Recent Scientific Results from VERITAS

Weidong Jin

on Behalf of the VERITAS Collaboration

Department of Physics and Astronomy, University of California, Los Angeles

TAUP2025, Xichang, China - Aug 28, 2025

Imaging Atmospheric Cherenkov Techniques

Light Pulses from the Night Sky associated with Cosmic Rays

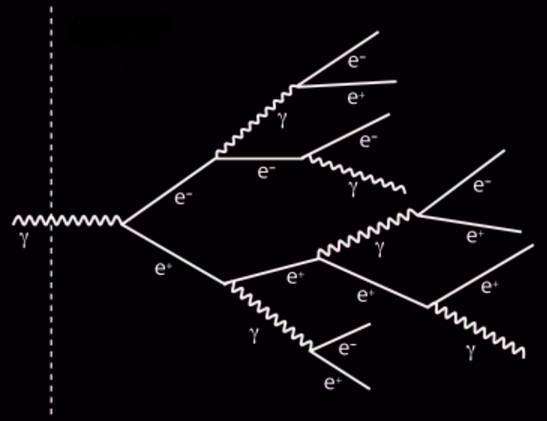
presence of light-pulses of short duration correlated with cosmic radiation.

A photomultiplier was mounted with its cathode at the focus of a parabolic mirror (see diagram, inset), the field of view of this 'telescope' being approximately $\pm 12°$ from the zenith. The output of the photo-tube was connected to an amplifier with equal differentiation and integration time-constants of 0·032 μsec. The apparatus was mounted in a field adjacent to this establishment at the centre of a square array of sixteen Geiger–Müller counters (each of area 200 cm.²; the sides of the entire array were 180 metres) designed by Cranshaw[3] for studies of extensive air-showers. The results obtained were as follows.

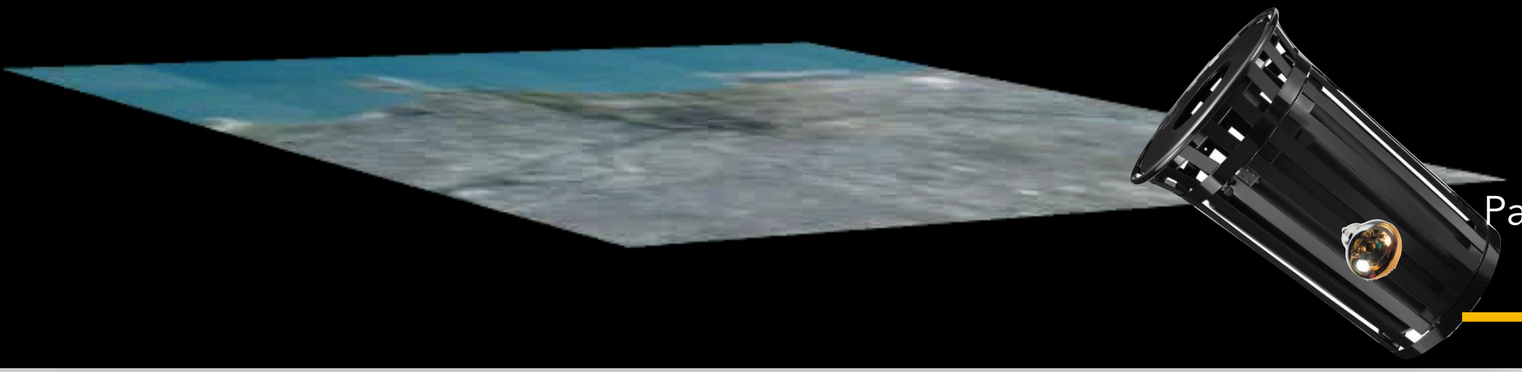
Galbraith, W. and Jelley, J. V. (1953)
Nature, 171(4347):349–350

VHE (> 100 GeV)

