
- VHE spectral slope is comparable to previous studies (Albert et al. 2006, Acciari et al. 2010).
- Multiwavelength SED modelling is carried out including quasi-simultaneous Swift and Fermi-LAT data.
- SED model: Leptonic one-zone Synchrotron Self-Compton with particle population having log-parabolic energy distribution.
- Diffusive shock acceleration is a viable mechanism.

Future plan: MAGIC-LST1 joint observation on 2023-03-16, 18 and 21. Joint analysis can improve the results. Ongoing efforts to recover data taken in moonlight.

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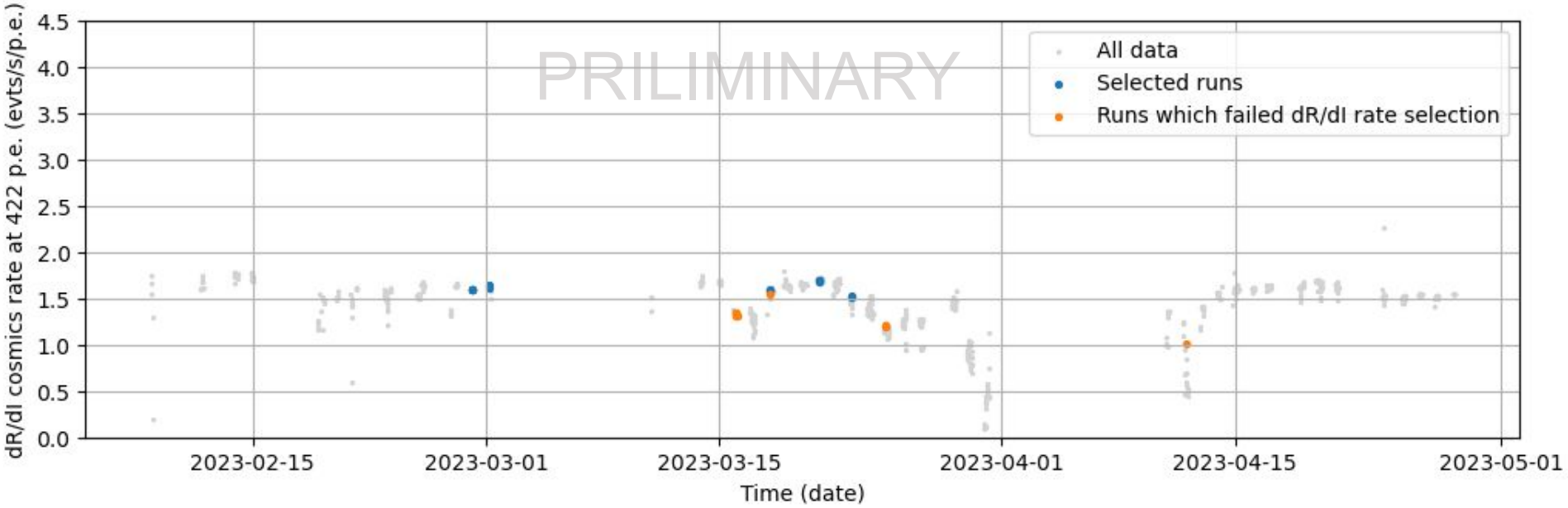
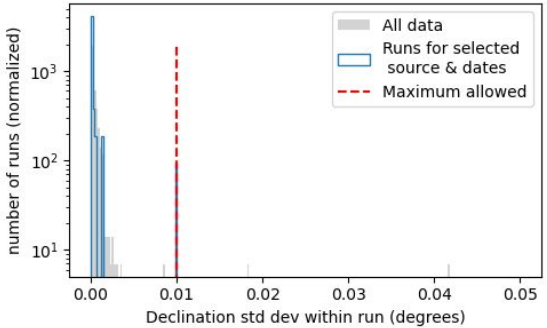
BACKUP SLIDES

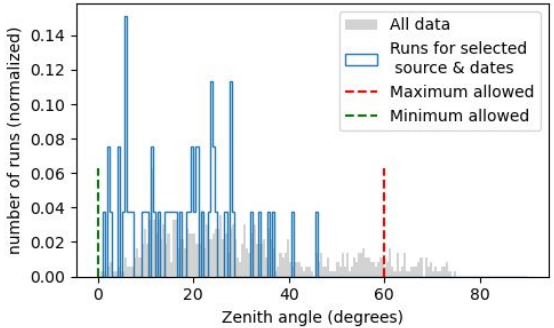
Observed and Monte-Carlo Data

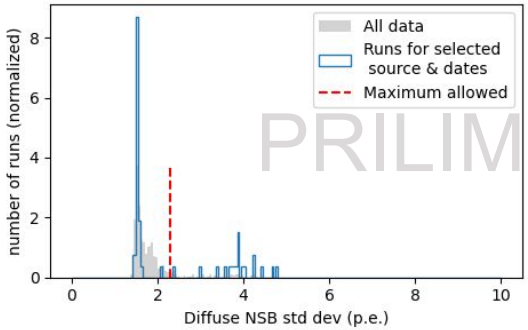
- Duration of selected observations = 2023-02-28 to 2023-04-12 (4.4 hours)
- MC and IRF: dec_2276

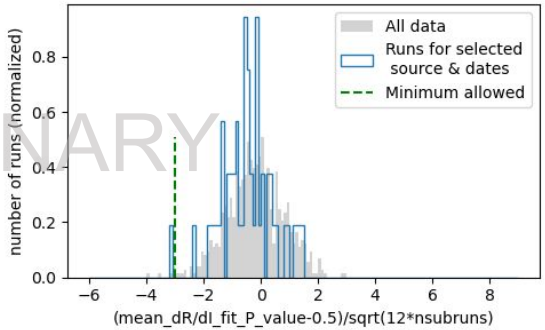


Applying Standard Cuts









Duration: 2023-02-28 to 2023-04-11

