

VERITAS follow-up of newly identified LHAASO sources

Samantha Wong, on behalf of the VERITAS Collaboration | TeVPA 2024 | samantha.wong2@mail.mcgill.ca





Outline

- I. VERITAS archival data overview
- II. Analysis strategy
- III. Analysis results: 1LHAASO J1902+0648
- IV. Next steps



VERITAS is an array of four 12m IACTs located near Tucson, AZ (USA) that has been taking data since 2007

VERITAS has an overlapping energy range with LHAASO, but can resolve smaller angular scales and finer energy bins



Instrument	Instantaneous FoV	Angular resolution (deg)	Energy range (TeV)	Effective area (m ²)
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LHAASO WCDA²	~ 2 sr	0.45 @ 1 TeV 0.21 @ 12 TeV	1 - 25	3200 @ 4.5 TeV
LHAASO KM2A³	~ 2 sr	0.5 @ 20 TeV 0.2 @ 100 TeV	> 25	~10 ⁵ @ 100 TeV

[1] <https://veritas.sao.arizona.edu/about-veritas/veritas-specifications>

[2] Performance of LHAASO-WCDA and Observation of Crab Nebula as a Standard Candle (LHAASO, 2021)

[3] Optimization of performance of the KM2A full array using the Crab Nebula (LHAASO, 2024)



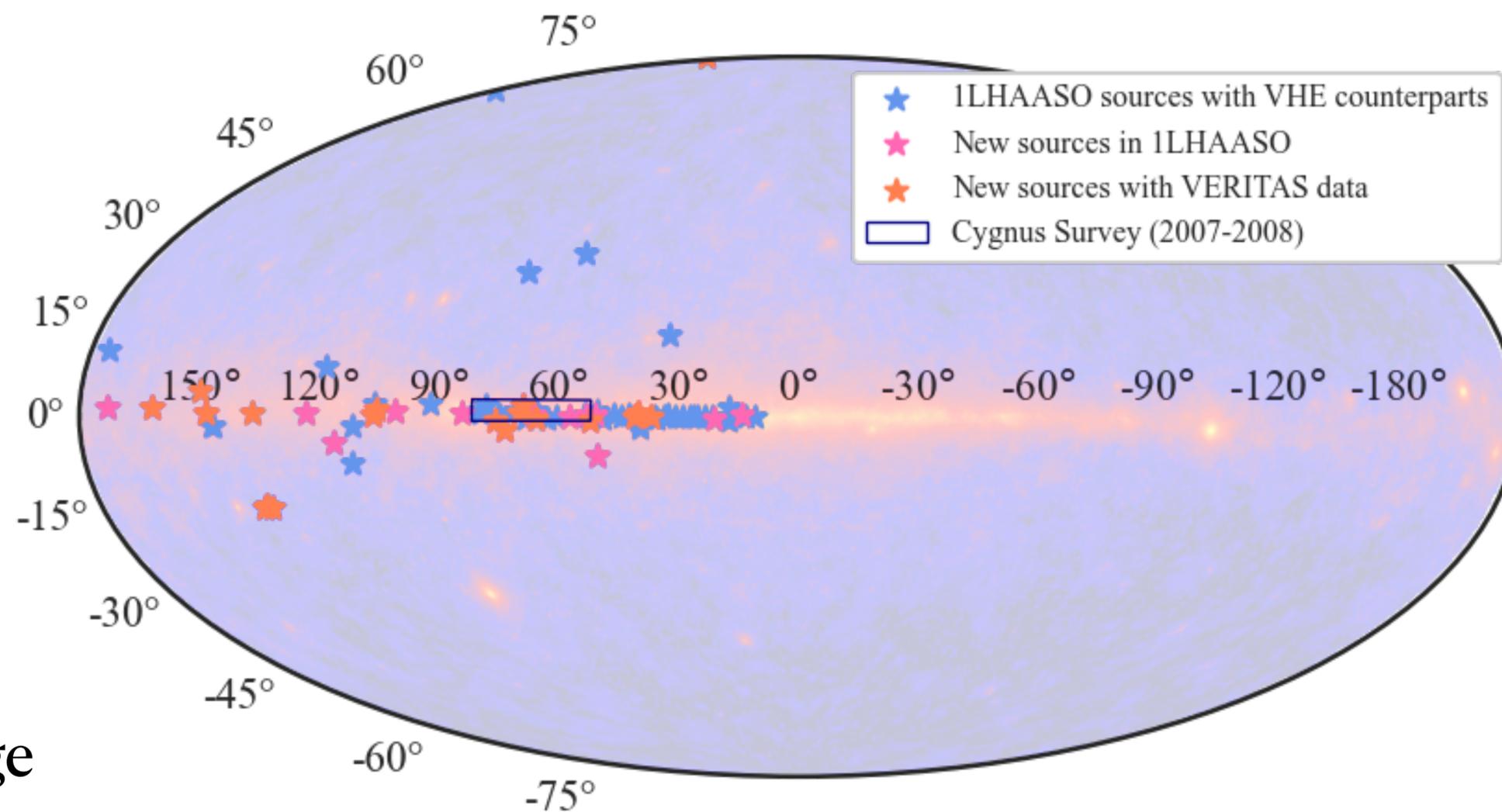
1LHAASO follow up with VERITAS

The first LHAASO catalog has revealed **32 new VHE/UHE sources** in the Northern sky

→ 16 of these sources have (tentative) pulsar or PWN/SNR associations

19 of these new sources overlap with archival VERITAS data!