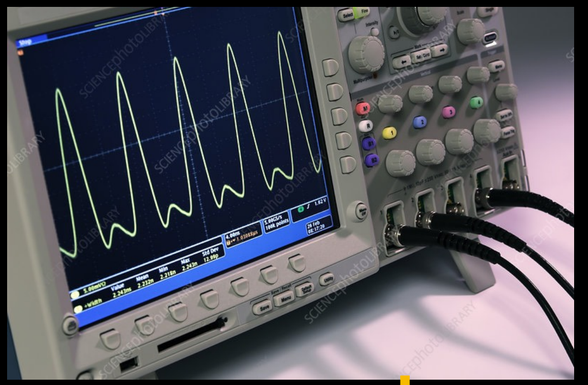
Electromagnetic cascade



Cherenkov condition $v > \frac{c}{n}$



Parabolic mirror



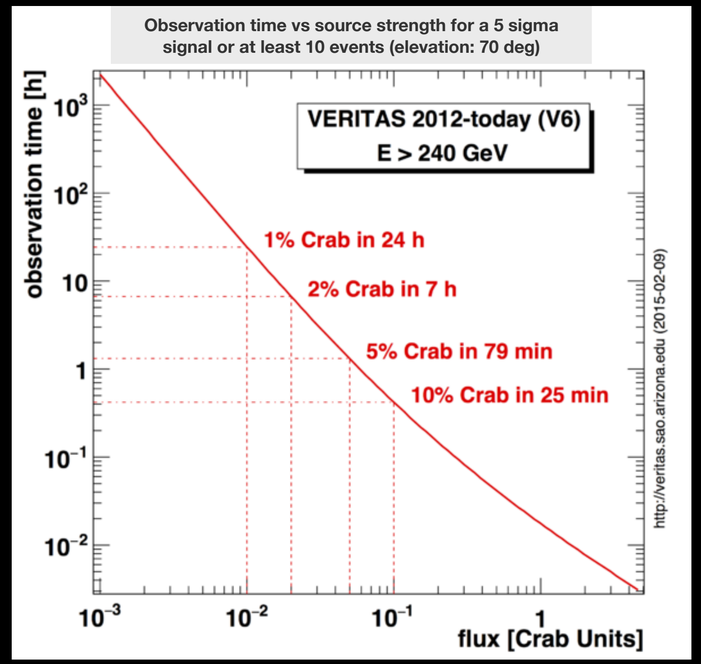
Oscilloscope

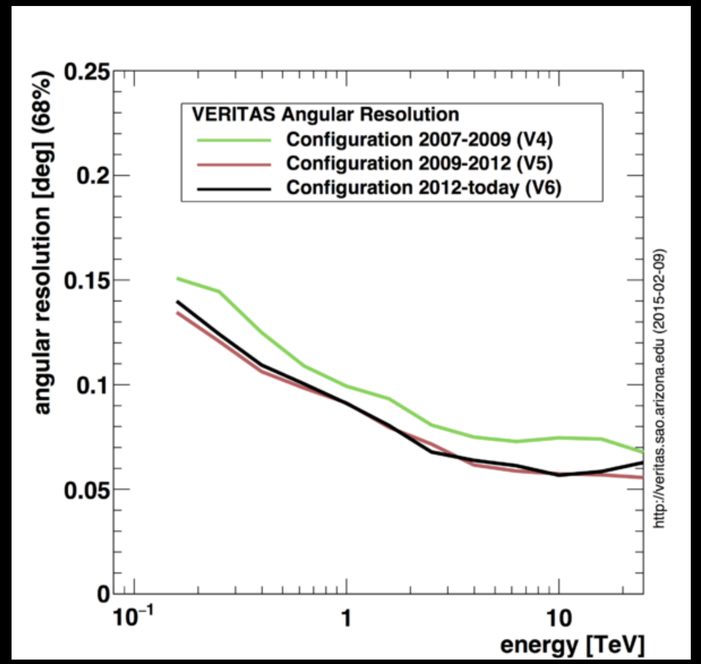
VERITAS Status

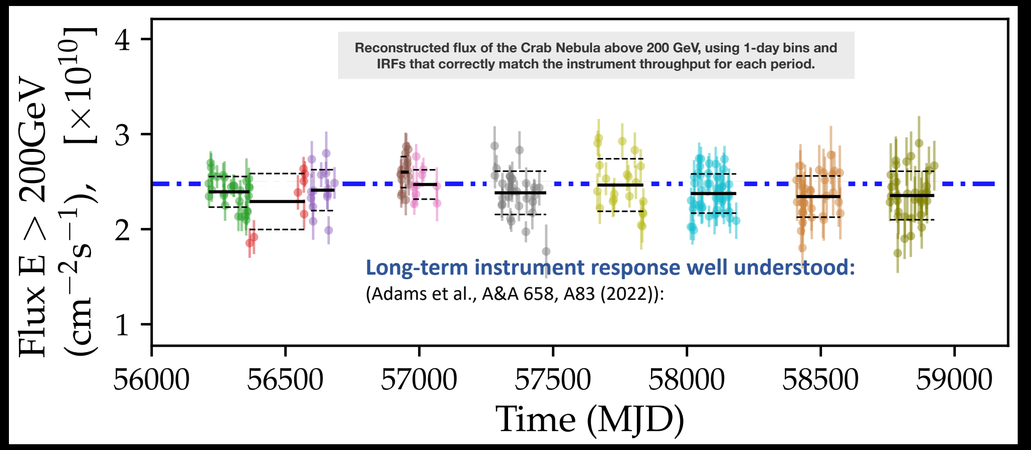
- Facility and Collaboration:
- Located at the Fred Lawrence Whipple Observatory in southern Arizona @ 1,268 m a.s.l.
- Array of 4 Davies-Cotton Imaging Air Cherenkov Telescopes. CTAO prototype SCT telescope co-located.
- Marking two decades of full-array operations.
- International Collaboration:
- ~80 members incl. 23 graduate students and 9 Postdocs.
- +10 active Associate Members.