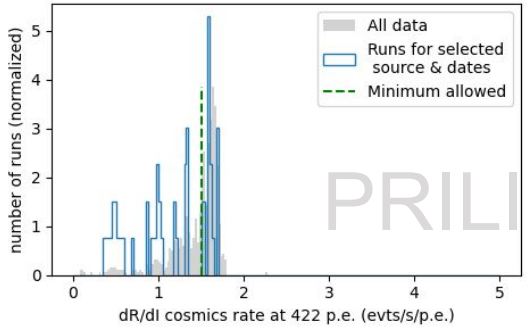
```
Number of runs (% is w.r.t. those in Sky region & zenith range):

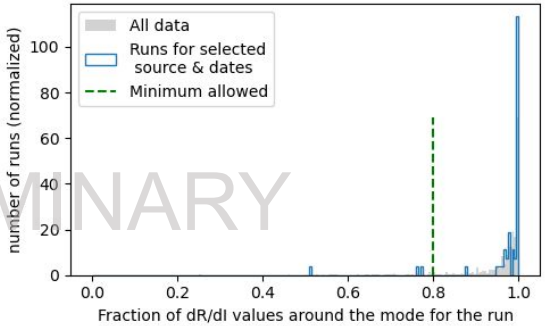
   In the requested Sky region and range of dates:      60
 + zenith in requested range:                           60
 + NSB in requested range:                              35 (58.3%)

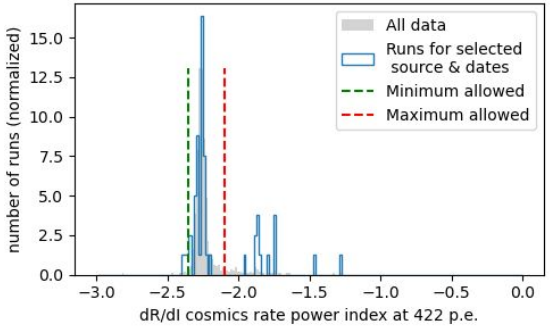
 + FF and pedestal interleaved events are present:      34 (56.7%)
 + Stable pointing:                                     34 (56.7%)
