VERITAS Observations of New LHAASO Sources

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on behalf of the VERITAS Collaboration
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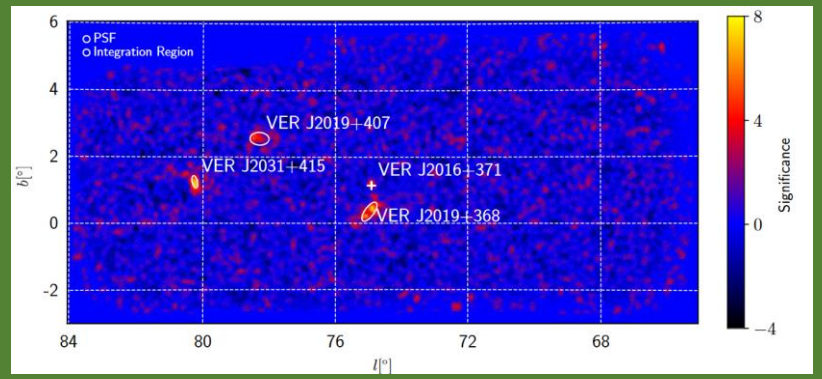
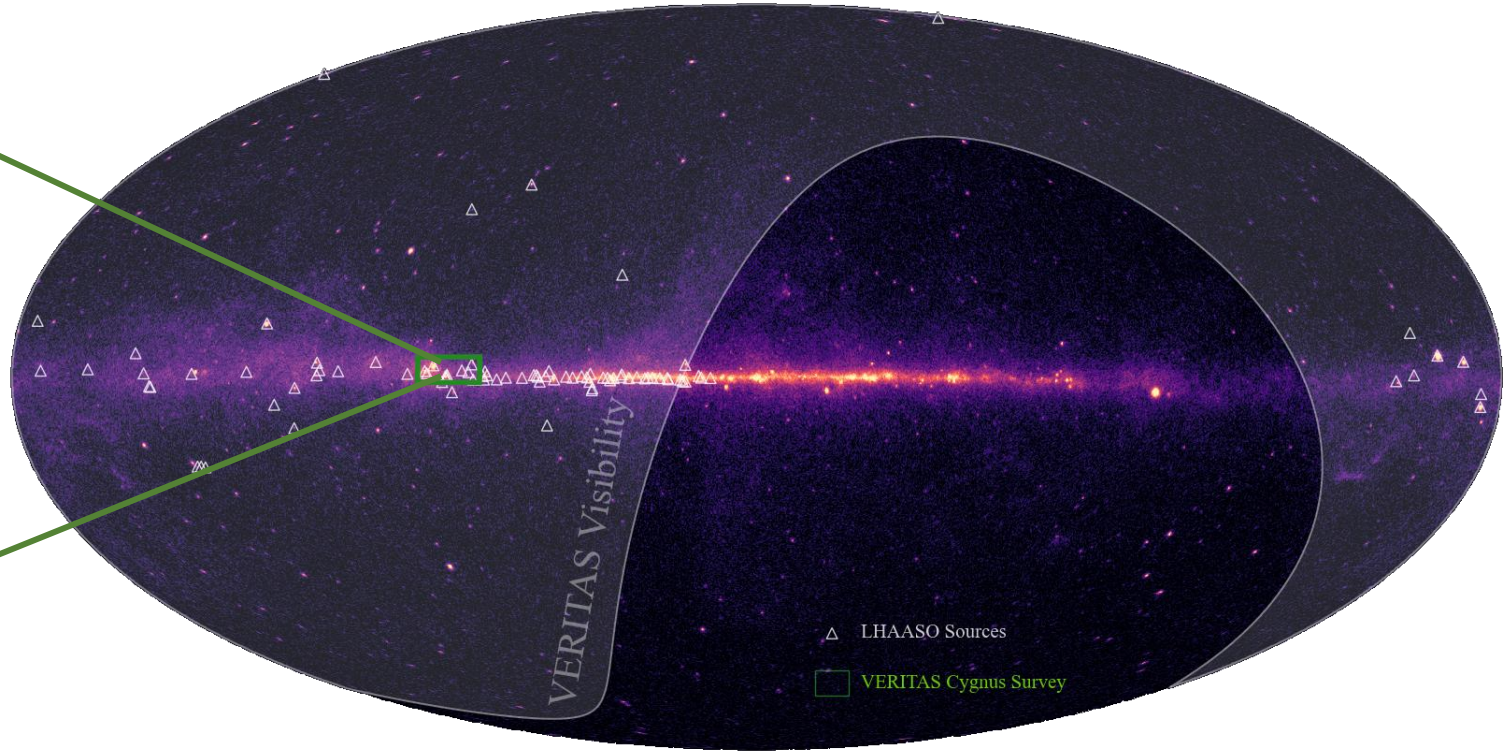
LHAASO Sources and VERITAS