→ However, the location and large extensions of some sources can make a traditional analysis difficult





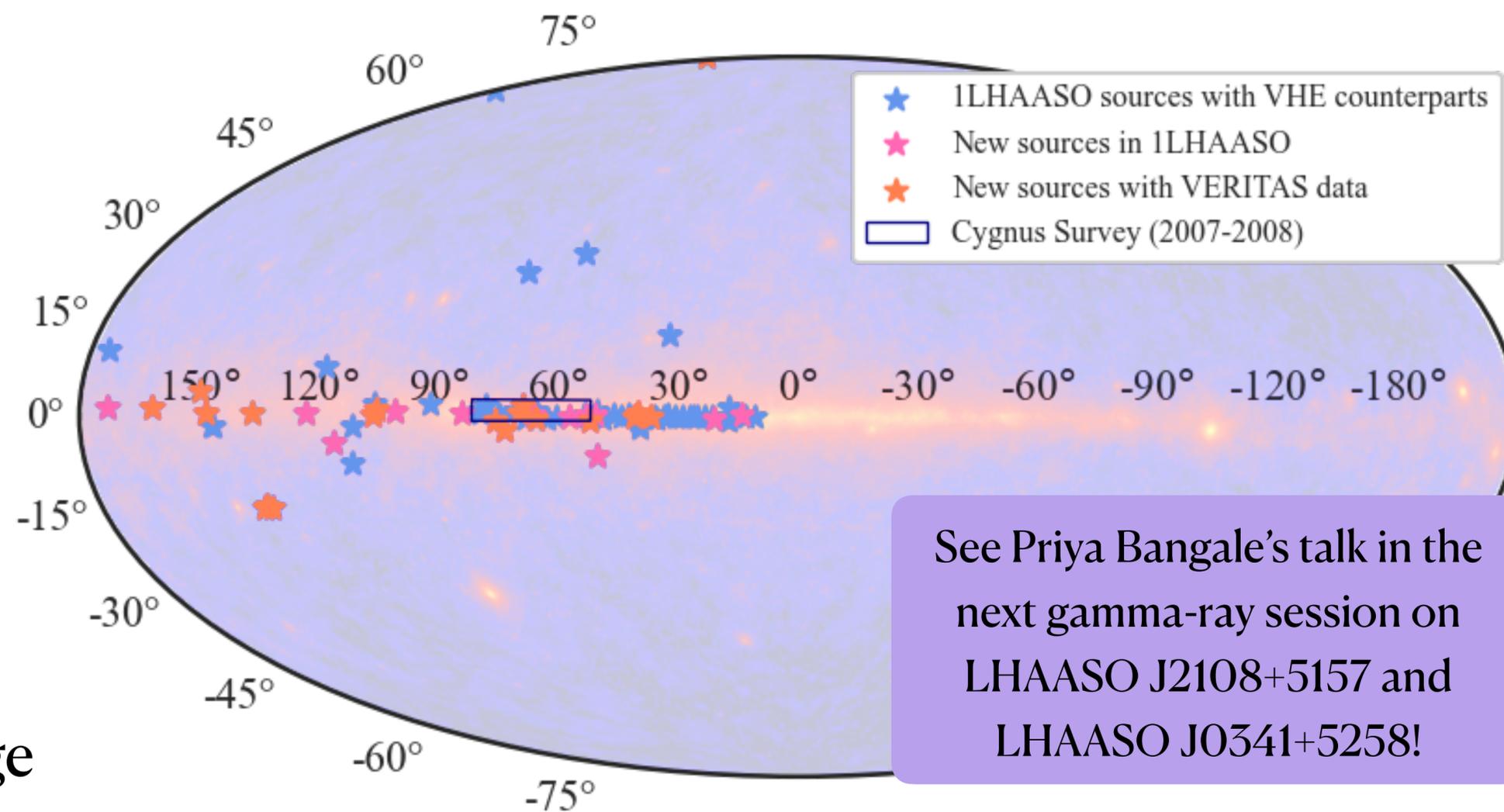
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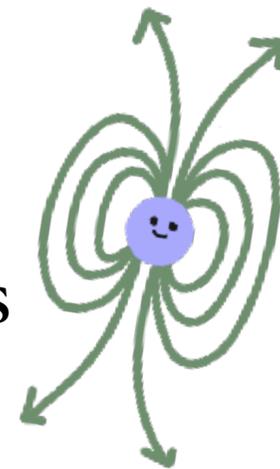
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Source types

13 SNR/Pulsar likely or tentative associations

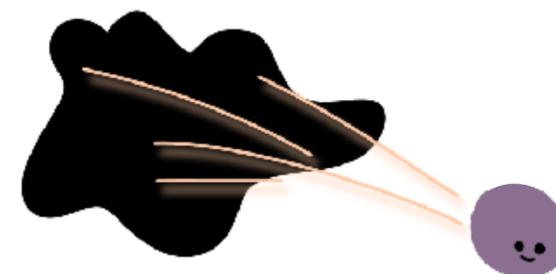


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KM2A-only detected sources (PeVatron candidates)

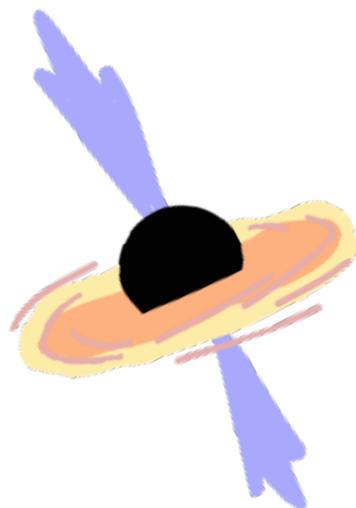
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Dark sources (no multiwavelength or only 4FGL unidentified) counterparts



