RS Ophiuchi nova outburst detection by the LST-1

A. Aguasca-Cabot, M. I. Bernardos Martín, D. Green, Y. Kobayashi and R. López-Coto
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7th Heidelberg International Symposium on High-Energy Gamma-Ray Astronomy
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cherenkov telescope array

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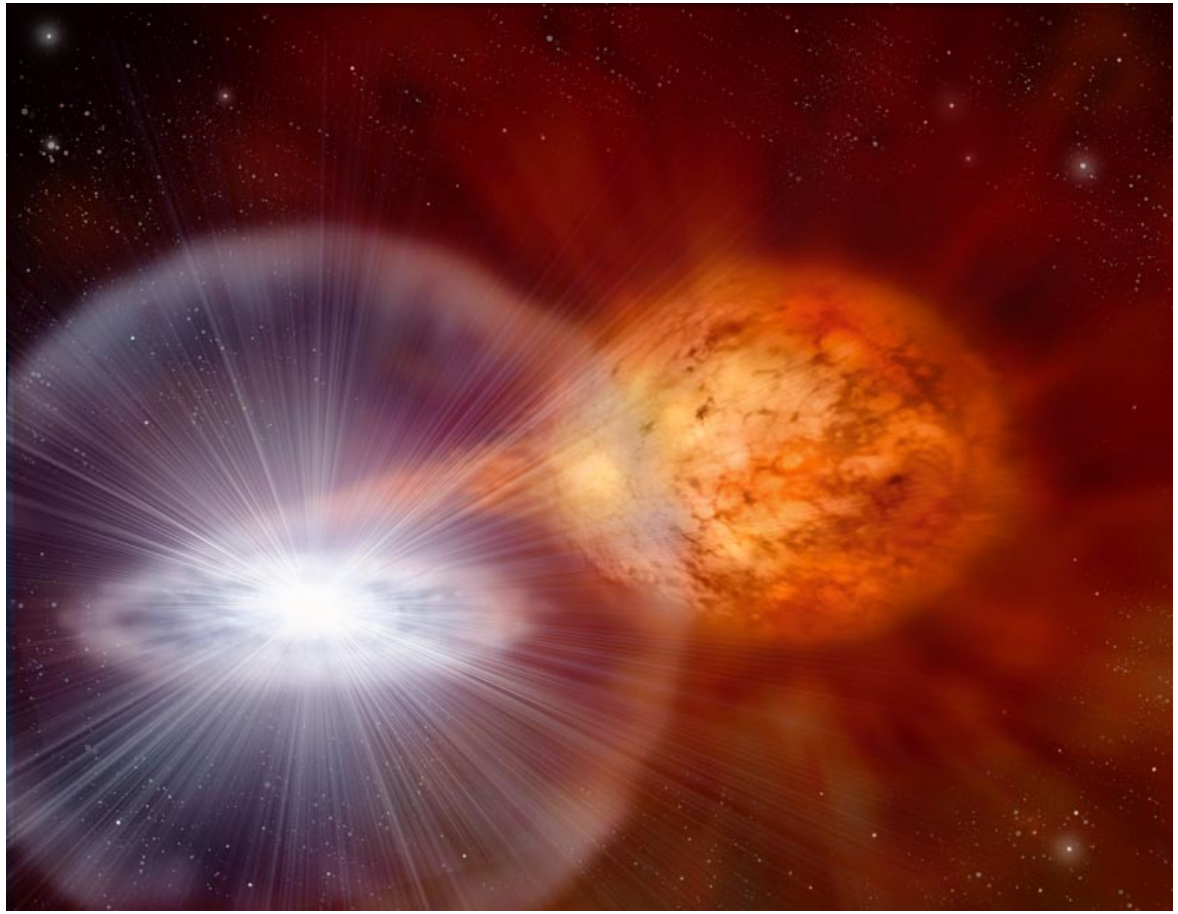
Outline

- RS Ophiuchi
- Large-Sized Telescope prototype LST-1
- LST-1 observation mode and data analysis
- RS Ophiuchi observations with LST-1
- Results
- Conclusions

RS Ophiuchi

- Symbiotic binary
  - White dwarf and red giant
- Recurrent nova outbursts
  - Thermonuclear runaway
  - Outburst every ~15 years
  - August 2021: First detection of a nova at VHEs (H.E.S.S. Collaboration 2022, Acciari et al. 2022).
- First detection of a nova at HE in 2010 (Fermi-LAT Collaboration 2010).