VERITAS Cygnus Survey



(VERITAS,2018)

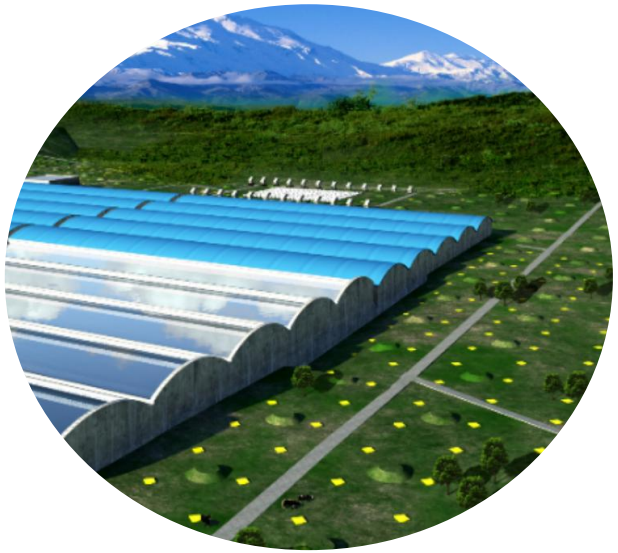


In 2023, LHAASO released their first complete catalog of the sky containing **32 new TeV sources**. The coincident position of VERITAS with LHAASO allows for a **natural overlap** with many of these new LHAASO sources.

The Cygnus survey of VERITAS also has a **deep exposure overlaping** with this region of interest.

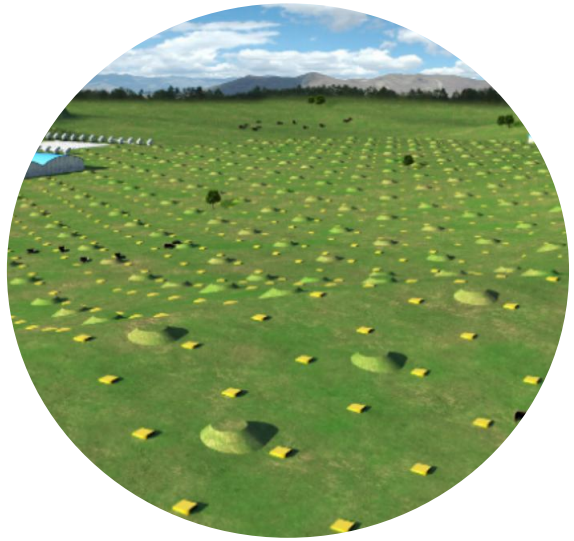
VERITAS and LHAASO

WCDA



- Wide FoV, survey instrument (~2 sr)
- Coarse angular resolution (~0.2-0.45˚)
- ~1 – 25 TeV Energy Range
- Smaller Effective Area (3200 @ 4.5 TeV)
- **Overlapping with the TeV energy range but worse angular resolution and less potential sensitivity.**

KM2A



- Wide FoV, survey instrument (~2 sr)
- Coarse angular resolution (~0.2-0.5˚)
- 20 TeV - 2000 TeV Energy range
- Large Effective Area (~10^5 @ 100 TeV)
- **Can determine whether a source is a PeVatron candidate and identifies new classes of UHE sources not bright in Fermi-LAT or HAWC.**

VERITAS

- Pointed Instrument (3.5 ˚ diameter)
- Good angular resolution (0.08 ˚ at 1 TeV)
- 85 GeV- 30 TeV Energy range
- Large Effective Area (~10^5 @ 1 TeV)
- **Provides a more detailed view of sources allowing for characterization and association.**

https://veritas.sao.arizona.edu/about-veritas/veritas-specifications
Performance of LHAASO-WCDA and Observation of Crab Nebula as a Standard Candle (LHAASO, 2021)
Optimization of performance of the KM2A full array using the Crab Nebula (LHAASO, 2024)

VERITAS Observation Types

Targeted Observations

Targeted observations are ones where VERITAS has taken **dedicated** time on a region with LHAASO-detected emission.

- For KM2A only sources, requires an extrapolation which is often **uncertain and model dependent.**
- Able to determine pointing to target regions of interest.
- Able to **coordinate** with other targeted multiwavelength campaigns.