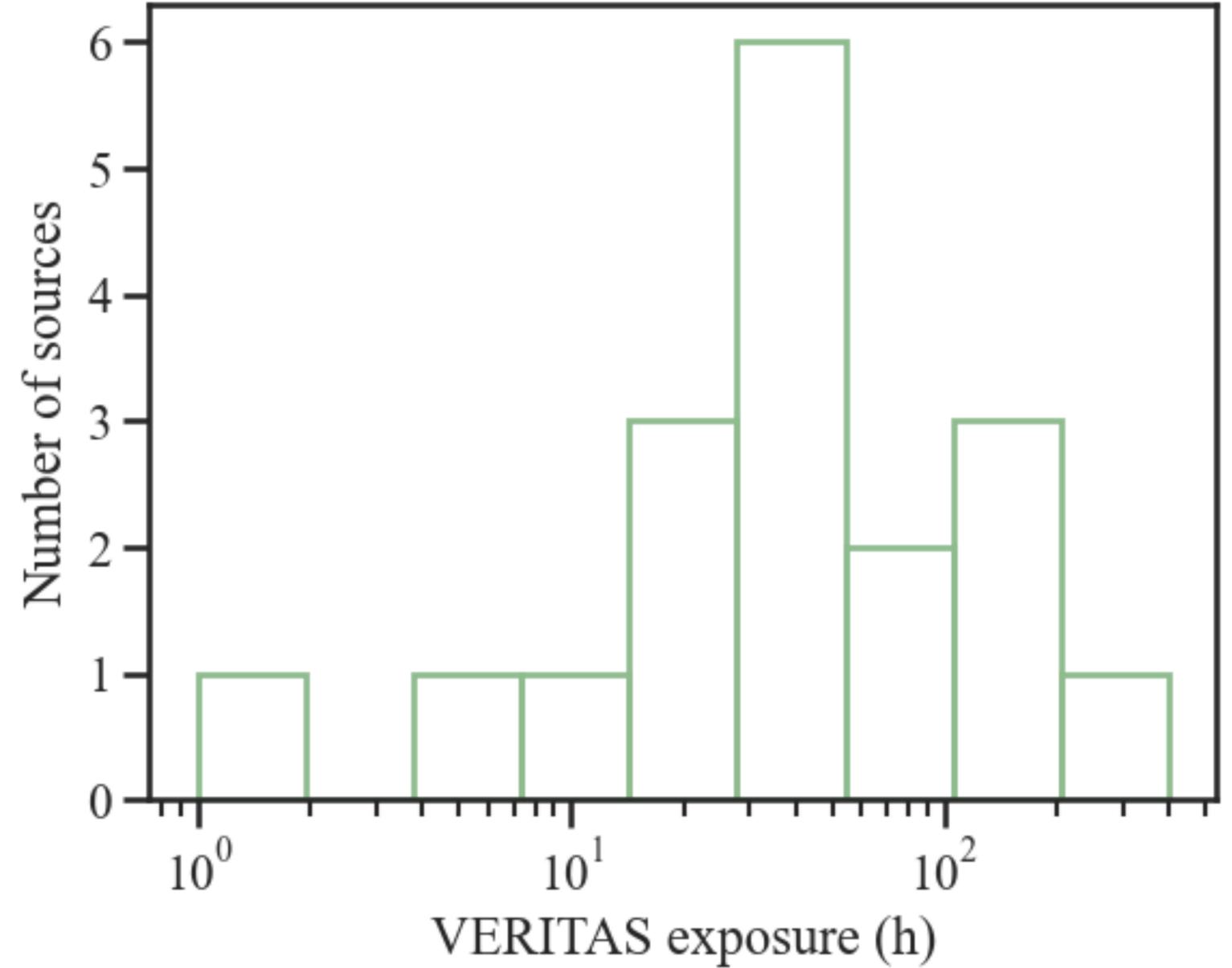
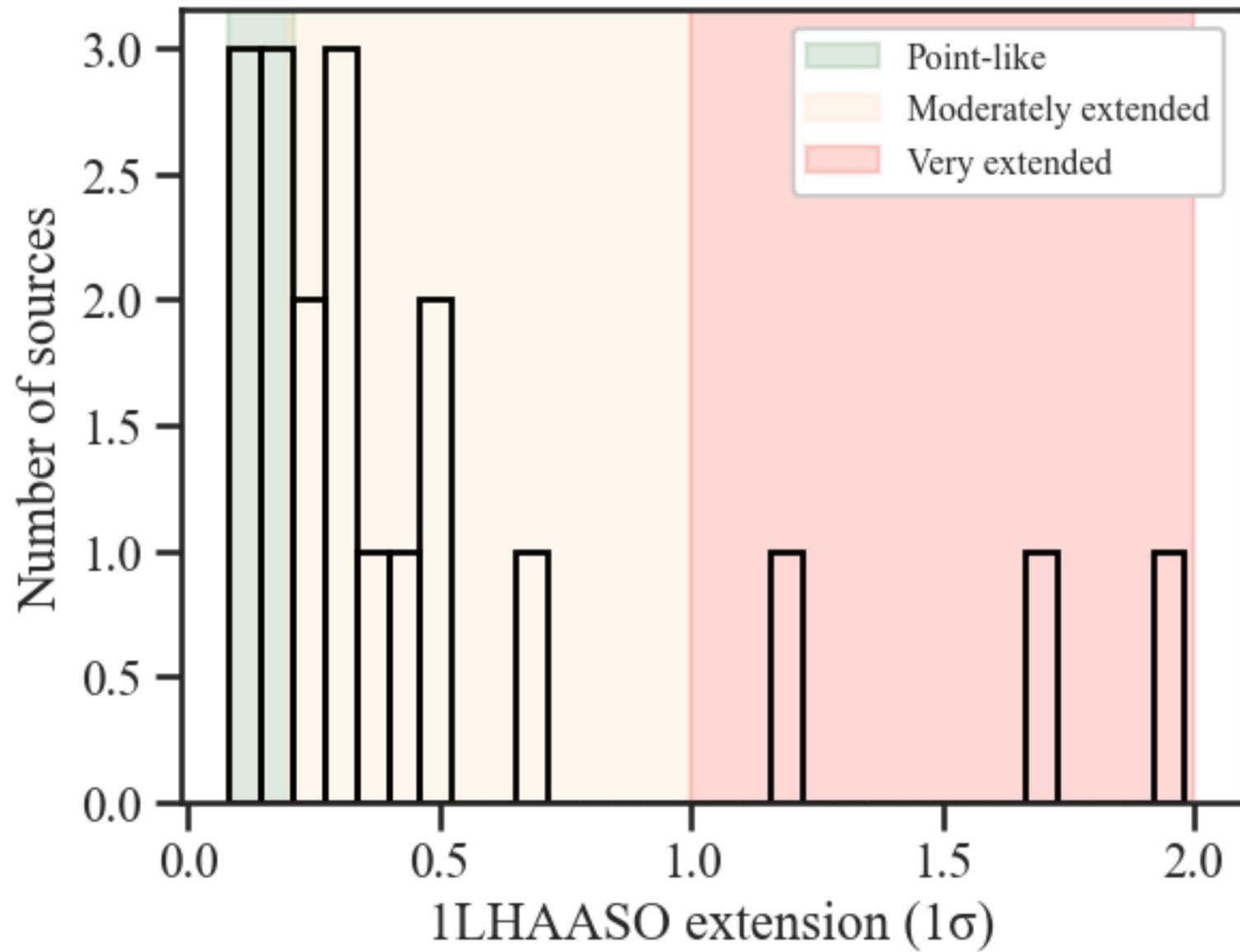
1