Credit: David A.Hardy/ www.astroart.org & PPARC.

Large-Sized Telescope prototype LST-1

- Cherenkov Telescope Array Observatory (CTAO)
  - Future observatory at VHEs
    - Northern hemisphere: La Palma
    - Southern hemisphere: Paranal
  - Three telescope types

Figure from: https://www.cta-observatory.org/.

Large-Sized Telescope prototype LST-1

- Cherenkov Telescope Array Observatory (CTAO)
  - Future observatory at VHEs
    - Northern hemisphere: La Palma
    - Southern hemisphere: Paranal
  - Three telescope types
- LST-1: Large-Sized Telescope prototype
  - Currently under commissioning phase
  - Good sensitivity at tens to hundreds of GeVs
  - Fast re-positioning speed to follow-up transient sources

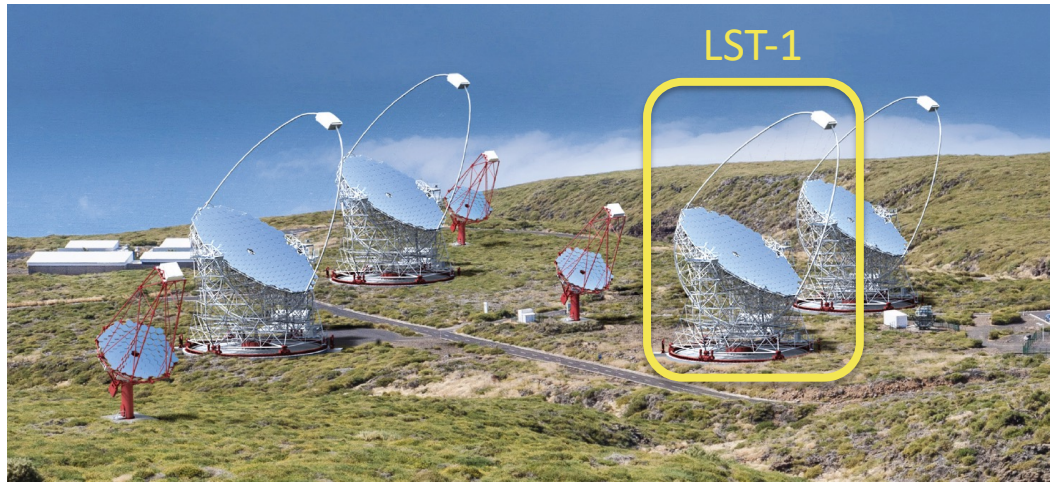


Figure from: https://www.cta-observatory.org/.

Friday 8th: Status of LST Project by J. Cortina

LST-1 observation mode and data analysis

- Observation mode
  - Mono-trigger analysis
    - Single telescope observation mode
  - Wobble mode: offset angle between nominal source position and telescope pointing position.

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  - Source-dependent analysis
    - Prior knowledge of the source position
    - RS Ophiuchi observations: LST-1 energy threshold down to ~45 GeV

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- Analysis method
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    - Prior knowledge of the source position
    - RS Ophiuchi observations: LST-1 energy threshold down to ~45 GeV
  - Analysis using MC simulations at a fixed sky position
    - A dedicated analysis with refined MC simulations is ongoing