Archival Observations

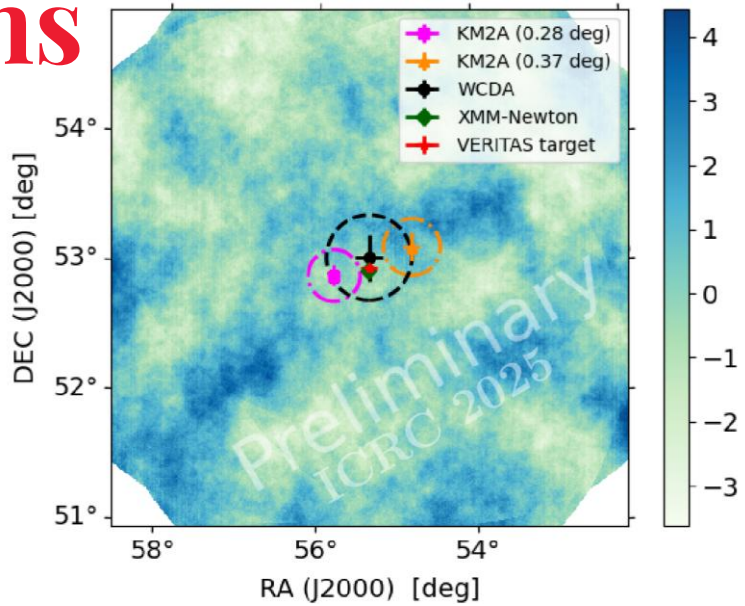
Archival observations are **serendipitous** observations where a LHAASO source was in the FoV of other VERITAS observations.

- Exposure **vary widely**
- Often in the field of view of bright gamma-ray sources, requiring **complicated exclusions**
- Often **highly offset** and only **partial coverage** of the LHAASO emission
- Can be **deeper** than many targeted observations because of decades of accumulation.

VERITAS Targeted Observations

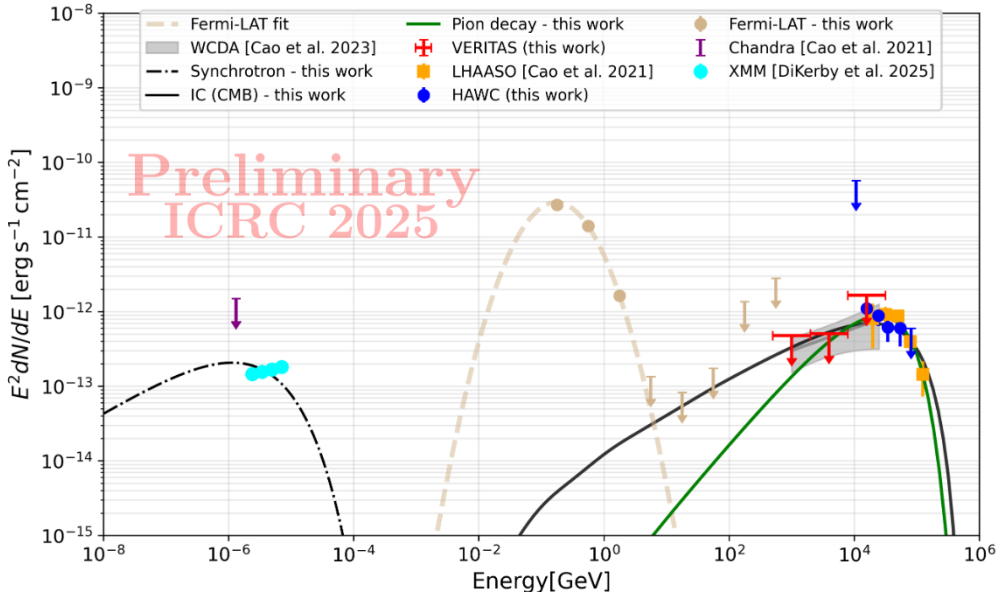
VERITAS has a campaign of targeted follow-up on **three LHAASO sources.**

These sources were selected based on the brightness quoted in the original KM2A detections and many were targeted prior to WCDA upper limits.



LHAASO J0341+5258

- Modestly extended $(0.29 \pm 0.06_{stat} \pm 0.02_{sys})^{\circ}$
- Partial spatial coincidence with a molecular cloud
- Non-detection in 50 hours of VERITAS data
- **Consistent with SNR+MC or PWN model**



Other campaigns have included **LHAASO J0621+3755, and LHAASO J2108+5157**. All have resulted in constraining upper limits.