Extragalactic (likely AGN) source





Source extensions & VERITAS exposures





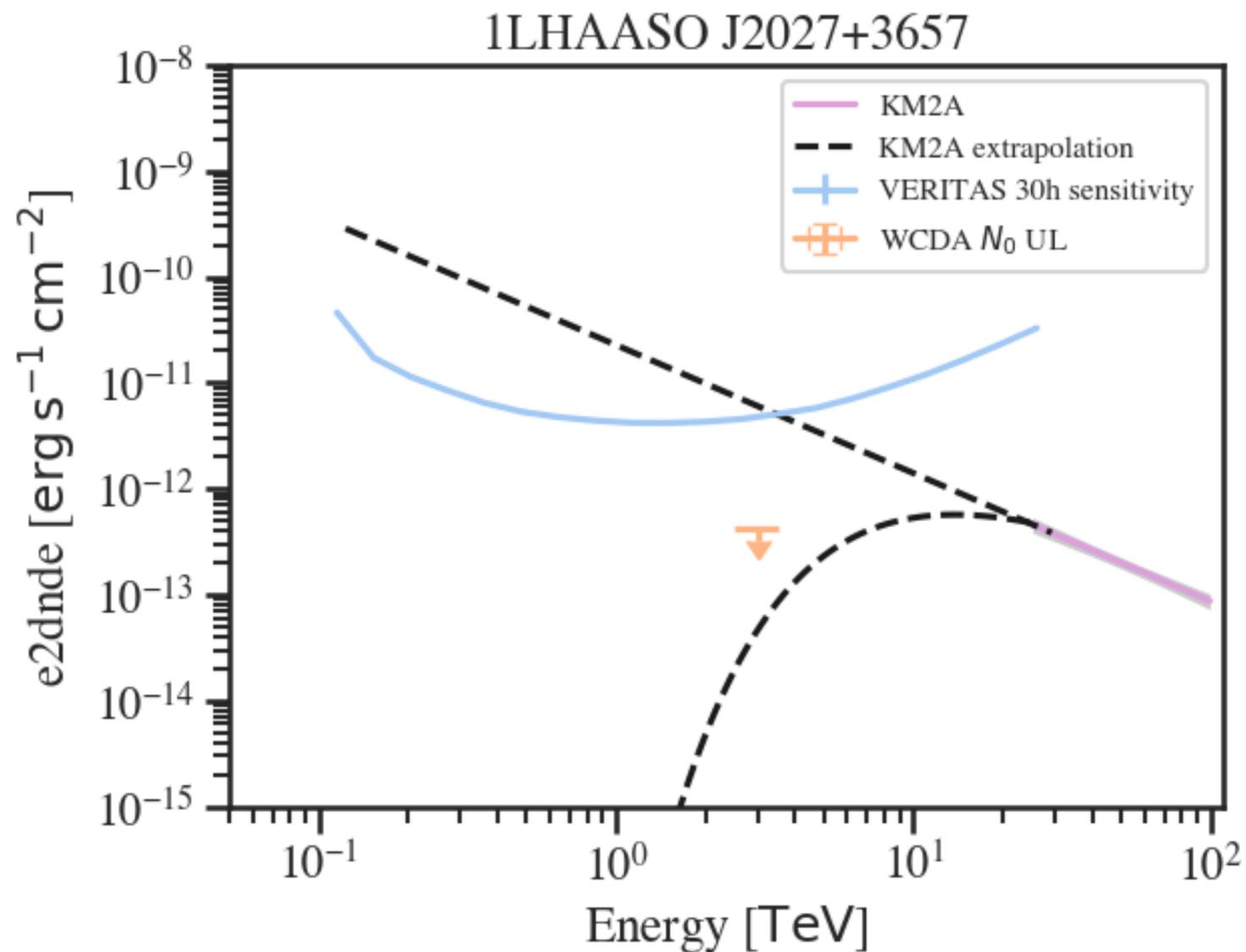
Analysis plan: point-like & moderately extended

Cut selection

Region selection

Significance analysis

Spectral analysis



Cut selection: choosing which **gamma/hadron separation cuts** to use — depends on the source spectral index

→ Tighter parameter cuts typically yield a higher energy threshold

1LHAASO power law spectral extrapolations can lead to unrealistic fluxes in the VERITAS sensitivity range