 + dR/dI fit P-value ok:                                34 (56.7%)
 + dR/dI LS periodogram ok:                             33 (55.0%)
 + dR/dI index ok:                                      30 (50.0%)
 + dR/dI rate ok:                                       18 (30.0%)
 + intensity threshold ok:                              18 (30.0%)
```

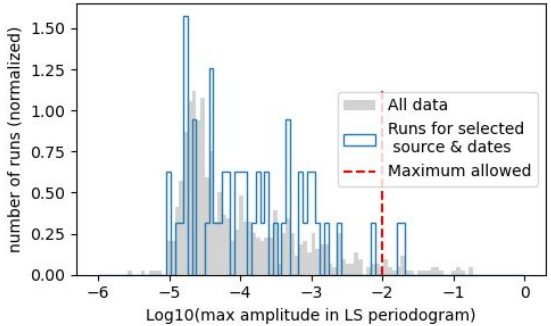
*** Median of the NSB standard deviation for the sample: 1.543 p.e. :: New MC not needed**

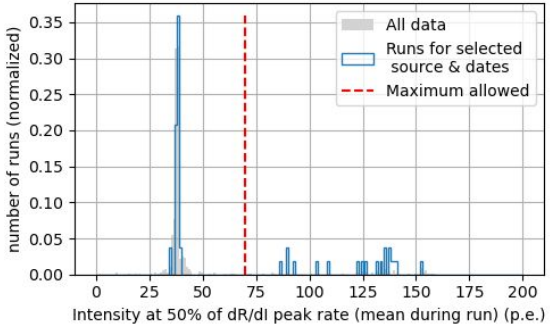