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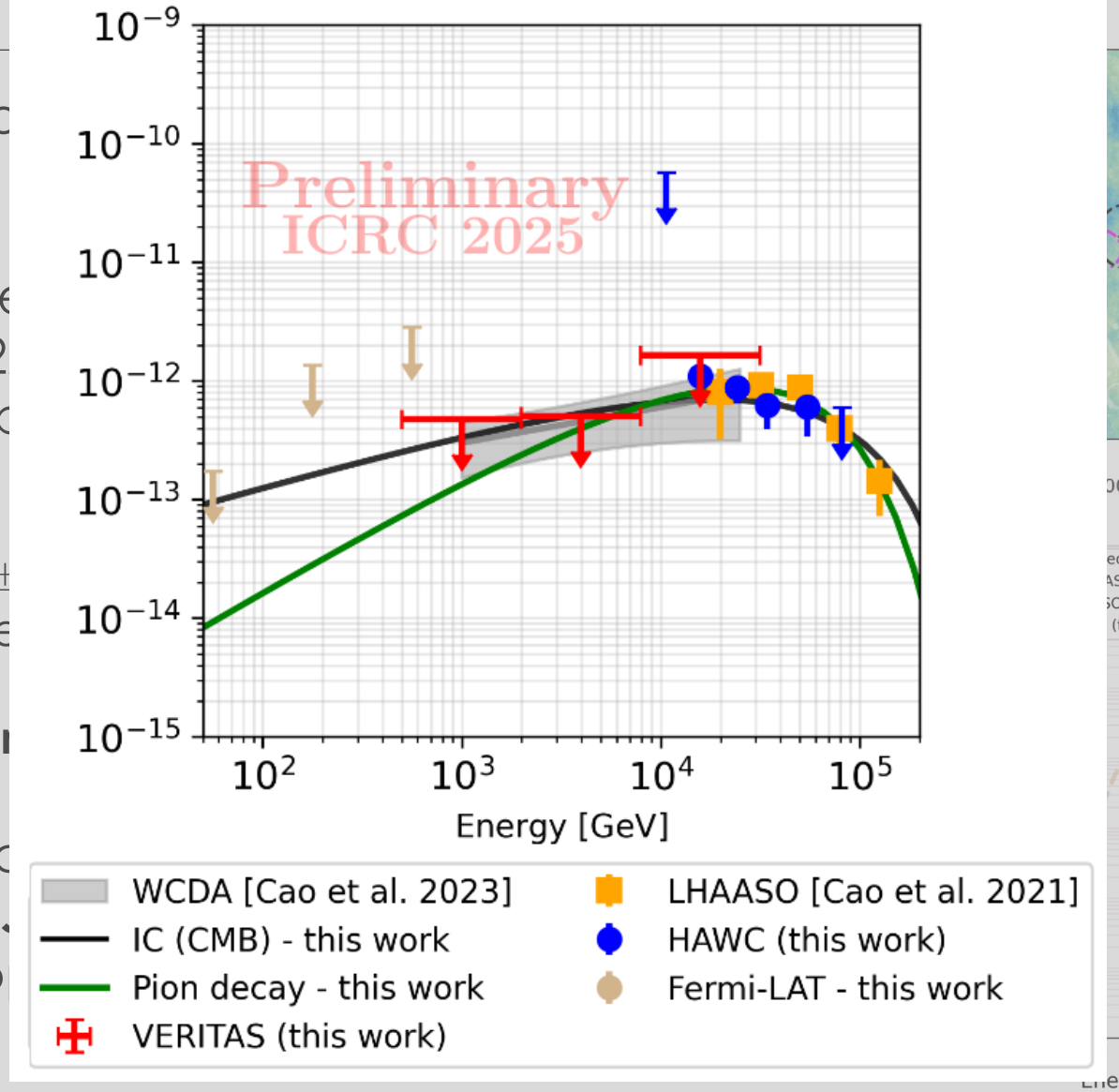

