VERITAS Observations of New LHAASO Sources

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on behalf of the VERITAS Collaboration
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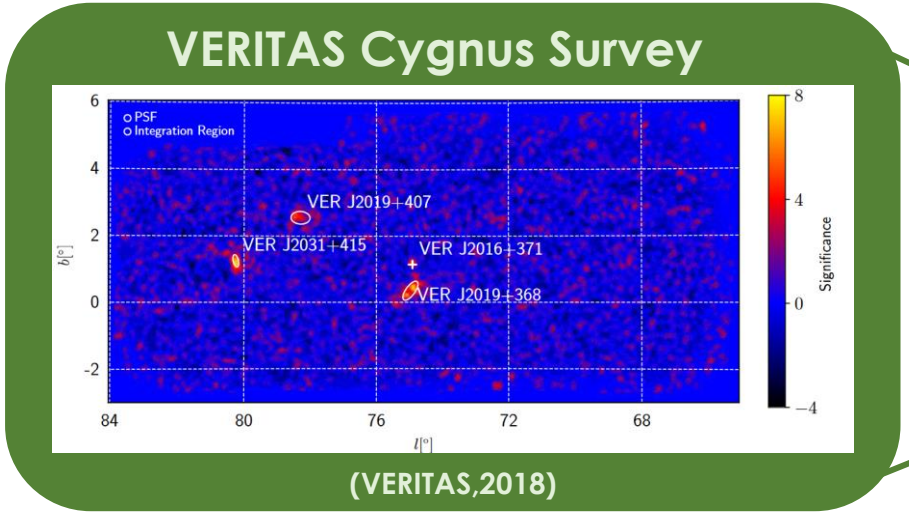
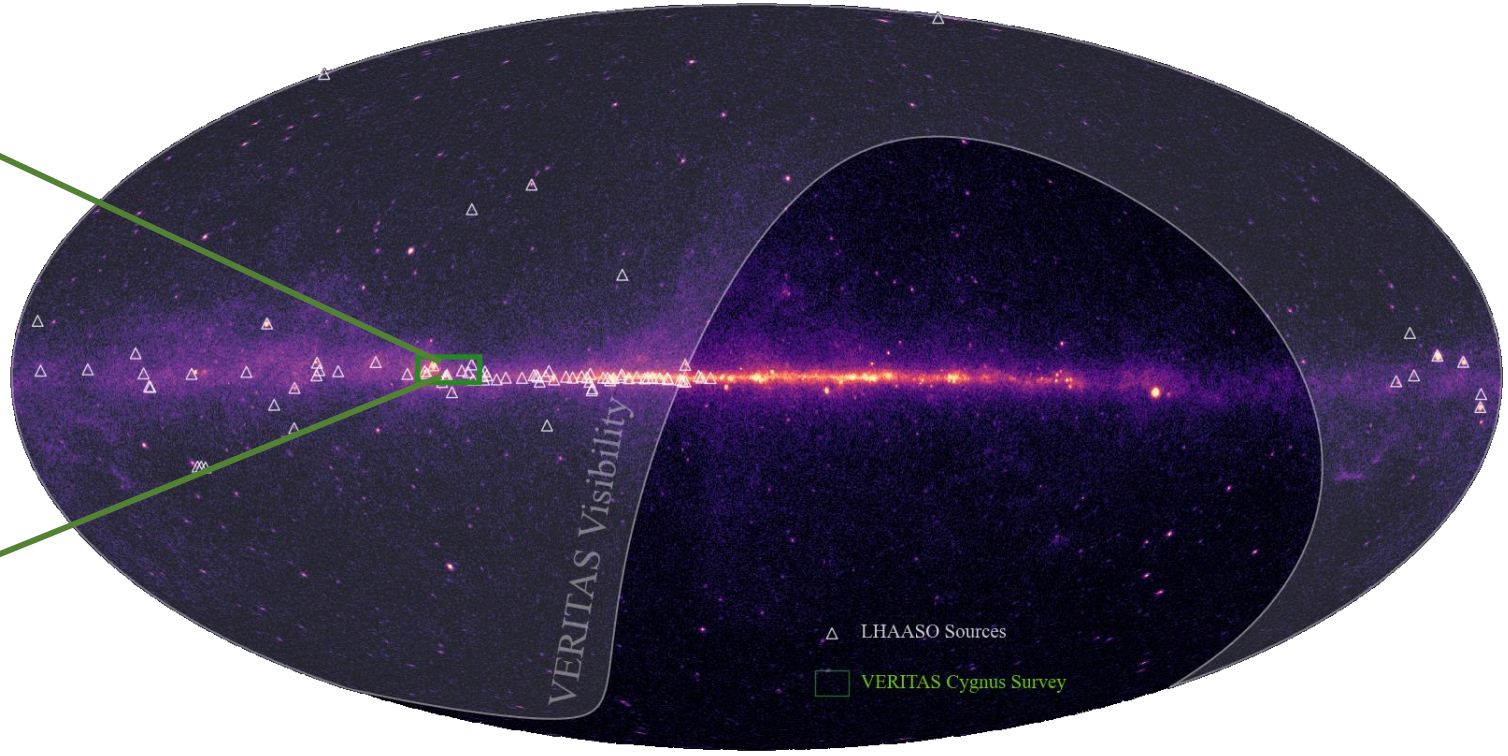
LHAASO Sources and VERITAS