RS Ophiuchi observations with LST-1

- Exclude runs with low transmission

Date (yyyy/mm/dd)	T-T0 (days)	Zenith angle (deg)	Atmospheric transmission 9km* (%)	Observation time after cuts (h)
2021-08-09	0.97	36-41	> 90	1.43
2021-08-10	1.97	36-56	> 90	2.69
2021-08-12	3.97	36-48	> 90	2.27
2021-08-13	4.99	37-51	15 - 90	
2021-08-14	5.97	37-51	65	
2021-08-15	7.03	41-54	55	
2021-08-29	21.01	36-41	> 80	0.97
2021-08-30	21.97	36-41	> 80	1.52
2021-09-01	24.05	61-64	> 90	0.32
2021-09-02	24.98	61-64	> 90	1.28

Right after outburst

Bad atmospheric transmission

After moon break

T0 = 59434.93 MJD

* MAGIC LIDAR measurements

RS Ophiuchi observations with LST-1

- Exclude runs with low transmission
- Analysis using only observations right after the outburst

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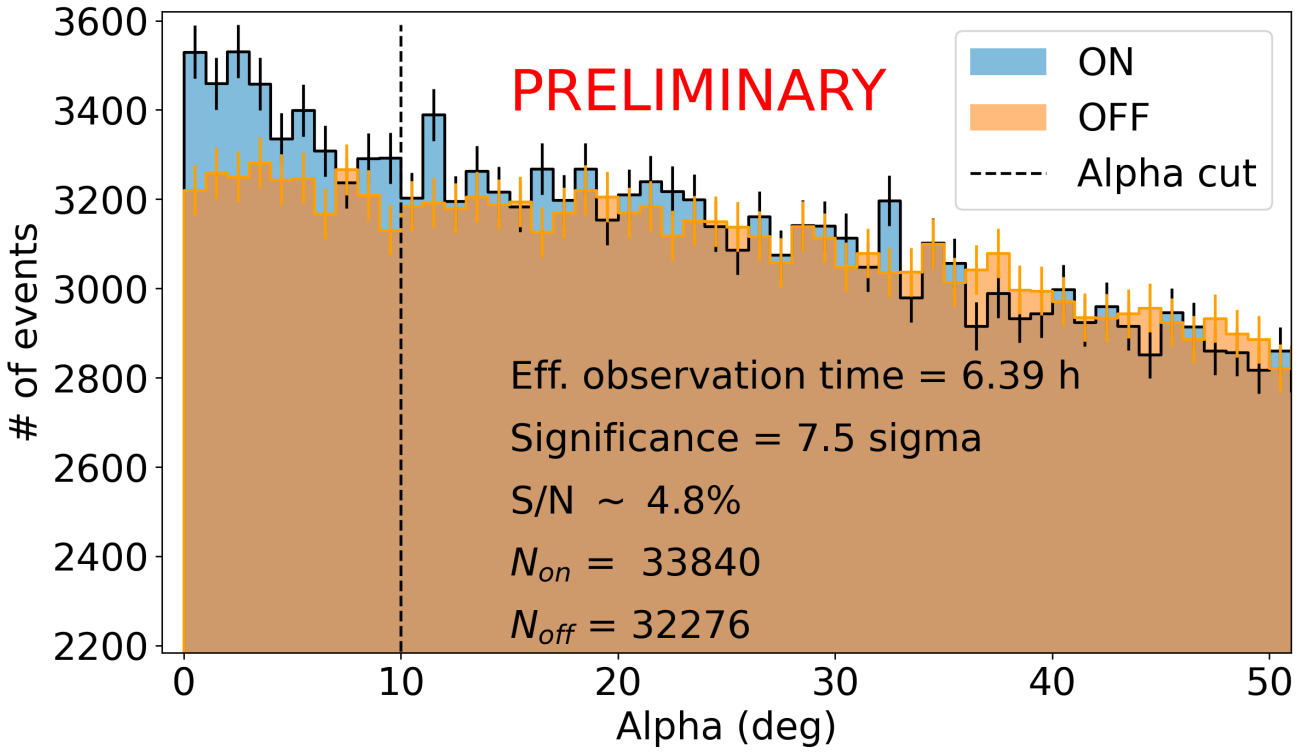
Results: Alpha plot