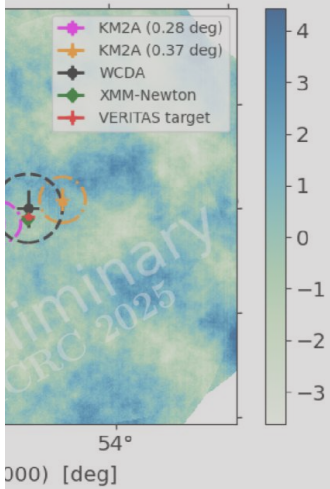

VERITAS Archival Observations

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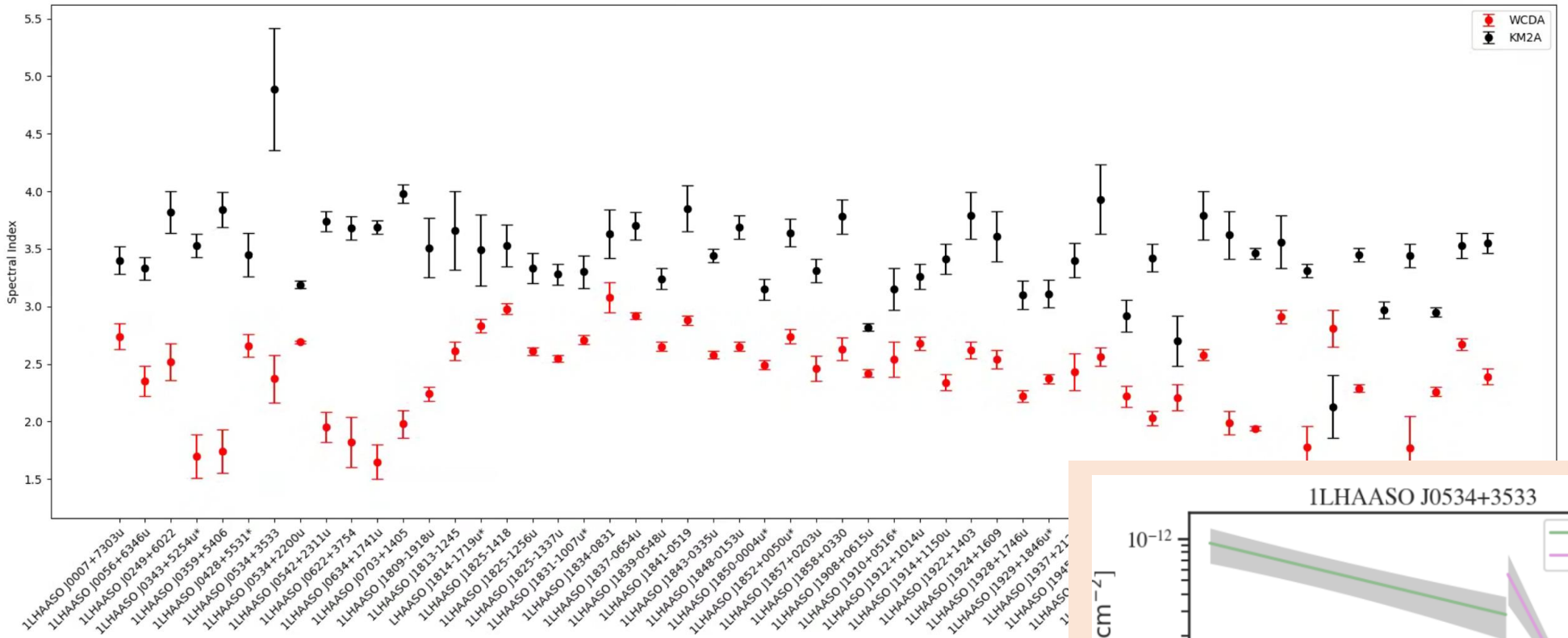
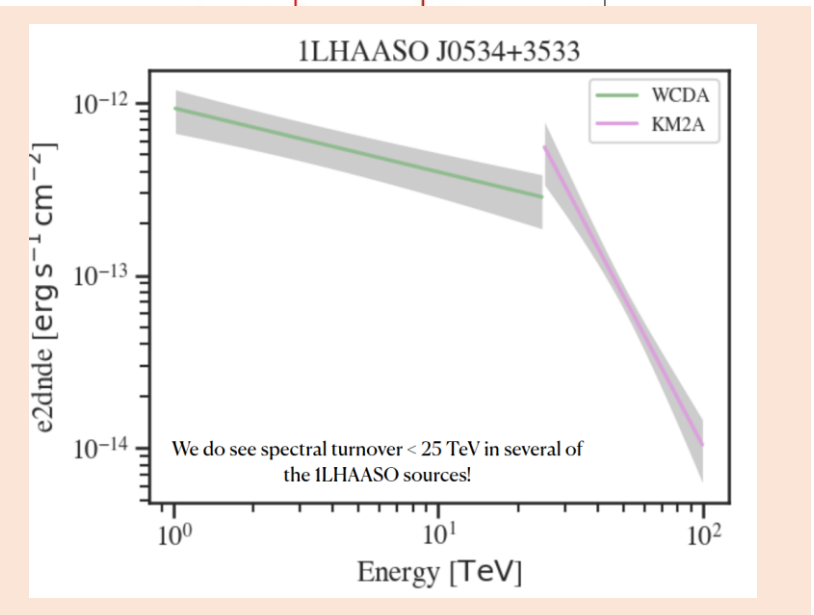
LHAASO Sources and VERITAS