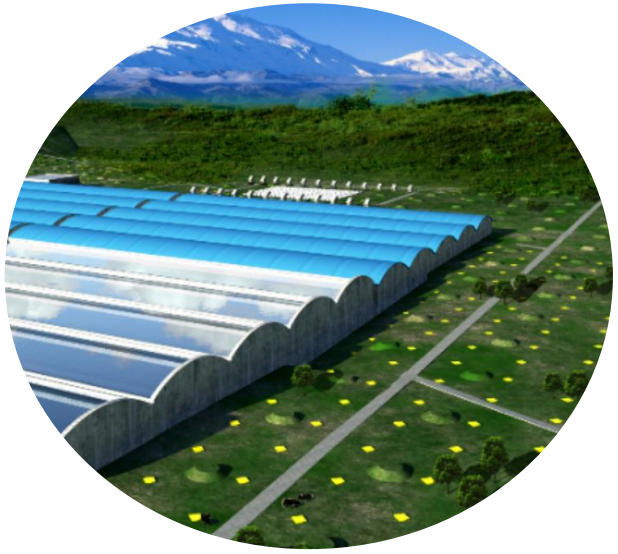




In 2023, LHAASO released their first complete catalog of the sky containing **32 new TeV sources**. The coincident position of VERITAS with LHAASO allows for a **natural overlap** with many of these new LHAASO sources.

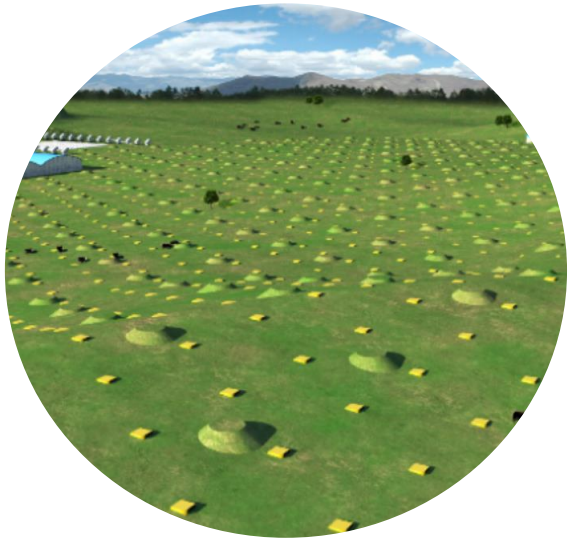
The Cygnus survey of VERITAS also has a **deep exposure overlaping** with this particular region of interest.

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)