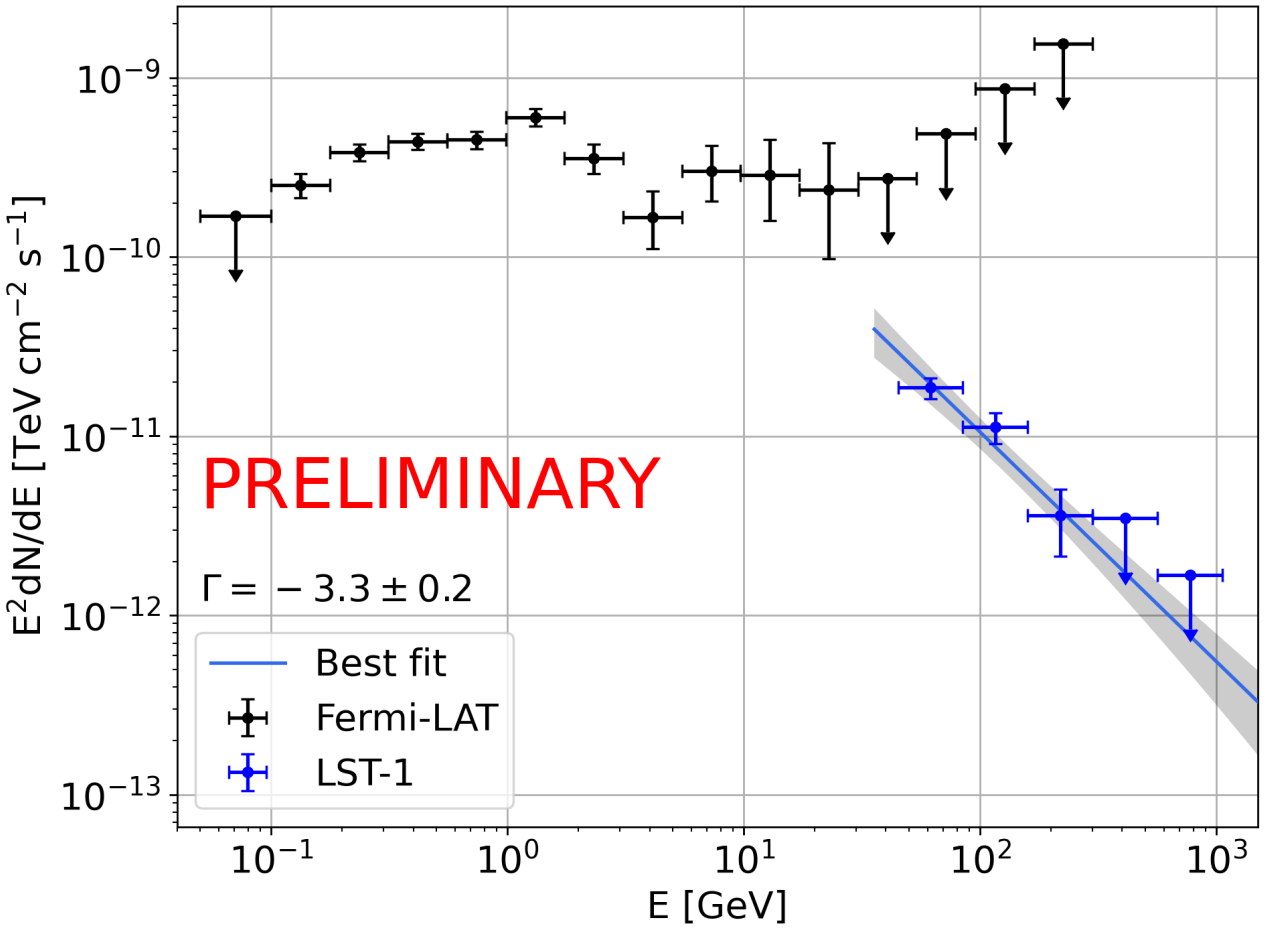
- Detection right after the outburst (Aug. 9, 10 and 12)
  - Alpha plot: angle distribution between event's major axis and:
    - Nominal source position (ON)
    - Reflected background positions (OFF)
  - Li & Ma significance*
    - 7.5
  - Signal-to-noise ratio
    - 4.8 %