→ Particularly true for KM2A-only detected sources



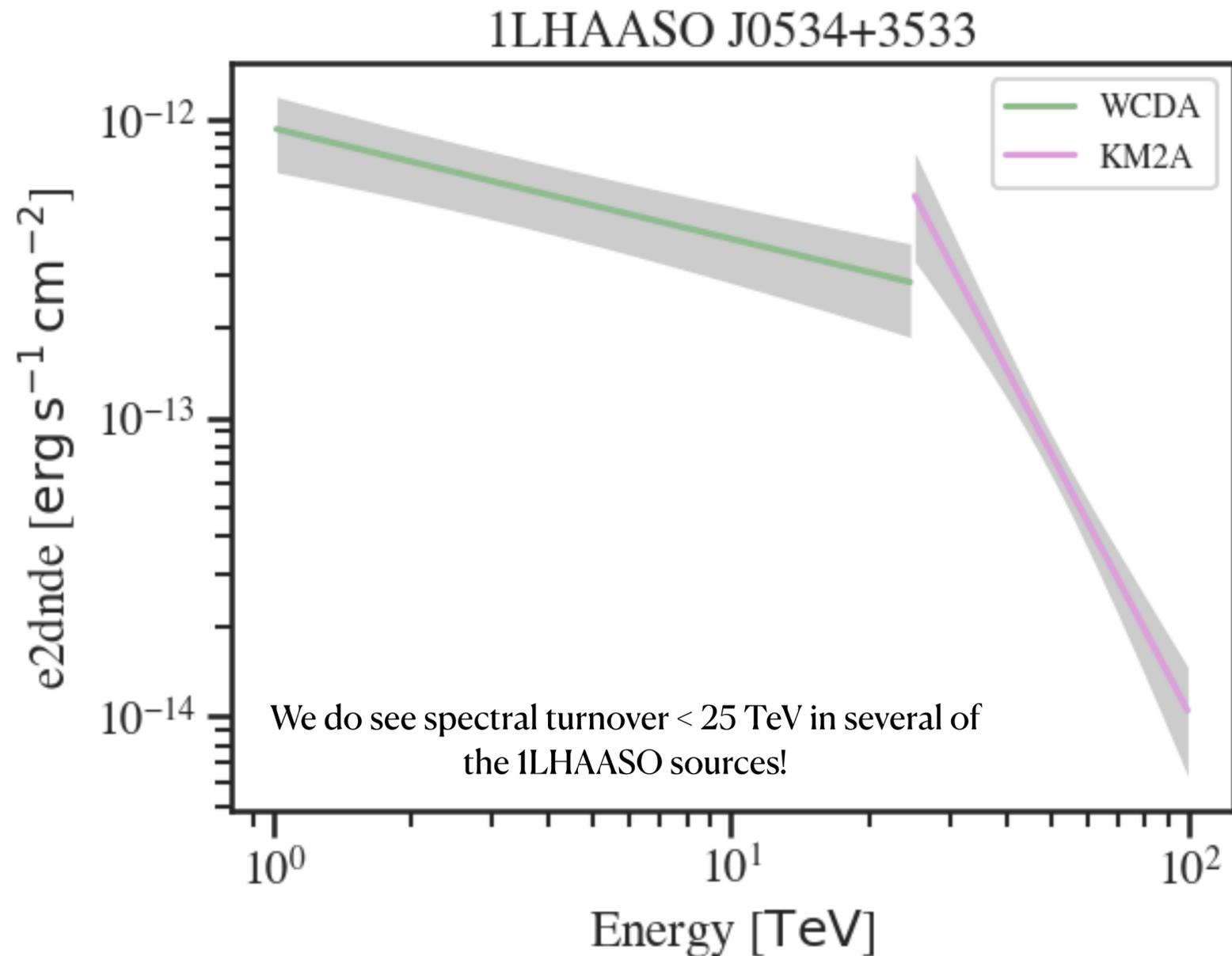
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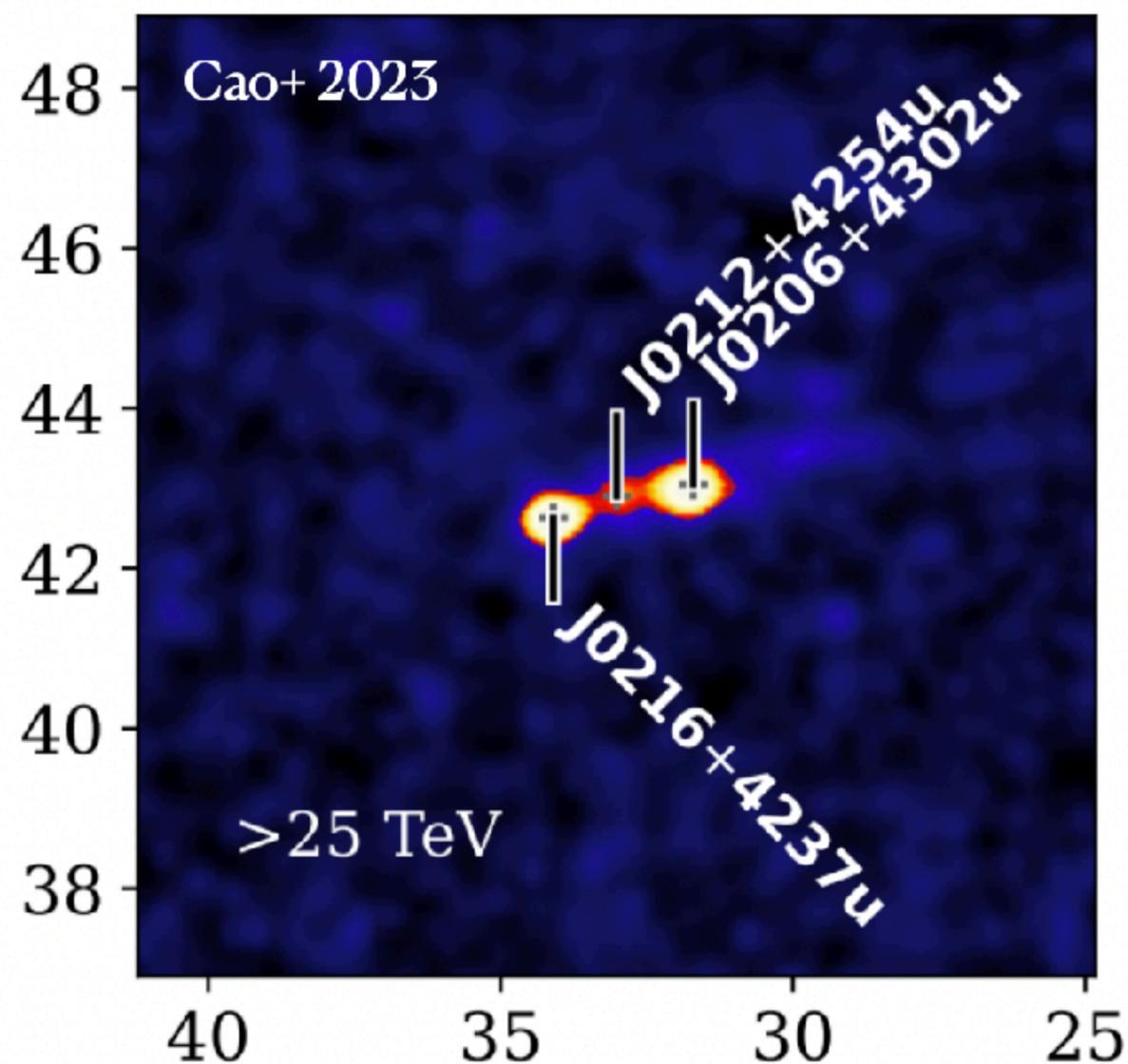
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Sources listed as point sources in 1LHAASO will first be analyzed using a **point source analysis using the VERITAS PSF** and subsequently re-analyzed with an integration radius of $1.58 * r_{39}$ (WCDA if available)