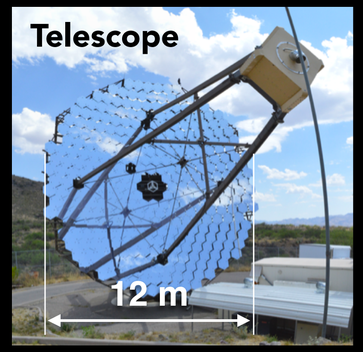
- Funding Sources:
- USA: National Science Foundation, Smithsonian Astrophysical Observatory
- Canada: Natural Sciences and Engineering Research Council
- Germany: Helmholtz Association
- News:
- Plans to apply for operations support from NSF for 2025-2028 window.

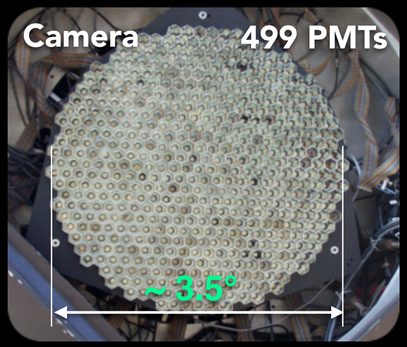
VERITAS Performance











Field of View	3.5° diameter
Energy Range	~85 GeV to ~30 TeV
Effective Area	~10^5 m^2 at 1 TeV
Sensitivity	1% Crab in <25 h

Angular Resolution (r_{68})	~0.08° @ 1 TeV
Energy Resolution	~17%
Sys. Errors: Flux	~20%
Sys. Errors: Spectral Index	~ 0.1

Recent VERITAS Announcements on Atel

VERITAS Follow-up of a Report of Enhanced Emission from 1ES 1727+502: Atel #17099 (March 2025)

- Following an LHAASO detection.
- Exposure: ~2.2 hours.
- Significant VHE detection, flux above 350 GeV: (9 ± 2) × 10^{-8} m^{-2} s^{-1}.

VERITAS Follow-up of a Report of Enhanced Emission from 1ES 1727+502

ATel #17099; *Amy Furniss (UC Santa Cruz) for the VERITAS Collaboration*
*on **22 Mar 2025; 04:41 UT***
Credential Certification: Amy Furniss (afurniss@ucsc.edu)

Subjects: Gamma Ray, >GeV, TeV, VHE, AGN, Blazar

𝕏 Post

We report the VERITAS measurement of very-high-energy (VHE; E> 100 GeV) emission from the blazar 1ES 1727+502 (z=0.055, RA: 17 28 18.62 Dec: +50 13 10.47, J2000). Observations were carried out in response to a report of the detection of VHE gamma-ray emission from 1ES 1727+502 by LHAASO (ATel #17088). Approximately 2.2 hours of gamma-ray observations were collected by VERITAS on 2025-03-20 (UTC) in bright moonlight conditions. A preliminary analysis of the data yields a significant detection with a flux above 350 GeV of (9+/-2)X10^-8 m^-2 s^-1 or approximately (8+/-2)% of the Crab Nebula flux above the same energy. The VHE flux from the source was observed to be higher than in the low state reported historically by MAGIC [1], but lower than the enhanced emission reported by LHAASO. When compared to the 50% Crab Nebula flux reported by LHAASO, this suggests a significant decrease of the flux from the source. VERITAS has previously measured a comparable intermediate-level flux in 2013 from the same source [2]. Questions regarding the VERITAS observations should be directed to Amy Furniss (afurniss@ucsc.edu). VERITAS (Very Energetic Radiation Imaging Telescope Array System) is located at the Fred Lawrence Whipple Observatory in southern Arizona, USA, and is most sensitive to gamma rays between 85 GeV and 30 TeV (http://veritas.sao.arizona.edu). [1] Aleksic, J., et al. "Discovery of very high energy gamma-ray emission from the blazar 1ES 1727+502 with the MAGIC Telescopes" in A&A, vol. 563, pp. A90, 2014. [2] Archambault, S., et al. "VERITAS Detection of Gamma-Ray Flaring Activity From the BL Lac Object 1ES 1727+502 During Bright Moonlight Observations," in ApJ, vol. 808, no. 2, pp. 110, 2015.