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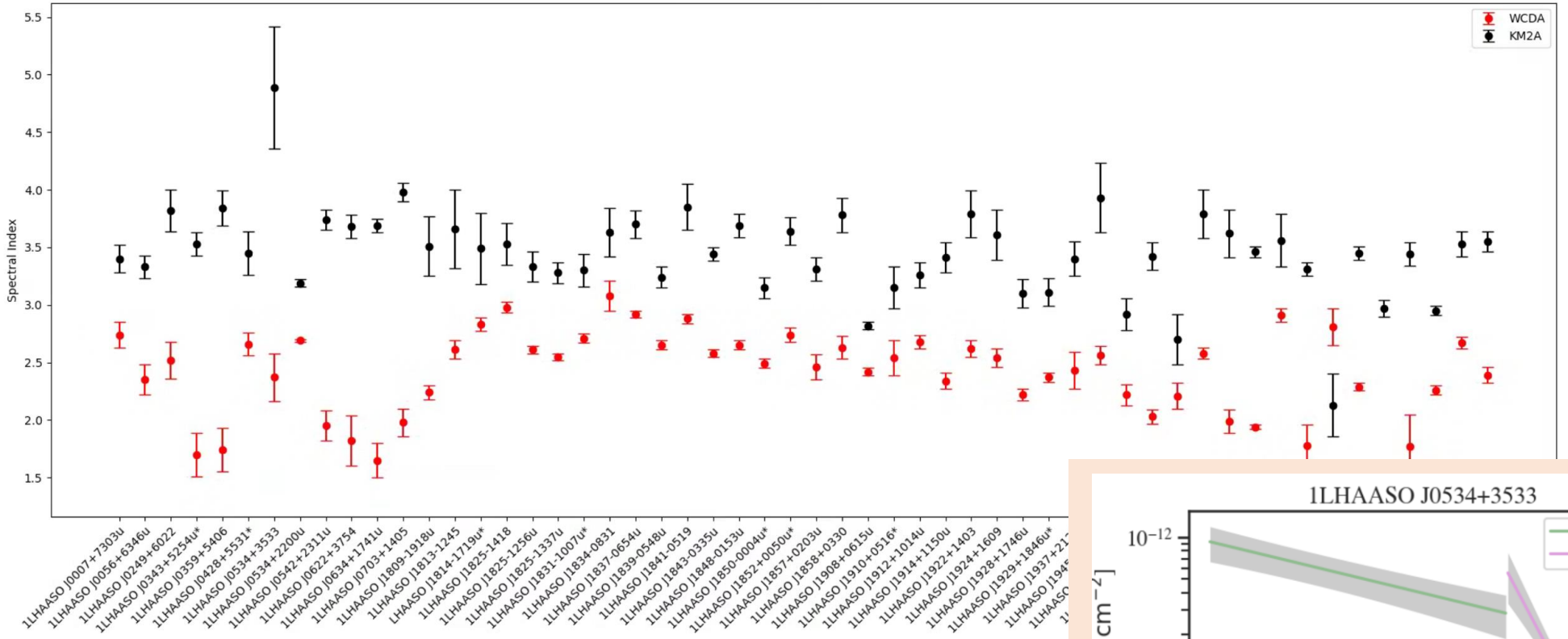
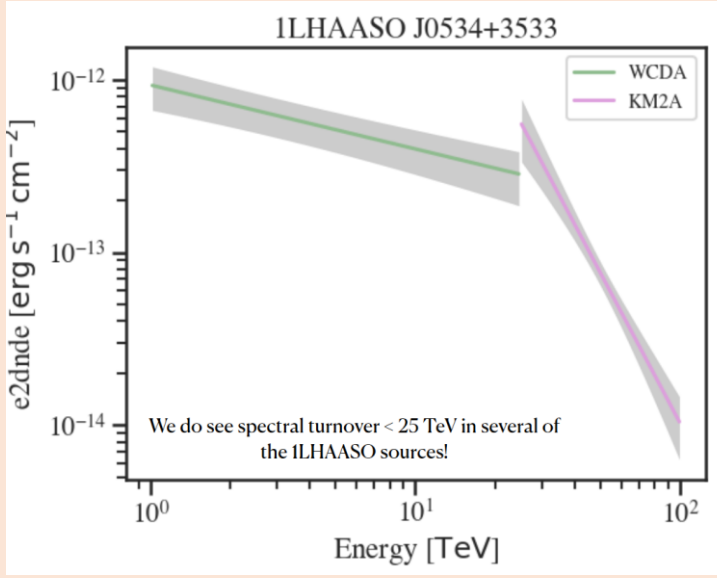
LHAASO Sources and VERITAS