Applying Standard Cuts

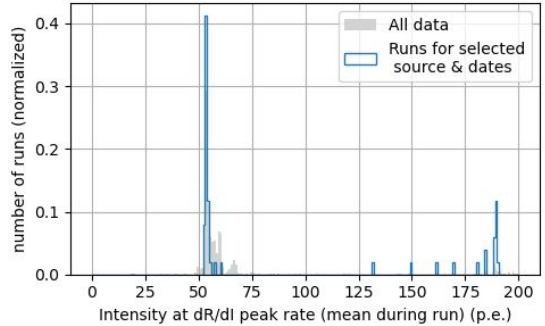












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 + NSB in requested range:                              35 (58.3%)

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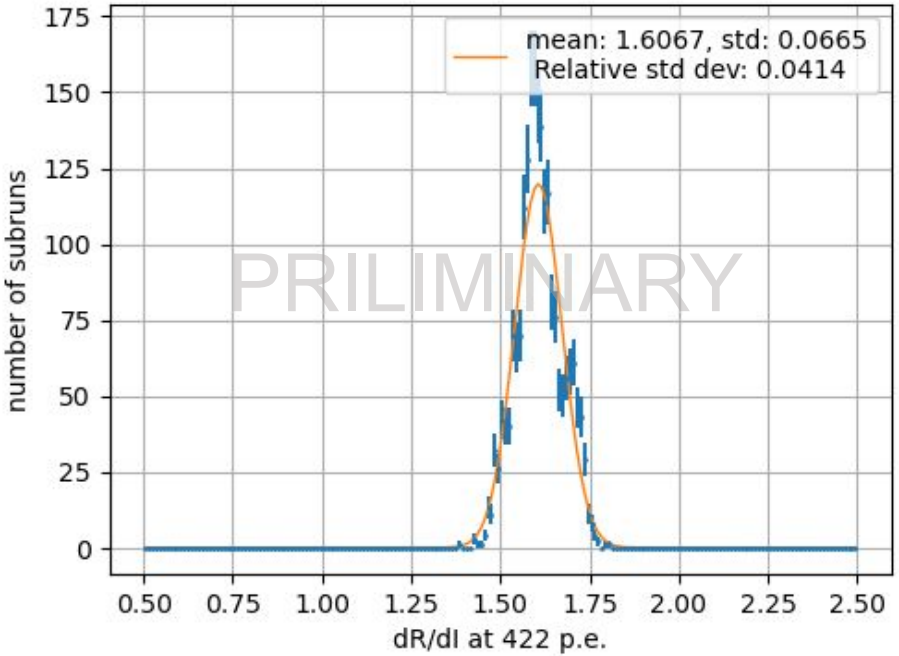
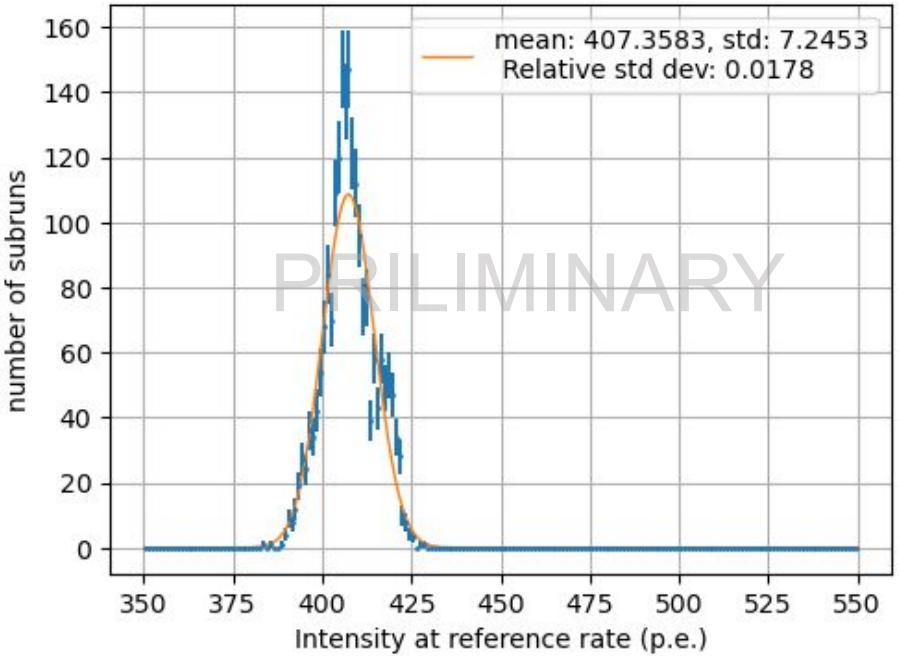
 + dR/dI rate ok:                                       18 (30.0%)
 + intensity threshold ok:                              18 (30.0%)
```