* Equation 17, Li & Ma 1983

Results: Spectral Energy Distribution (SED)

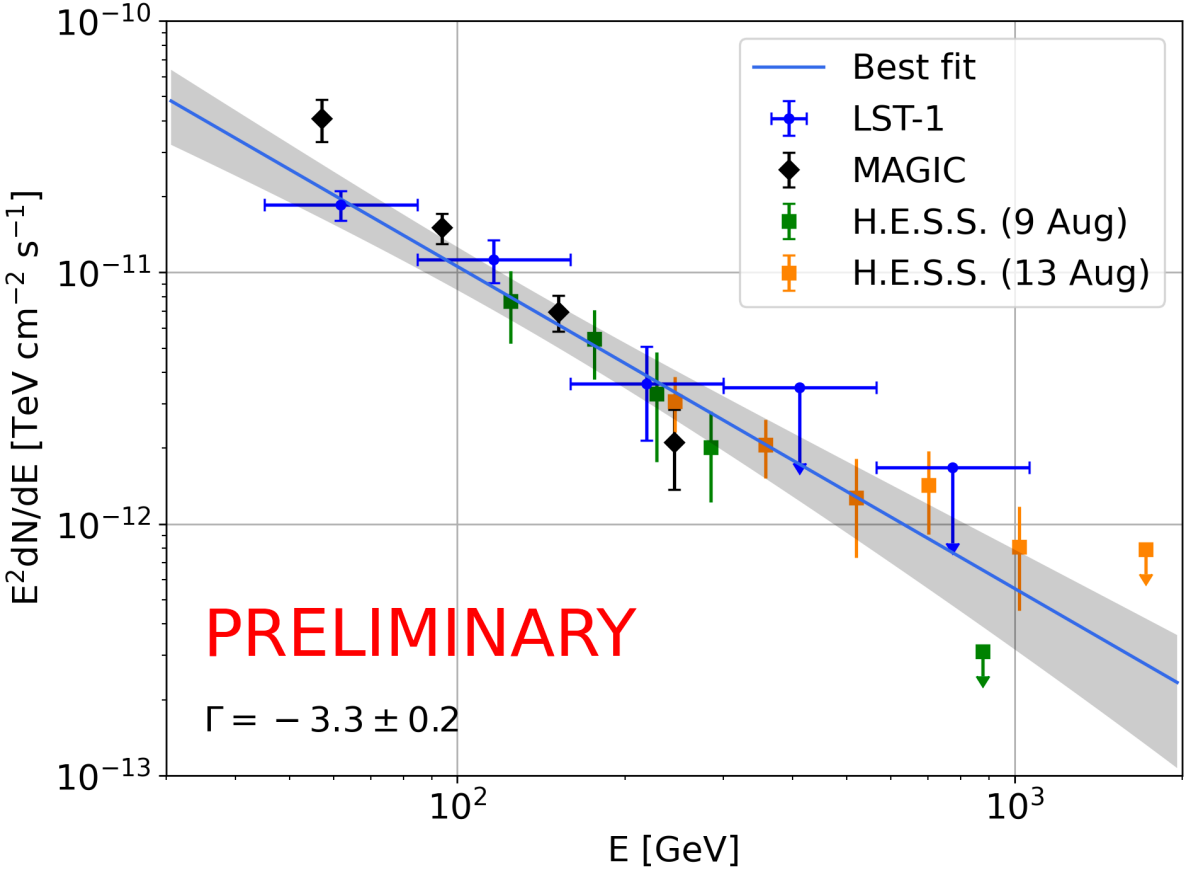
- LST-1 & Fermi-LAT: 4-days average RS Ophiuchi SED



- Best LST-1 fit model and flux points (blue)
  - Observations from Aug. 9, 10 and 12
- Fermi-LAT dedicated analysis (black)
  - Average over LST-1 observation dates (Aug. 9-12)
- Smooth transition

Results: Spectral Energy Distribution (SED)