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

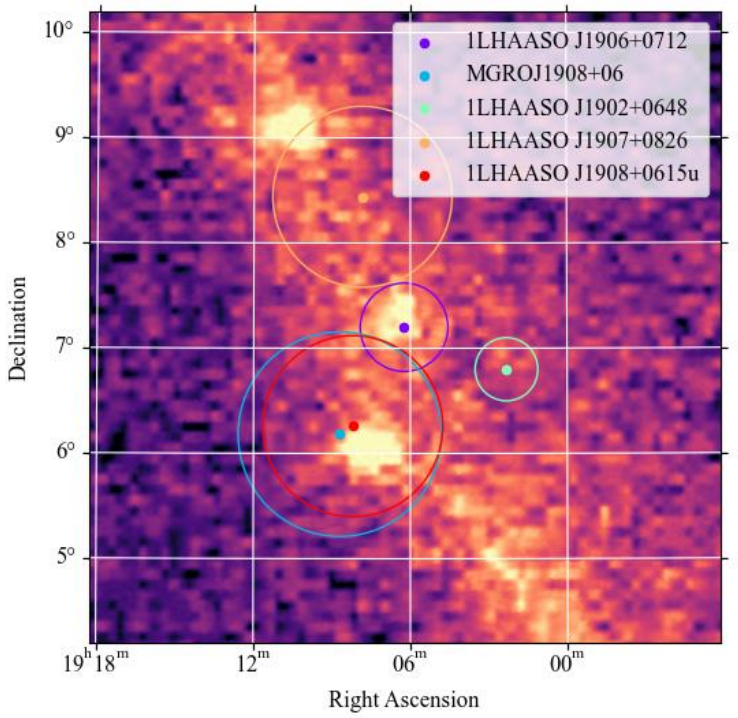
LHAASO Source

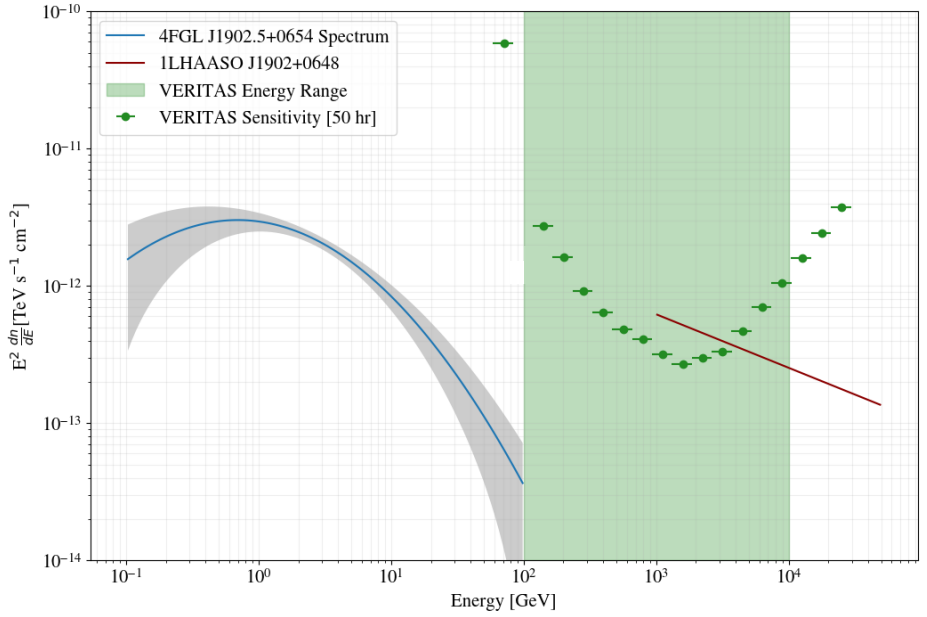
"1LHAASO J1902+0648 is a **point-like source** with a significance of TS = 46.2 **only detected by WCDA**. The unidentified GeV source 4FGL J1902.5+0654 is 0.12◦ from this 1LHAASO source."
(LHAASO, 2023)