*** Median of the NSB standard deviation for the sample: 1.543 p.e. :: New MC not needed**

Applying Standard Cuts

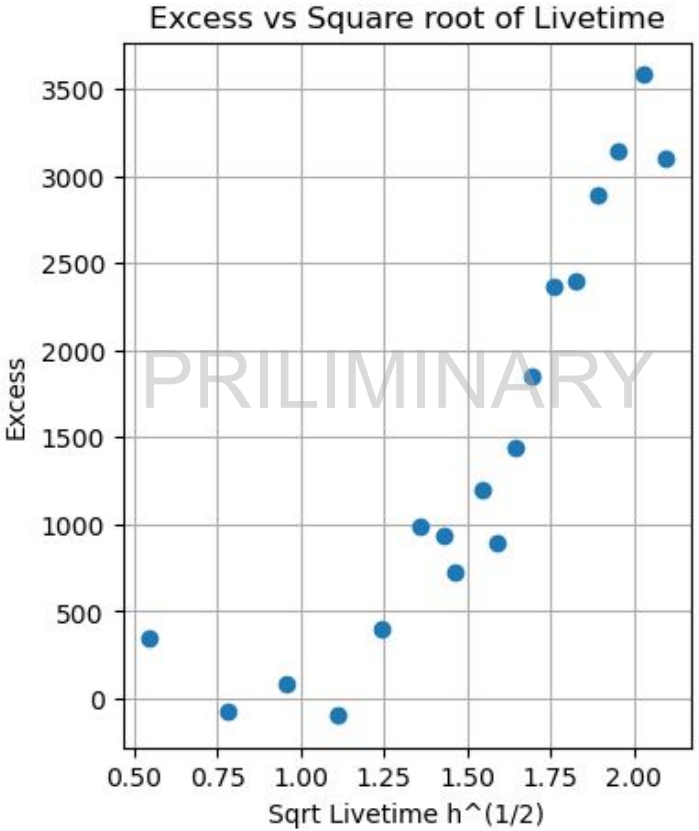
- Duration of selected observations = 4.4 hours

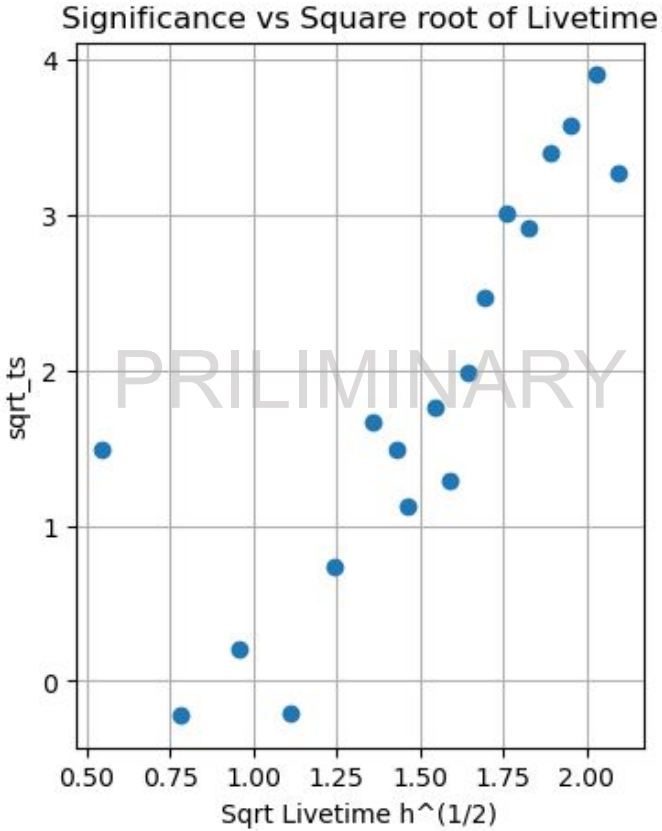




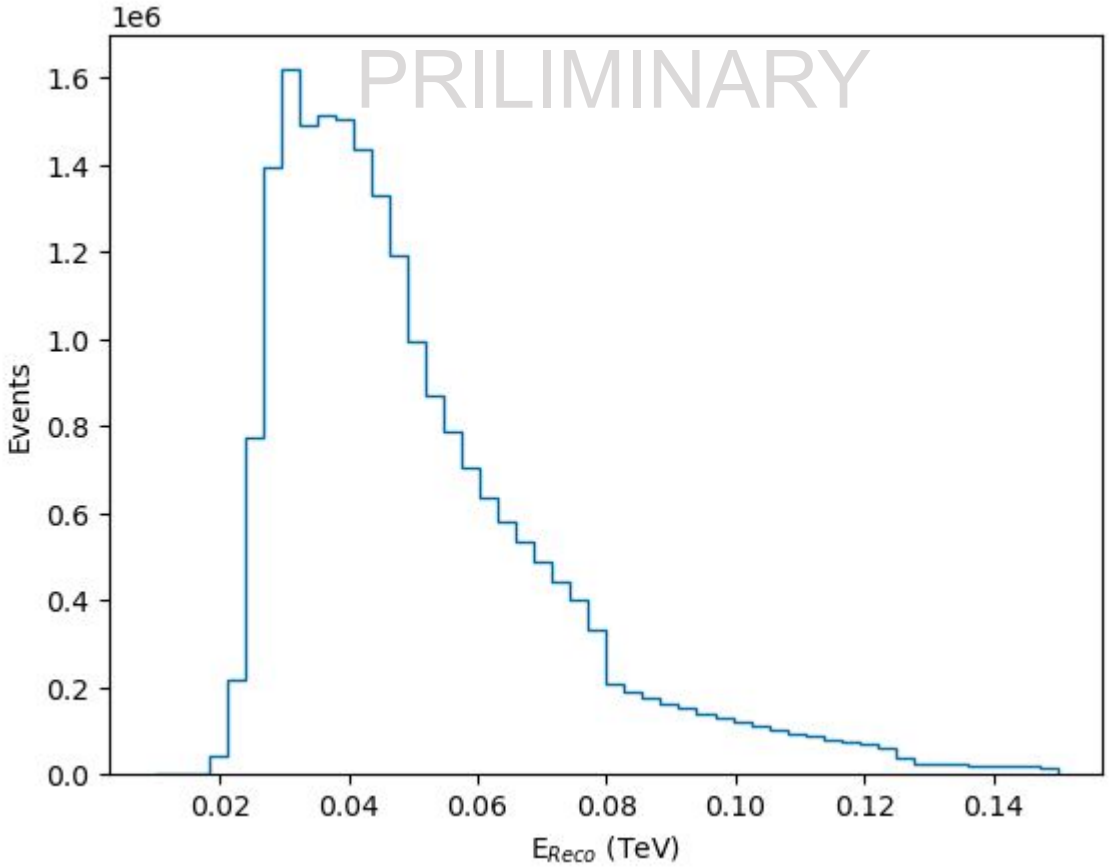
Applying Standard Cuts (θ^2 distribution)

- Duration of selected observations = 4.4 hours
- MC and IRF: dec_2276

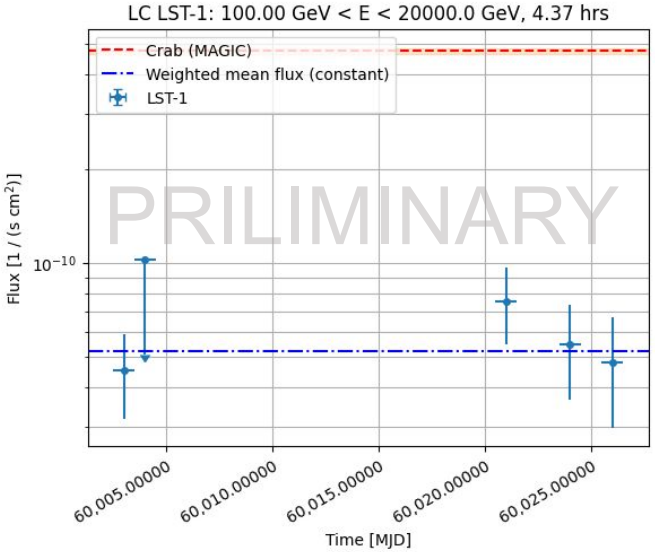


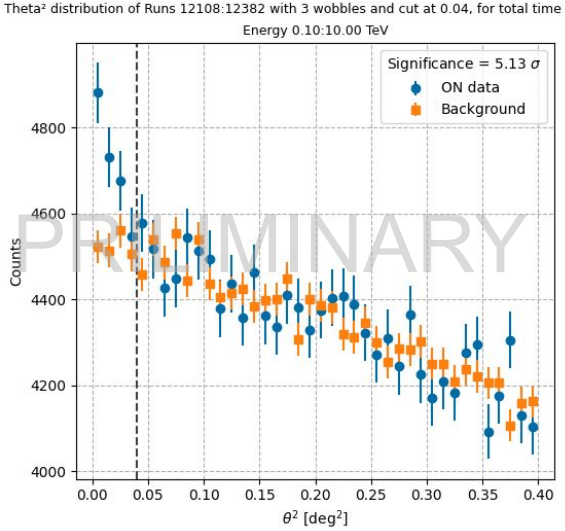