Moderately extended sources are analyzed with an integration radius of $1.58 * r_{39}$

All analyses of sources < 1 deg will use the **ring background method** to estimate background counts

→ We generally want a ring area to integration area ratio of 20 (point-like) or 3 (extended)

→ Nearby sources & bright stars are excluded ⇒ ring size adjusted iteratively



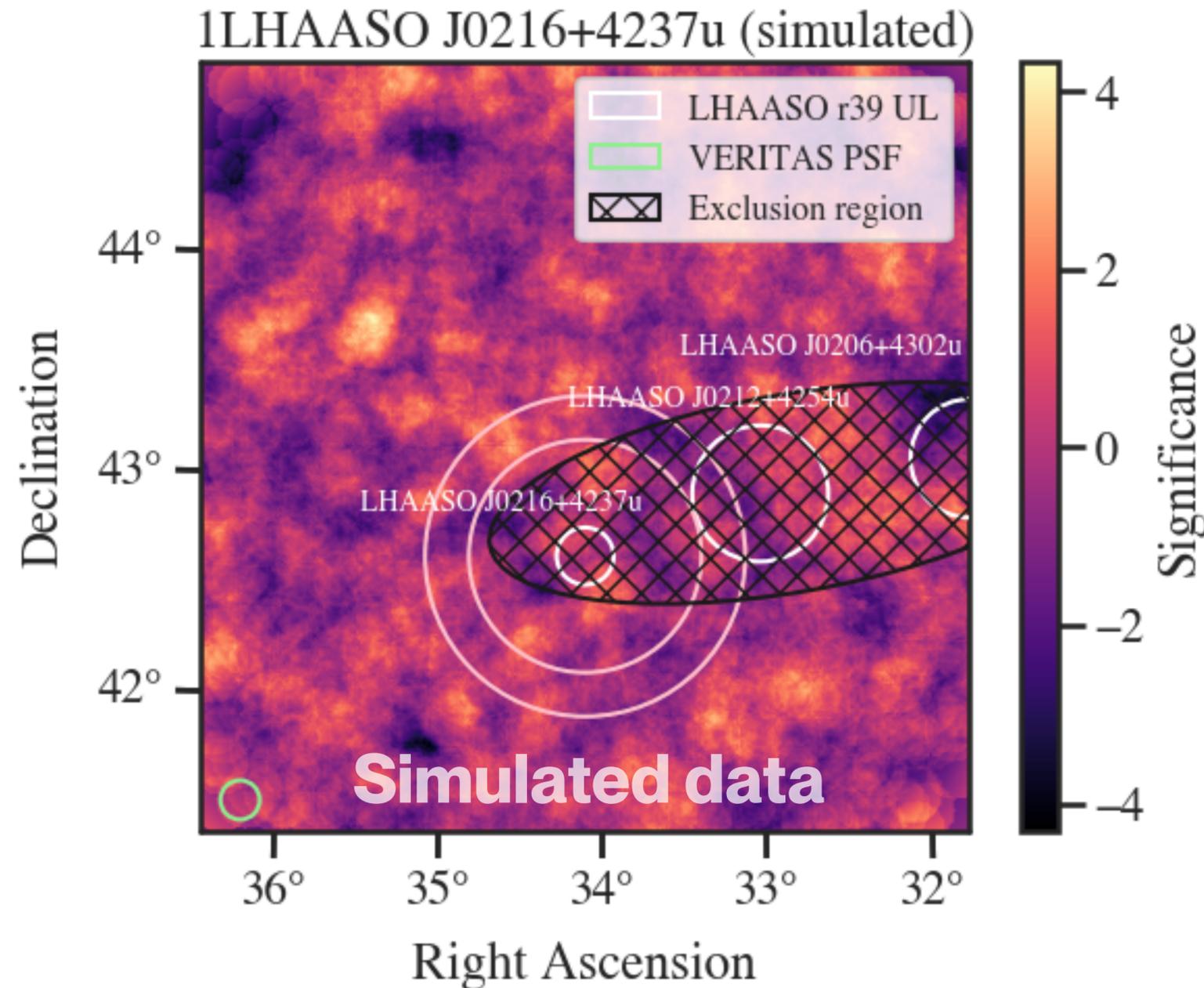
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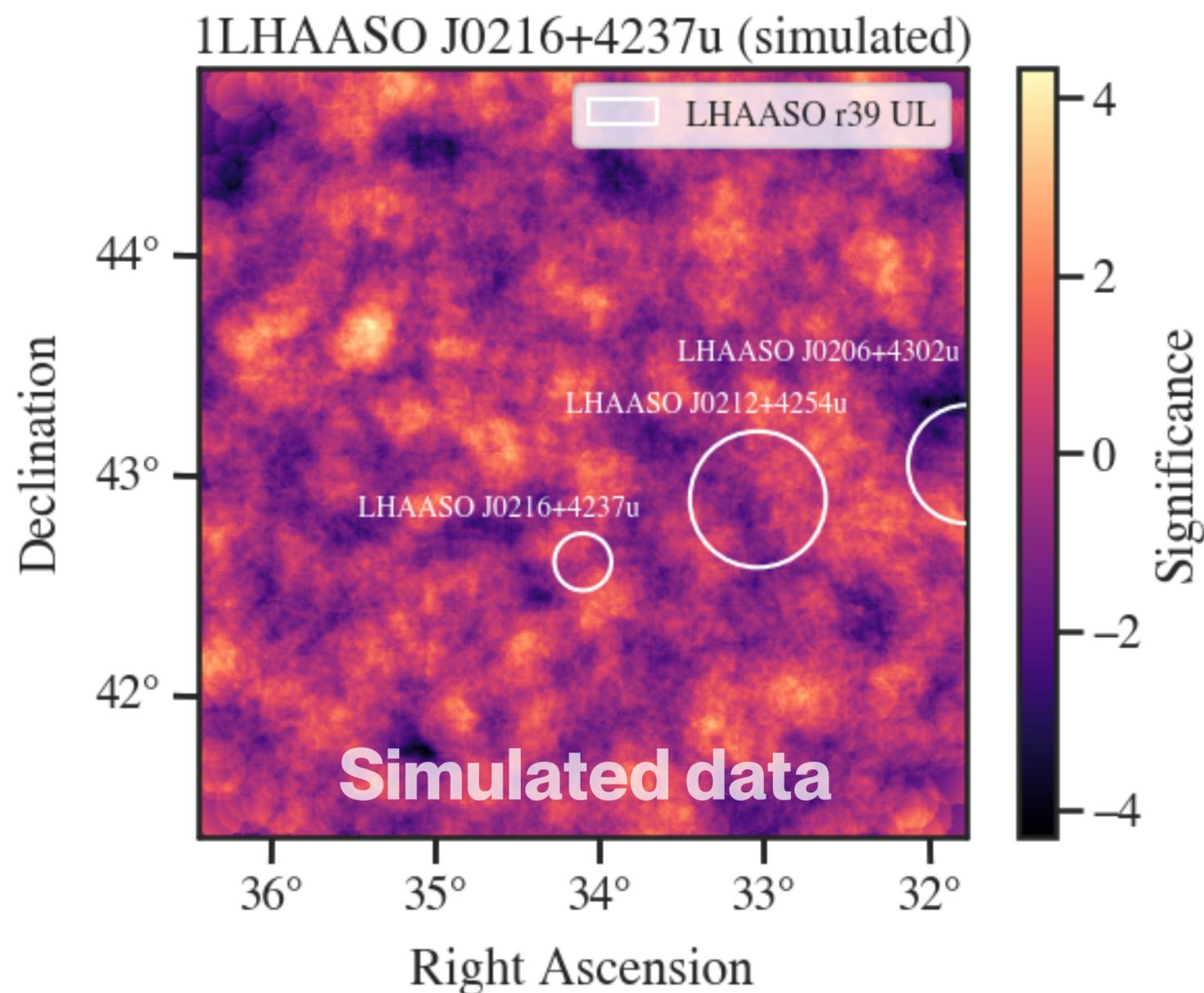
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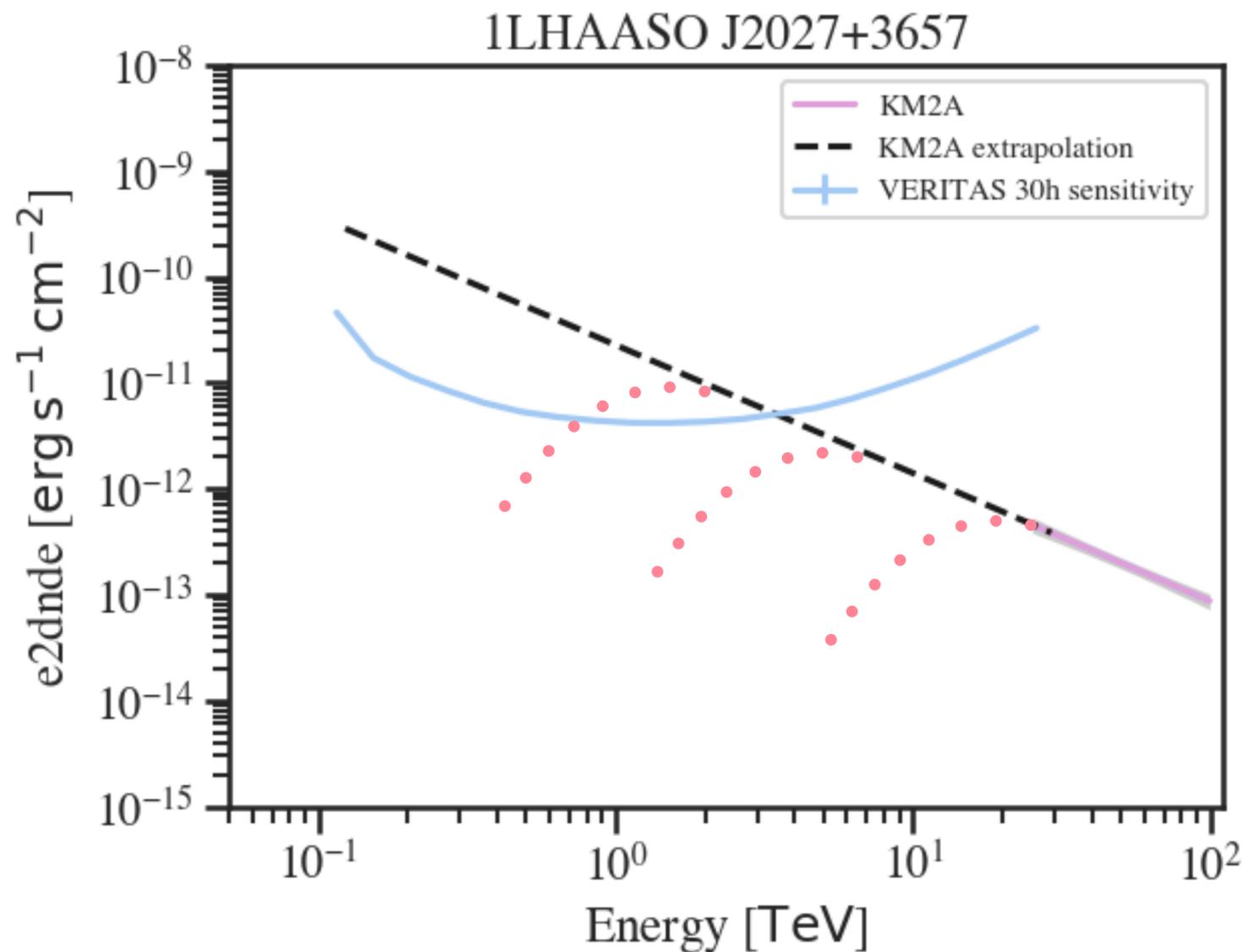
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Spectral analysis tools are currently **under development** for extended sources