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

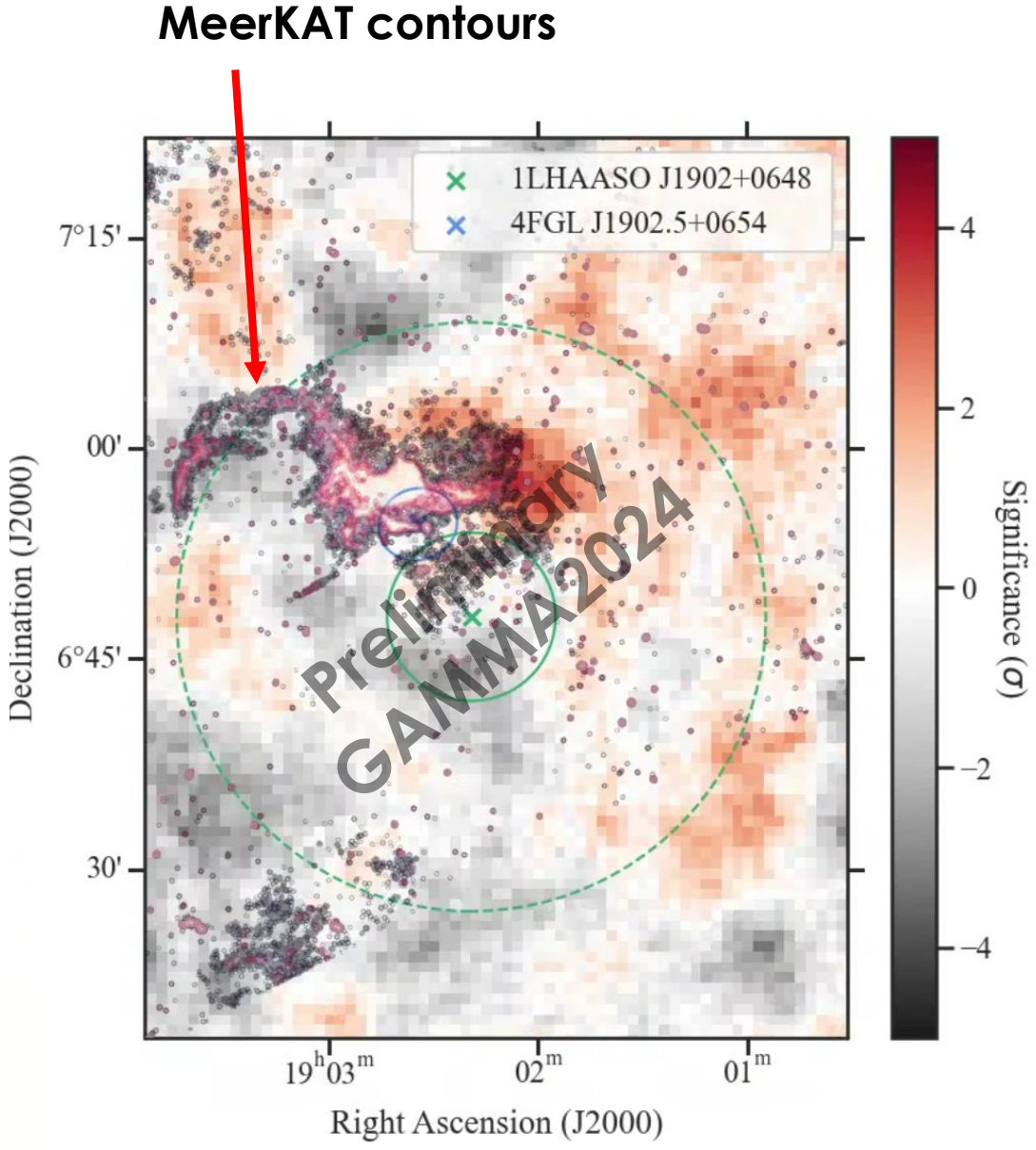
With current soft "point-like" analysis at the best-fit LHAASO source location **we find no evidence of signficant emission (-0.52 σ) after 42 hours of observations.**

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**

We are requesting XMM-Newton follow-up of these sources as they do not appear in many previous catalogs.