There is often a large **spectral break** between the reported WCDA and KM2A, meaning it is difficult to predict one spectrum from the other for single-detector sources. This leads to dramatic overestimation of the flux of these sources at VHE. Constraing the true spectral shape is something IACTs can do even in the case of non-detections. **This break is likely due, in some cases, to unreported curvature in the spectrum.**

1LHAASO J1902+0648

LHAASO Source

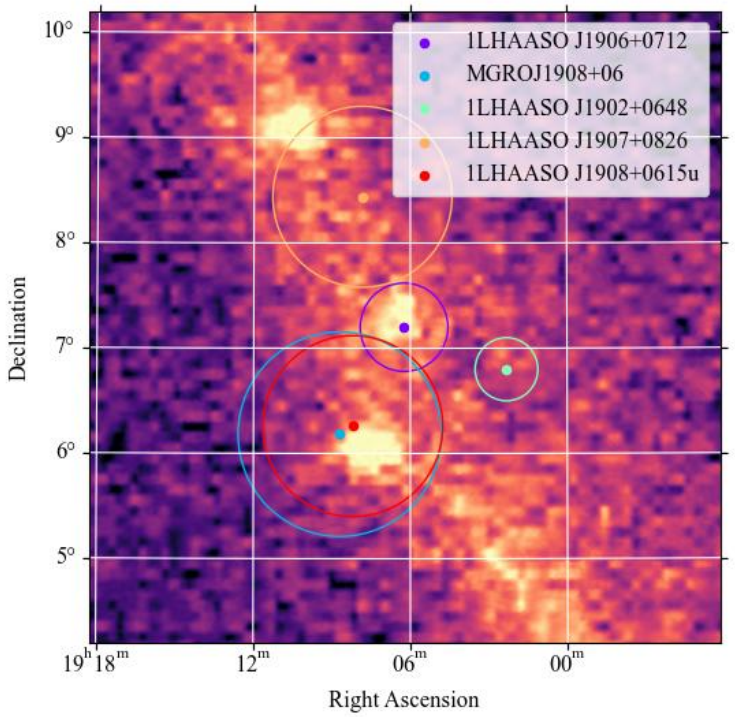
"1LHAASO J1902+0648 is a **point-like source** with a significance of TS = 46.2 **only detected by WCDA**. The unidentified GeV source 4FGL J1902.5+0654 is 0.12◦ from this 1LHAASO source."
(LHAASO, 2023)

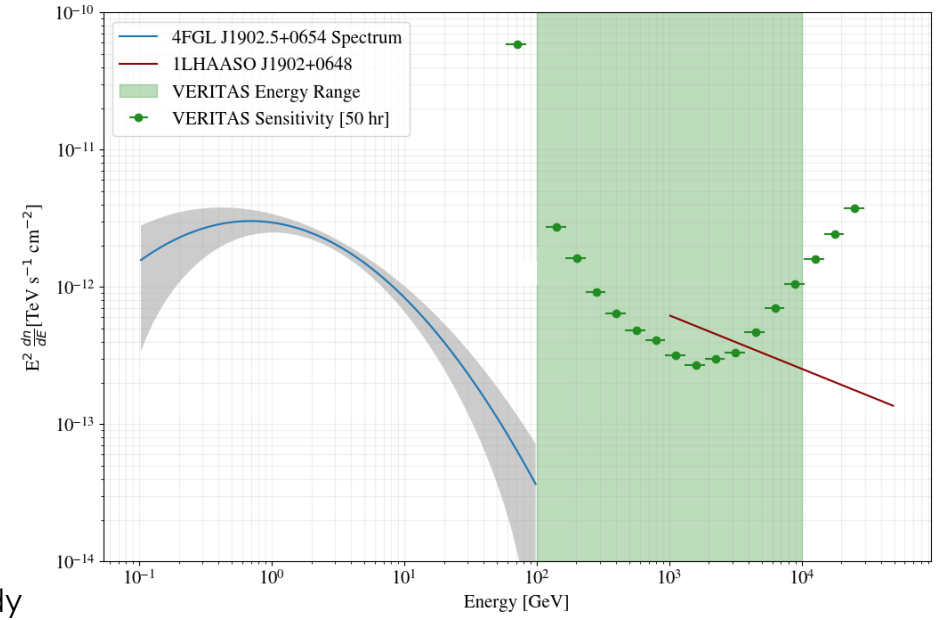
Only detected by WCDA, meaning that it is likely not a "PeVatron".

Fermi Source

4FGL J1902+0654 has no firm identification and is only been classified by automated machine learning tools (Only ~8 references including the 3FGL, 4FGL, and LHAASO).