- LST-1, MAGIC and H.E.S.S. SEDs



- LST-1, average analysis* (Aug. 9, 10 and 12)
- MAGIC, 4-days joint analysis (Aug. 9-12)
- H.E.S.S. August 9th & 13th SEDs

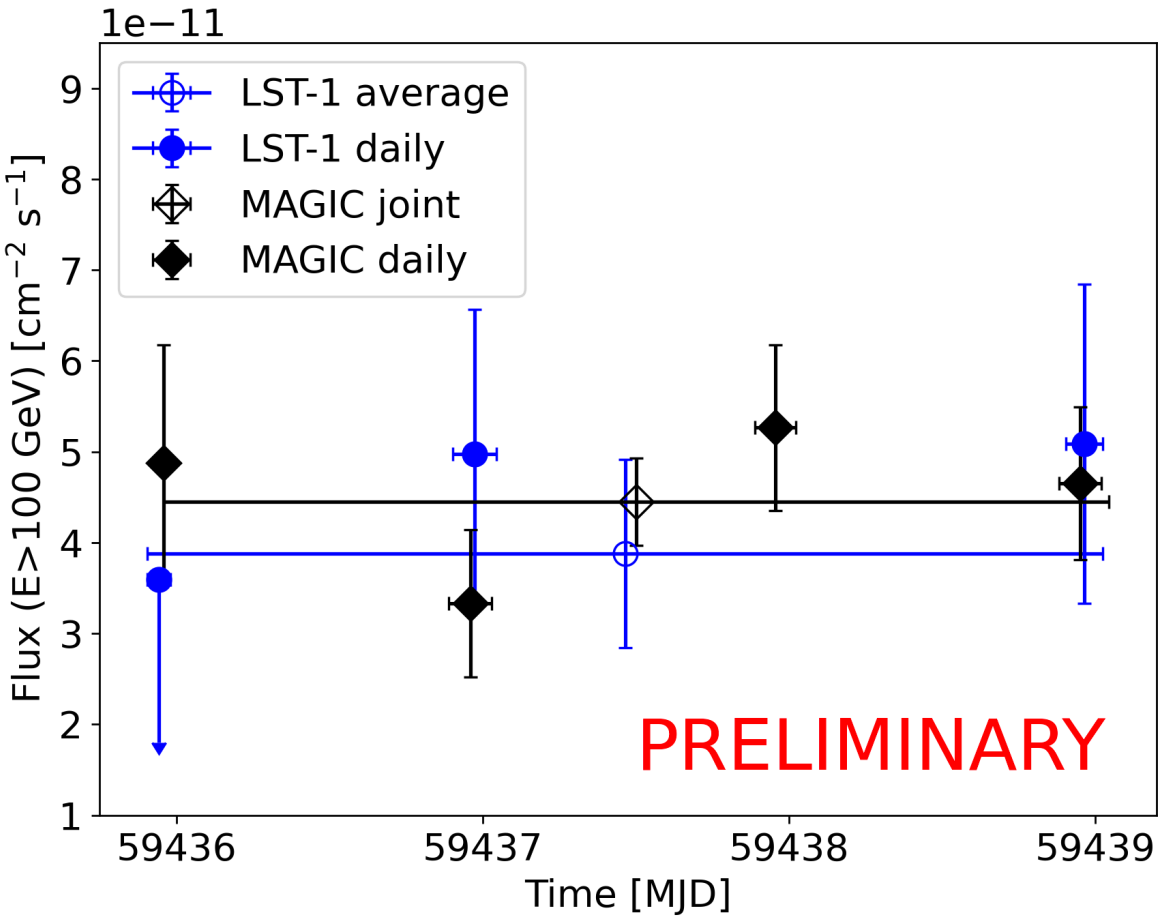
- Compatible SEDs

MAGIC flux points (black) from Acciari et al. 2022.
H.E.S.S. flux points from H.E.S.S. Collaboration 2022.