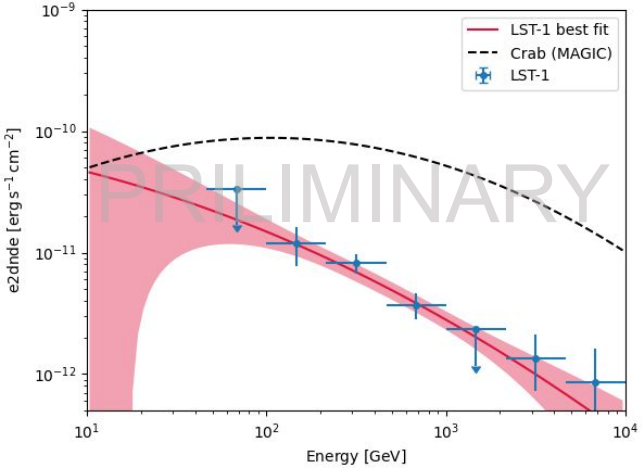
Applying Standard Cuts (Energy Threshold)



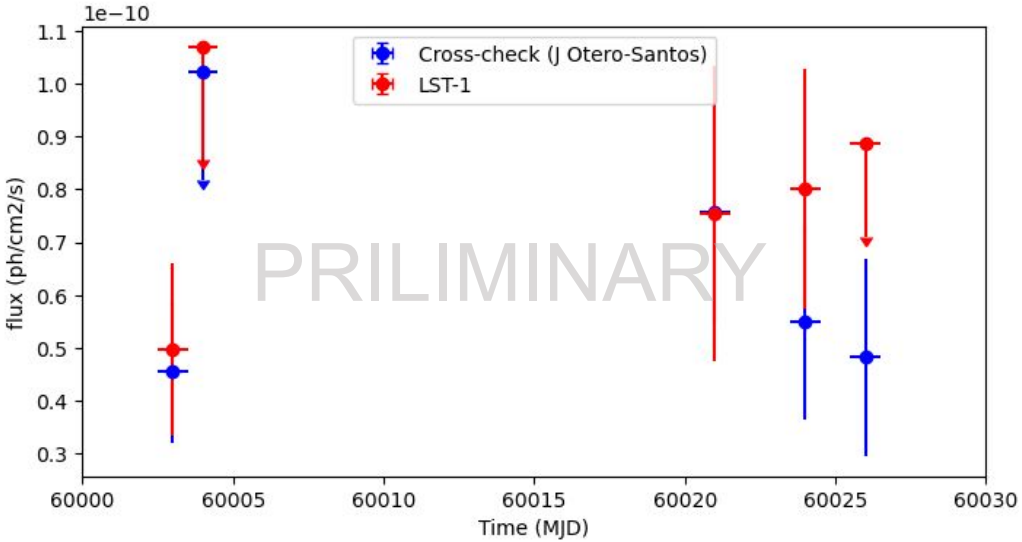
1ES 1218+304: Cross-check (J Otero-Santos)

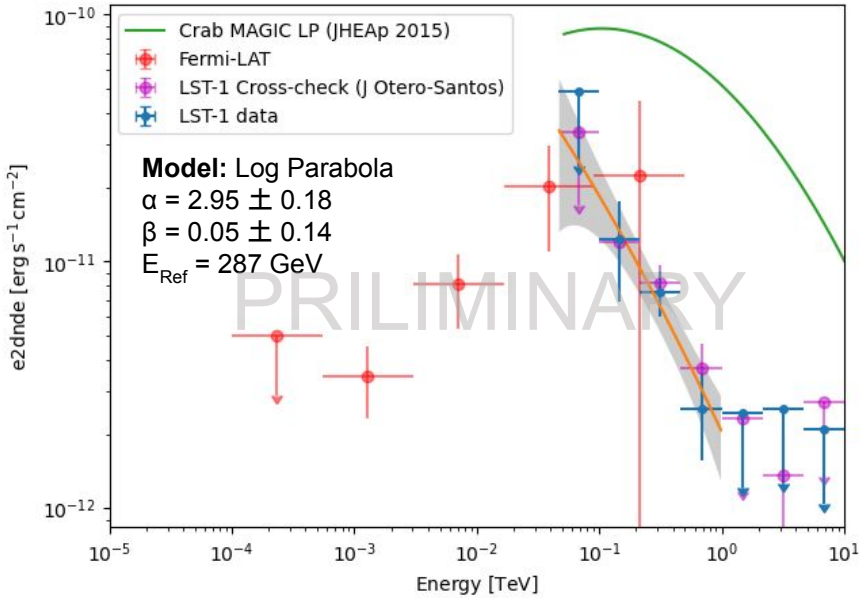




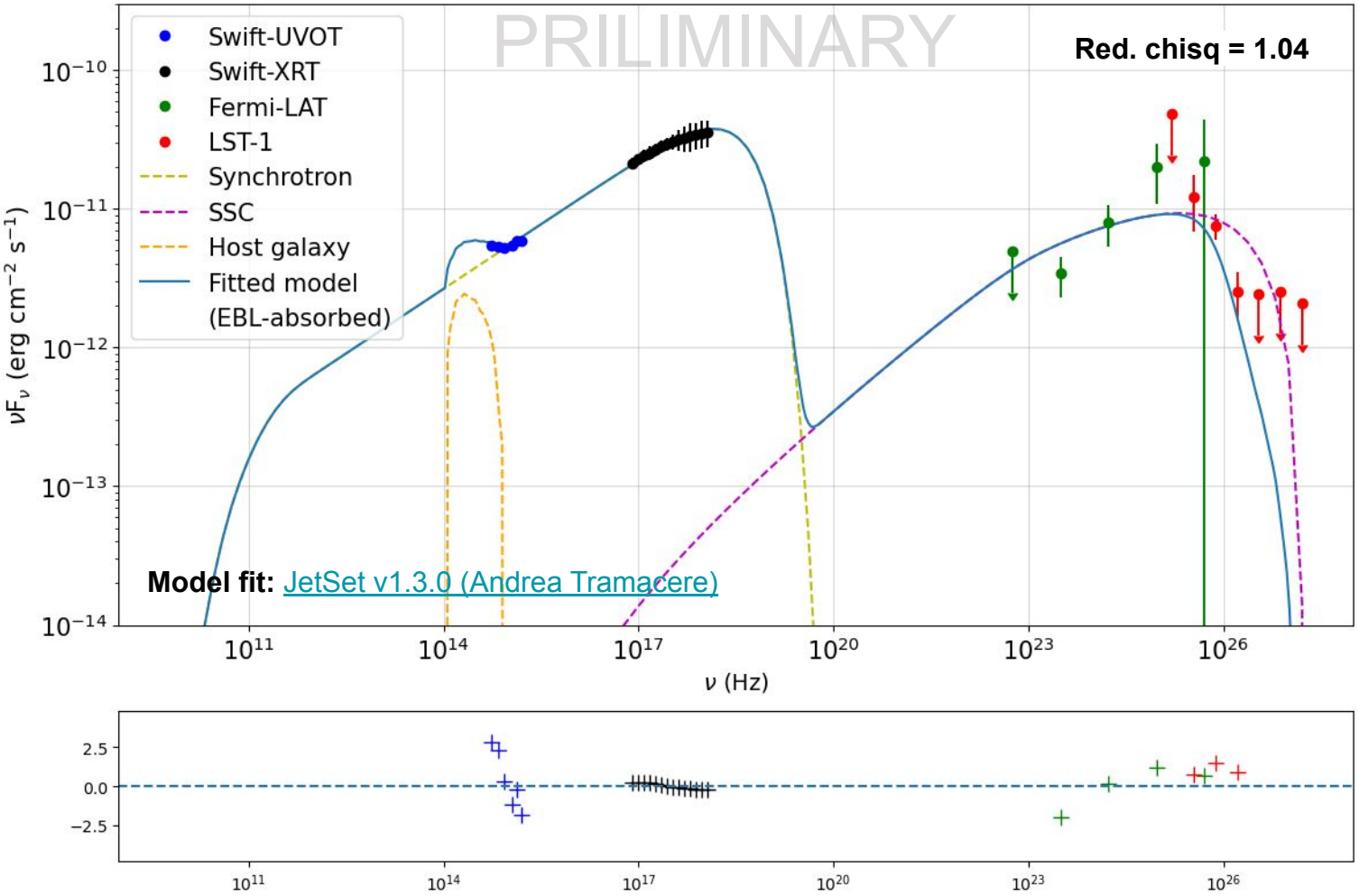


LST-1 Light curve and Spectrum (Cross-Check)

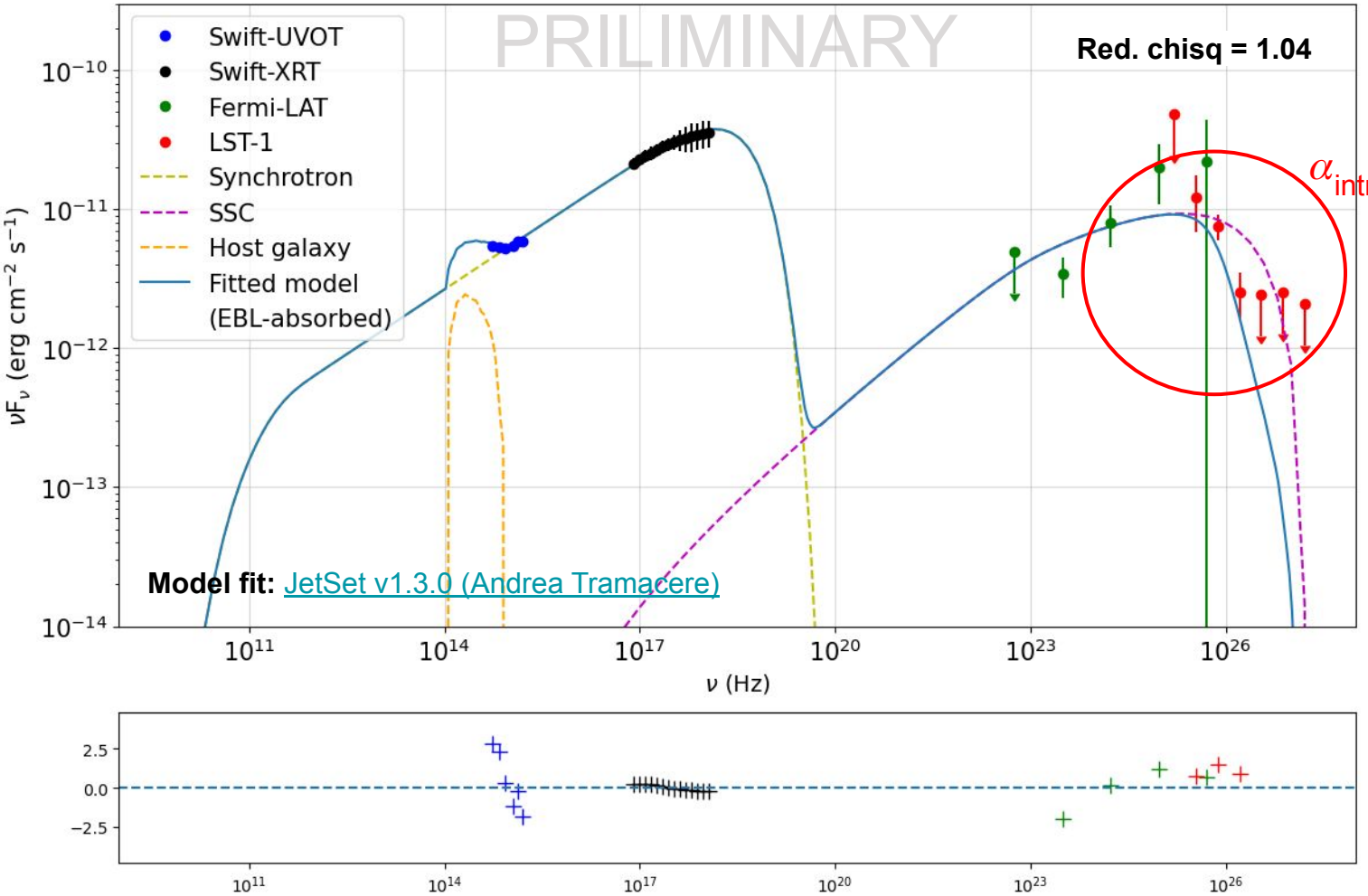




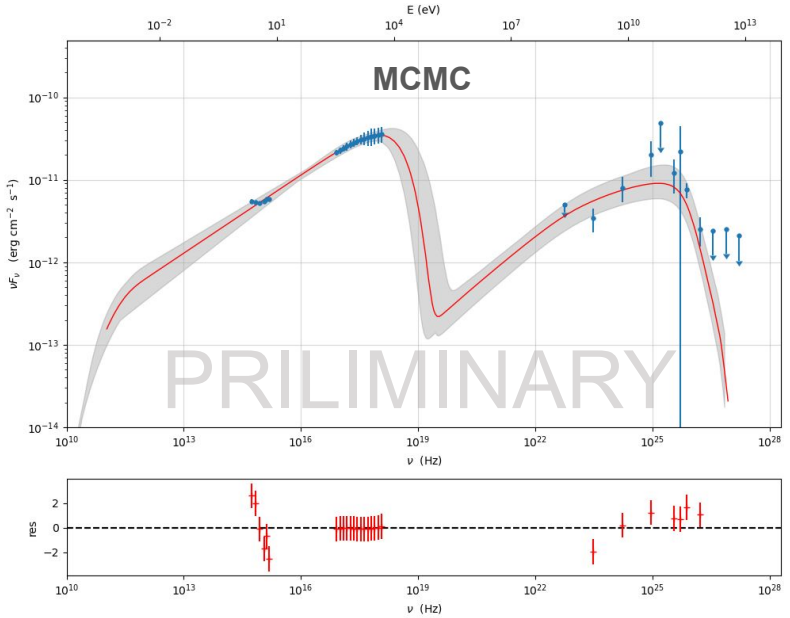
The Broadband Spectral Energy Distribution

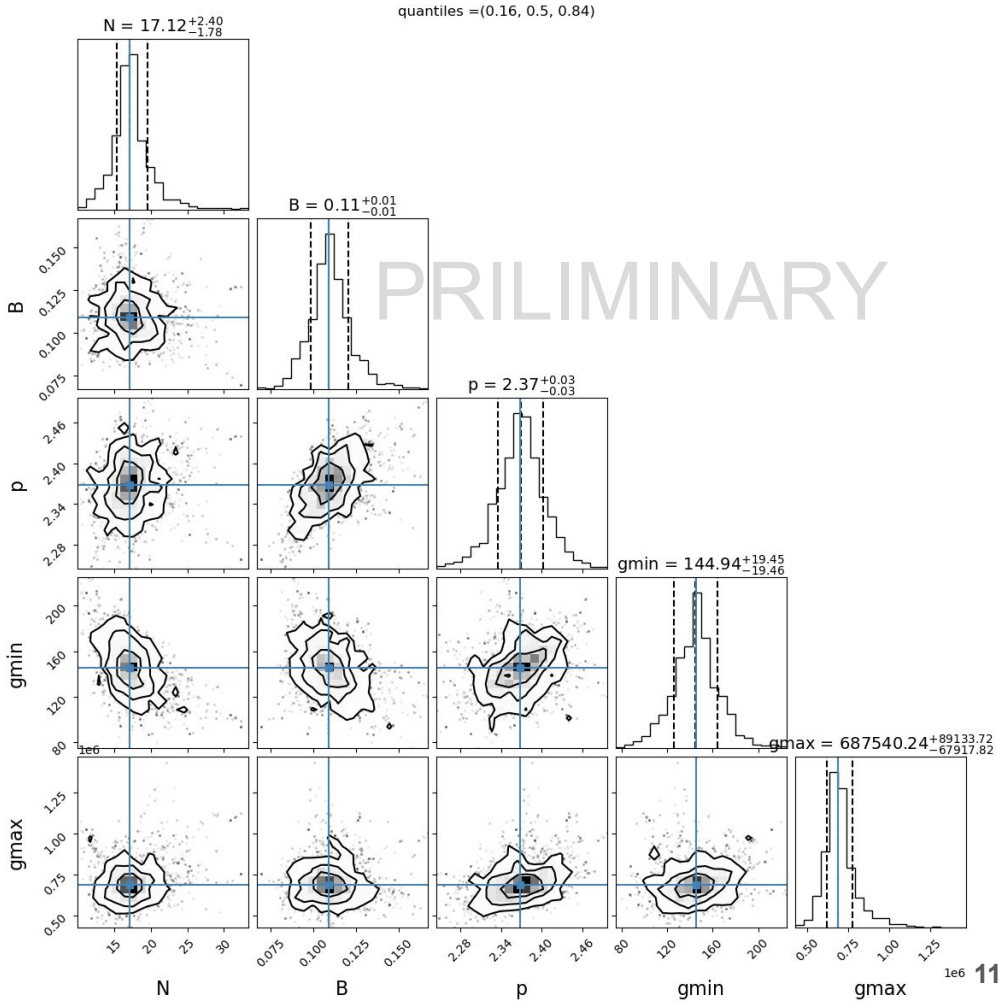


The Broadband Spectral Energy Distribution