Automated classifier will often have difficulty and categorize this source as "OTHER".





1LHAASO J1902+0648

VERITAS Study

With current soft "point-like" analysis at the best-fit LHAASO source location **we find no evidence of signficant emission (-0.52 σ) after 42 hours of observations.**

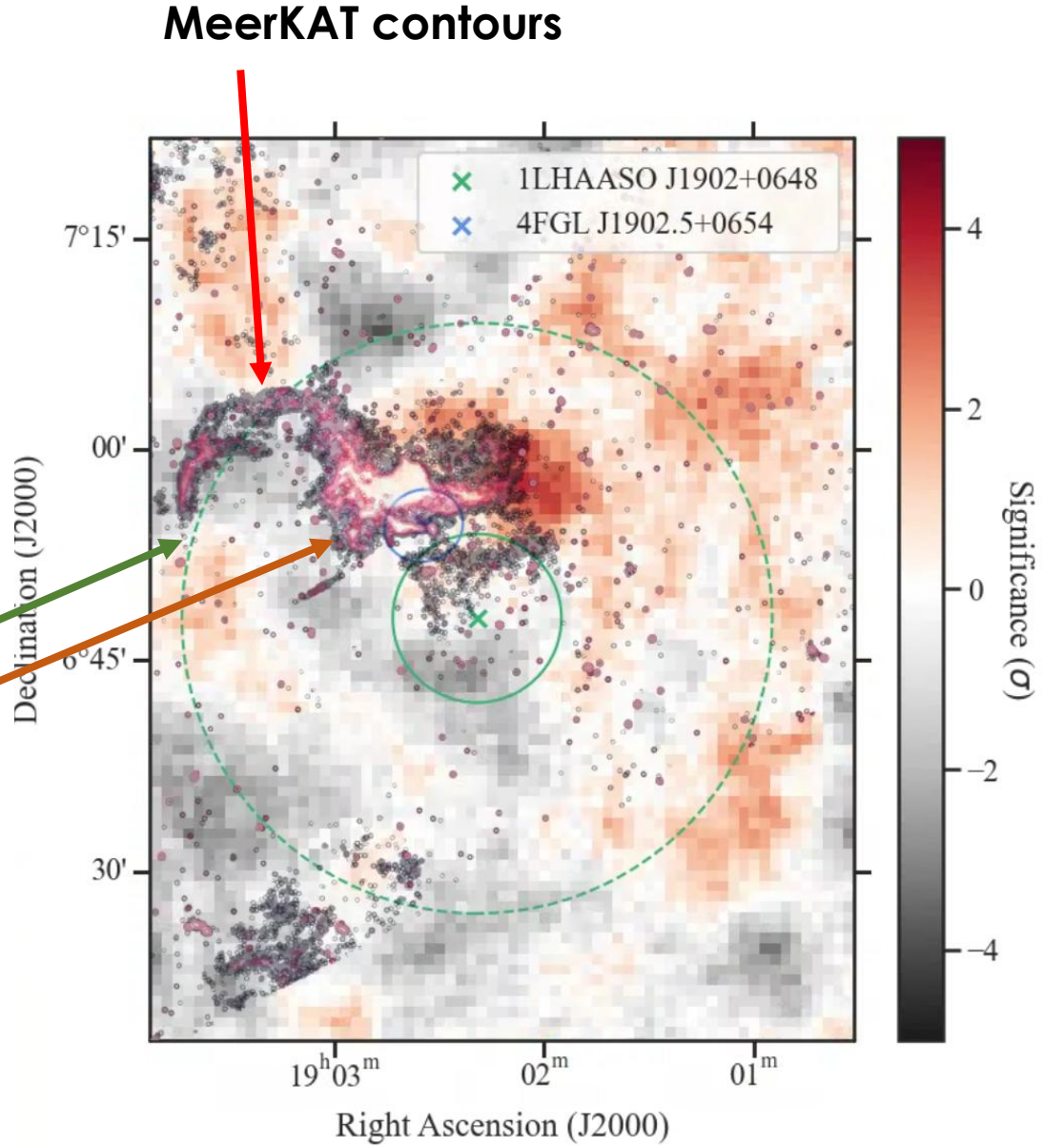
Potential Associations

VERITAS is currently investigating the broader LHAASO error region for potential counterparts. We have two possible candidates from MeerKAT:

- **A potential SNR**
- **A star-forming region**

There is a significant offset between the emission in the Fermi-LAT band and the LHAASO emission. Is this systematic?