* Stack all observations into a single binned array

Results: Light curve

- LST-1 and MAGIC light curves
  - Daily and average fluxes for August 9, 10 and 12
  - Compatible average fluxes
  - Compatible daily fluxes
  - Light curve compatible with a constant flux for the first days



MAGIC light curve from Acciari et al. 2022.

Conclusions

- Clear detection of RS Ophiuchi by LST-1

  6.4 h observations in the first 5 days after the outburst. Detection significance of ~ 7.5 sigma.

- LST-1 allows us to study RS Ophiuchi down to ~45 GeV

  LST-1 data smoothly connects with Fermi-LAT data. Physical interpretation is ongoing.

- Preliminary results compatible with MAGIC/H.E.S.S. results

- LST-1 has exceptional capabilities for transient source studies below 100 GeV

  High effective area < 100 GeV makes LST-1 perfect for transient sources.

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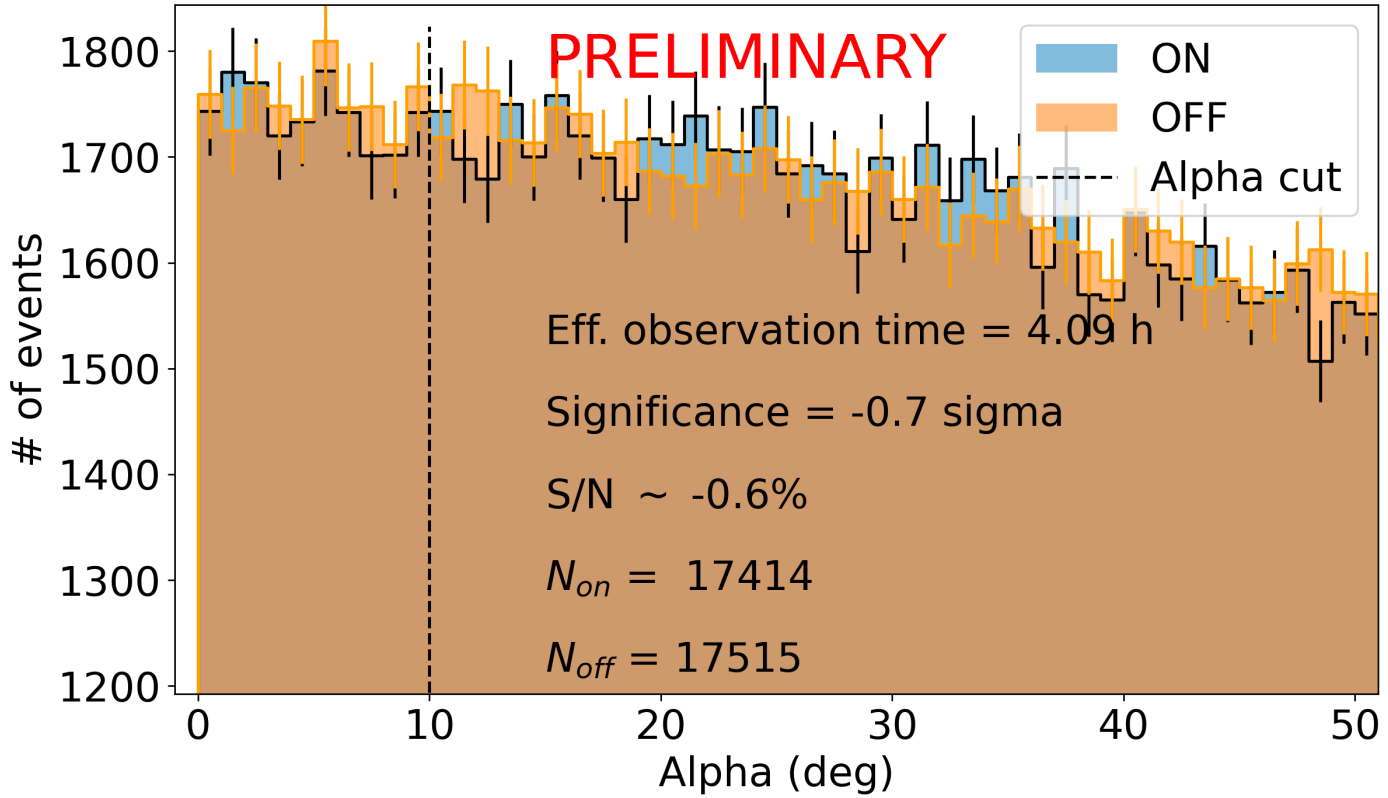
Backup