Even non-detections may be able to constrain any **spectral turnover (or cutoff)** in WCDA detected sources and may be able to provide **detections at < 25 TeV** for sources slightly too dim for WCDA



Preliminary results: 1LHAASO J1902+0648

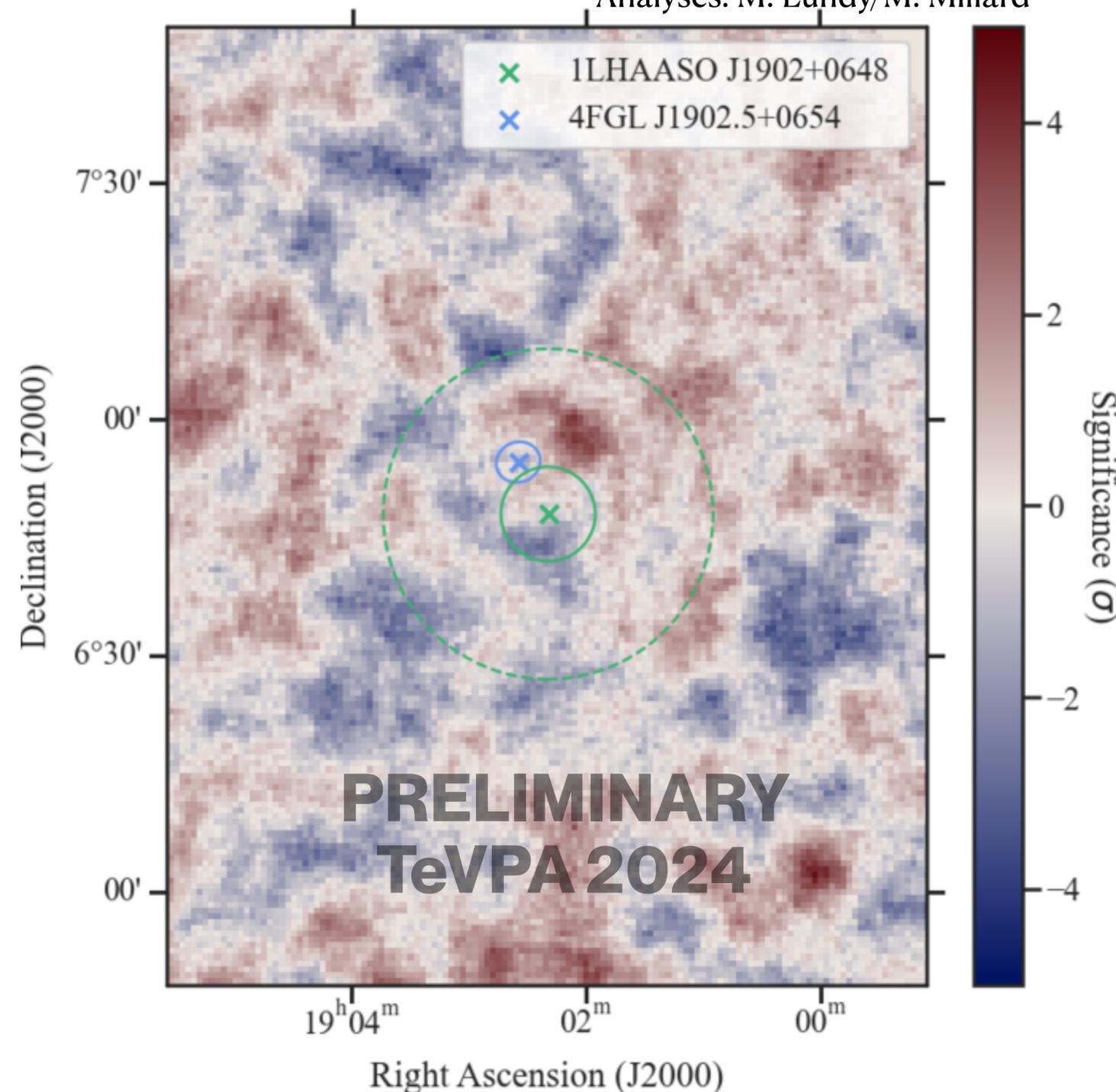
Point-like source ($r_{39} < 0.15$ deg) only detected by WCDA \Rightarrow not a PeVatron candidate

No known multiwavelength counterparts besides potential association with unidentified *Fermi*-LAT source 4FGL J1902.5+0654

42 hours of archival VERITAS data overlap with the source region

VERITAS **non-detection** at the LHAASO source position with a significance of **-0.5 sigma**

Analyses: M. Lundy/M. Millard



Summary & conclusions

VERITAS has over **400 hours** of spatially coincident data with 1LHAASO sources

→ The **finer angular and spectral resolution**, as well as the **lower energy threshold** of IACTs will help understand the nature and possible associations of newly discovered sources

We're currently analyzing all **point-like sources**, while we finalize analysis pipelines for moderately extended sources

A preliminary VERITAS follow-up paper of 16 sources with which we have archival data is in progress.

→ Analysis team: A. Chromey, N. Korzoun, M. Lundy, M. Millard, N. Ning, S. O'Brien, L. Riitano, and SW

After 2028, **CTAO** will build off of the work of current IACTs to follow up these sources with an extended energy range and higher sensitivity



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CTAO (North)⁴	4 deg (LST), 7 deg (MST), 8 deg (SST)	0.06 @ 1 TeV	0.02 - 300	~ 5 x 10 ⁵ @ 10 TeV

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[4] <https://www.ctao.org/for-scientists/performance/>

Thank you!

Questions?