This is one more example of an unclear relationship between Fermi->IACT->LHAASO



Conclusions

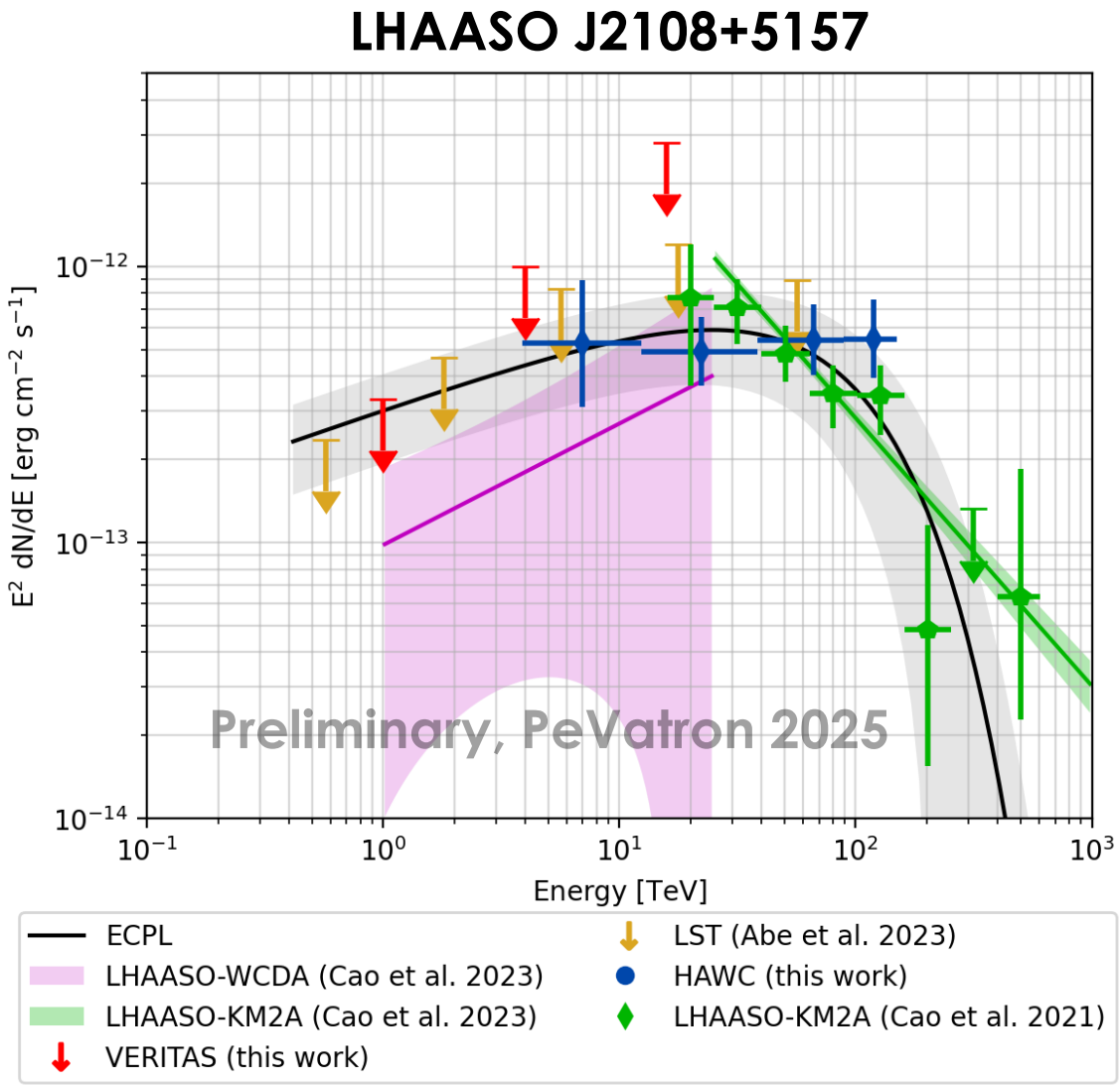
IACT follow-up is the natural step forward to advancing our knowledge of the VHE/UHE sky. **The ability to target sources and resolve ambiguities will only come from a detailed study of these sources.**

This is also one of the first times that the current generation of IACTs all can **utilize the same software package (*gammapy*).** There may be room for collaboration with sources where multiple IACTs have deep exposures.

VERITAS will continue to provide key insights on these sources and **a large release of our current archival results is being prepared.**

CTAO will rely on the current generation when considering and selecting targets during its early years of operation.

New/novel techniques that are applicable to all IACTs are being developed at VERITAS including the recent **low-rank pertubation method (see talk by Ruo Yu Shang).**



Questions & Discussion

Contact: mwl2145@columbia.edu
Acknowledgements: https://veritas.sao.arizona.edu/