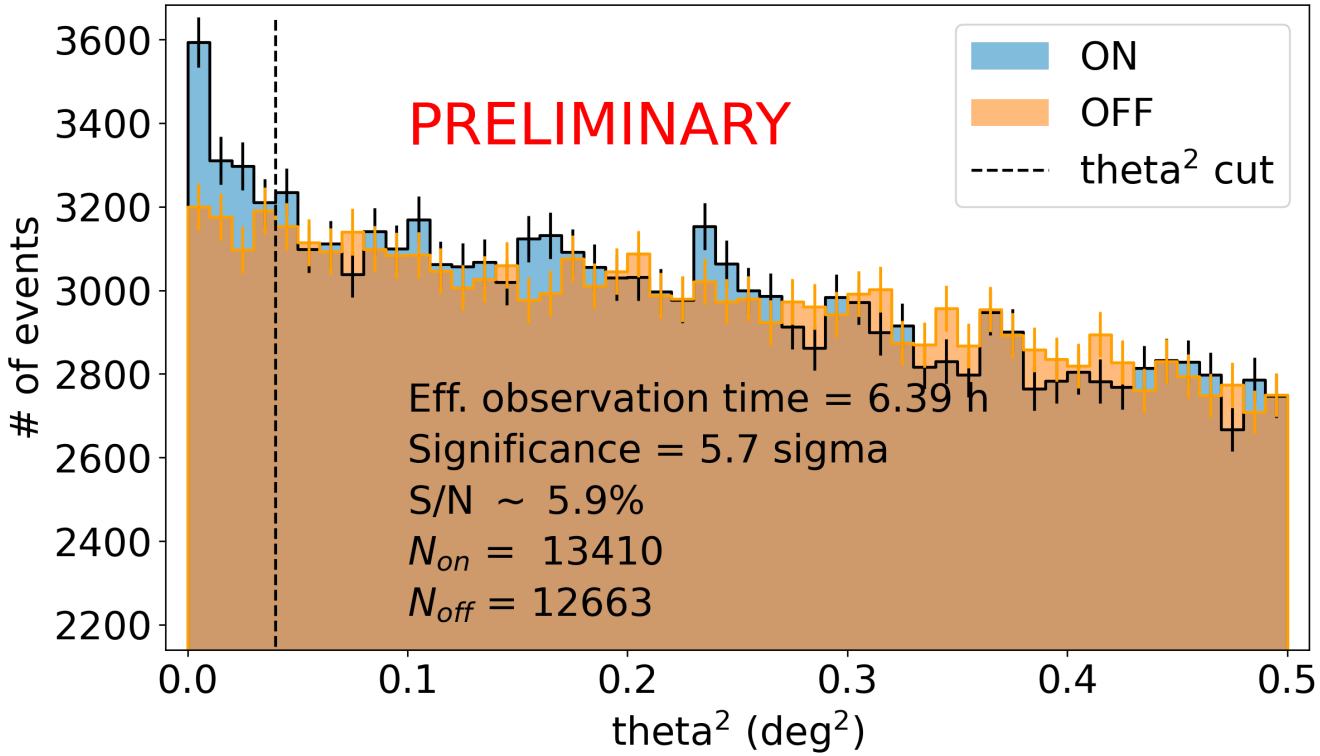
Backup: source-dependent

- No detection after moon break ($T-T_0 > 21$ days)



Backup: source-independent

- Detection right after the outburst (first 4 days)
  - Theta^2 plot: squared angular distance distribution between event's direction and
    - Nominal source position (ON)
    - Reflected background positions (OFF)
  - Li & Ma significance*
    - 5.7
  - Signal-to-noise ratio
    - 5.9 %



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