The Broadband Spectral Energy Distribution

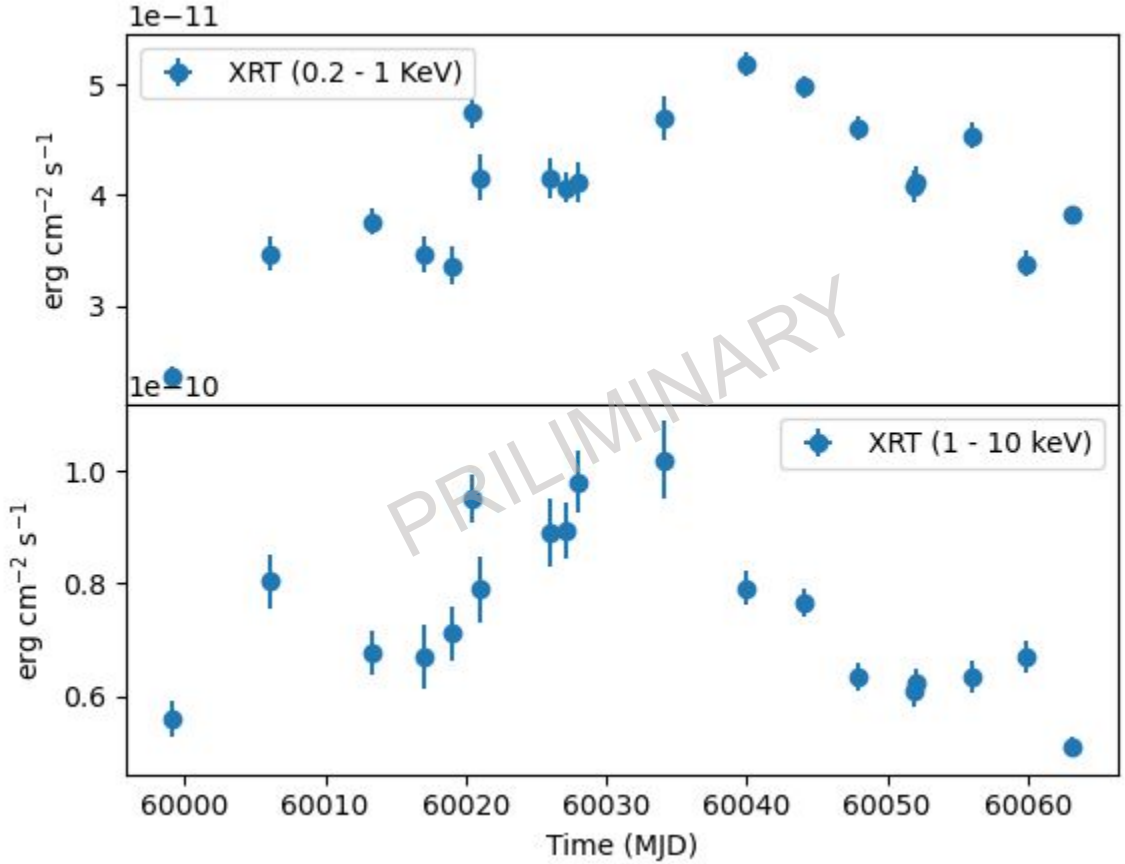




Particle density, N = 17 ± 2 cm^{-3}
Magnetic field, B = 0.11 ± 0.01 G

Index, p = 2.37 ± 0.03
Minimum Lorentz factor, γ_{min} = 145 ± 19
Maximum Lorentz factor, γ_{max} = (6.9 ± 0.9) × 10^5

Soft-Lag in X-ray



Soft-lag: energy dependent Synchrotron cooling. Observed here.
Hard-lag: energy-dependent acceleration. Observed by Suzaku (https://arxiv.org/pdf/0804.2529)

Harder when Brighter in X-ray