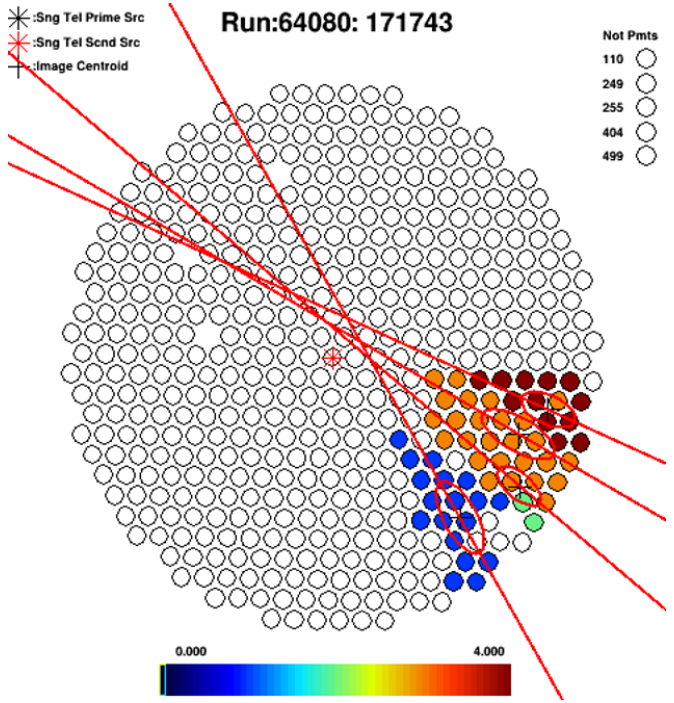


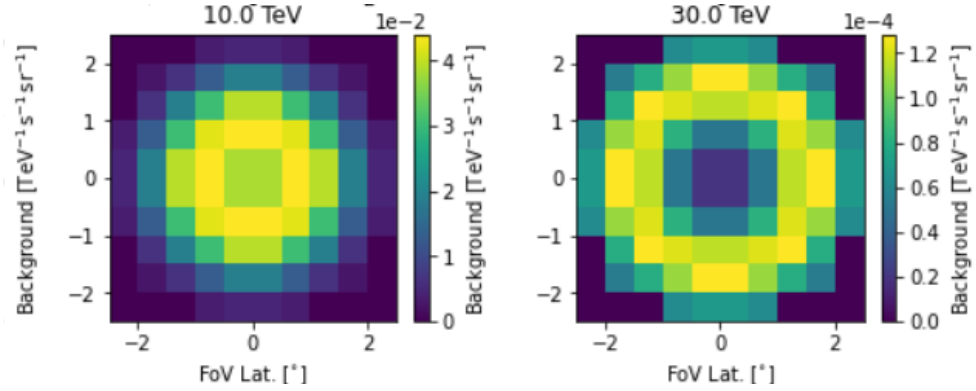
Next Steps: High Energy Optimization

UHE sources require IACTs to deal with the **highest energy events** that are often less important for traditional analysis (composing often less than 1% of total events).

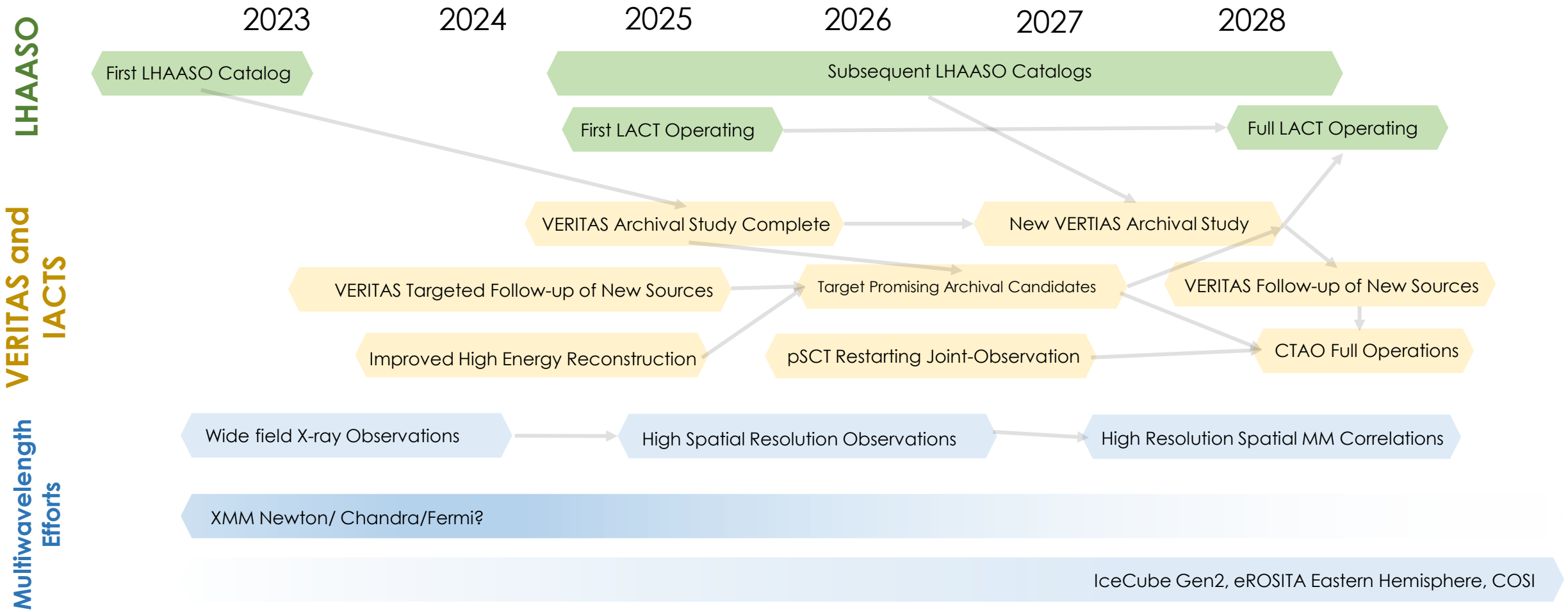
These images pose some particular challenges to analysis, often being **highly truncated with non-standard acceptances**. Machine learning techniques will also traditionally not be trained with many simulated events at the highest energies, since simulations typically reflect distributions of softer spectrum sources

It's possible at these energies for IACTs to become **signal dominated instruments, with almost gamma-ray pure samples**





Potential Landscape Moving Forward...



...with a high degree of uncertainty on all dates

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.**

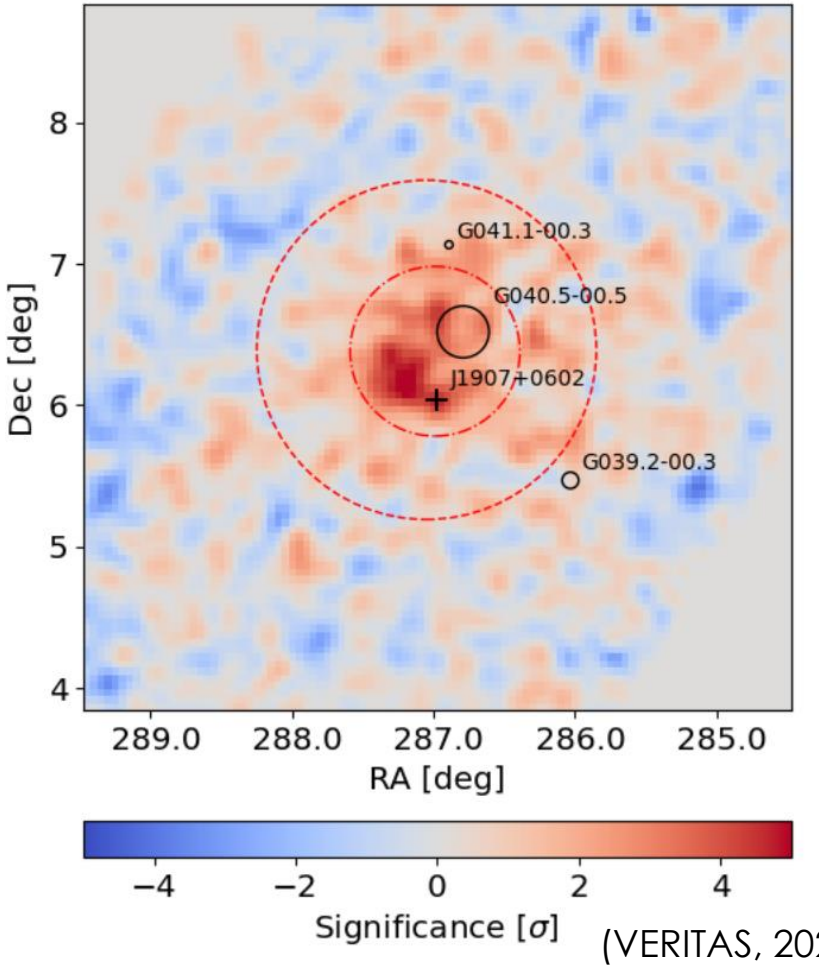
This is also one of the first times that the current generation of IACTs all can **utilize the same software package (*gammapy*).** There may be room for collaboration with sources where multiple IACTs have deep exposures.

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.

More LHAASO sources are expected to arrive in the coming years and the VERITAS archive will (likely) continue to overlap.

New/novel techniques that are applicable to all IACTs are being developed at VERITAS including our recent **low-rank pertubation method** used for MGRO J1908+06 for sources at ~2-3 degree scales. This will be applied to more diffcult extended LHAASO sources.

Low rank perturbation method applied to the very extended MGRO J1908+06



(VERITAS, 2024)

Questions & Discussion

Contact: matthew.lundy@mail.mcgill.ca
Acknowledgements: https://veritas.sao.arizona.edu/