VERITAS Detection of Very-High-Energy Gamma-Ray Flaring Activity from OP 313

ATel #16993; *Amy Furniss (UC Santa Cruz) for the VERITAS Collaboration*
*on **25 Jan 2025; 16:12 UT***
Credential Certification: Amy Furniss (afurniss@ucsc.edu)

Subjects: Gamma Ray, >GeV, TeV, VHE, AGN, Blazar

Referred to by ATel #: 17000, 17003, 17005, 17016, 17051

𝕏 Post

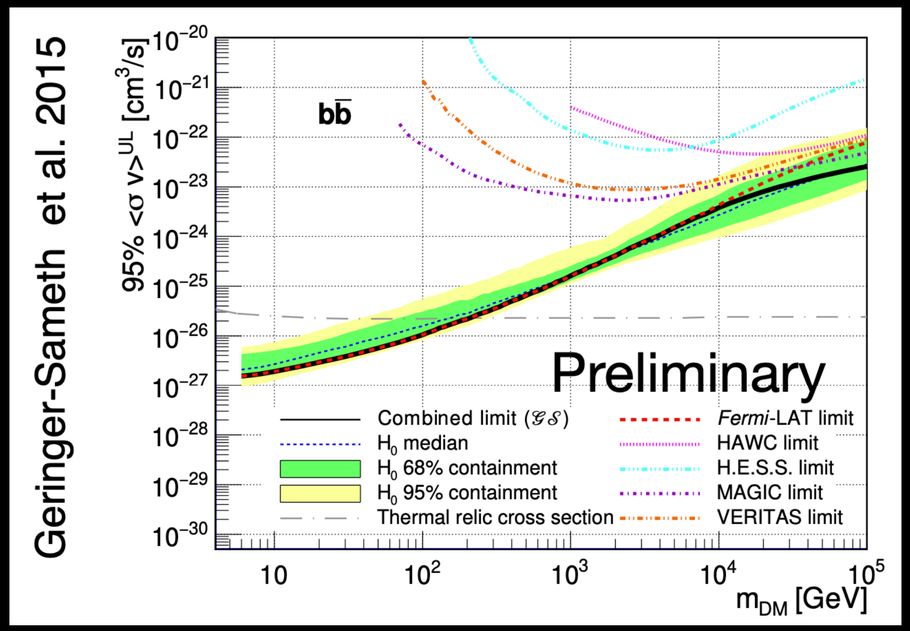
We report the VERITAS detection of very-high-energy (VHE; E> 100 GeV) flaring activity in the flat-spectrum radio quasar (FSRQ) OP 313 (z=0.997, R.A. = 197.61943 deg, Dec. = +32.34549 deg, J2000.0). Following the GeV gamma-ray activity observed by Fermi-LAT (reported in ATel #16970), approximately 1.7 hours of observations were collected by VERITAS on Jan 24, 2025 (UTC). A preliminary analysis of these data yields a detection with a statistical significance of 15 standard deviations and a flux of (7.8 +/- 1.0)e-7 m^-2 s^-1 above 150 GeV, which corresponds to (21 +/- 3)% of the Crab Nebula flux above the same threshold energy. OP 313 (also known as B2 1308+326 or RGB J1310+323) is undergoing a flare that has lasted for two weeks in gamma-ray and optical frequencies, as highlighted by recent ATels (#16951, #16964, #16970, #16972, #16977, #16979, #16991). VERITAS will continue to observe OP 313 as long as observations are feasible. Multi-wavelength observations are encouraged. Questions regarding the VERITAS observations should be directed to Amy Furniss (afurniss@ucsc.edu). VERITAS (Very Energetic Radiation Imaging Telescope Array System) is located at the Fred Lawrence Whipple Observatory in southern Arizona, USA, and is most sensitive to gamma rays between 85 GeV and 30 TeV (http://veritas.sao.arizona.edu).

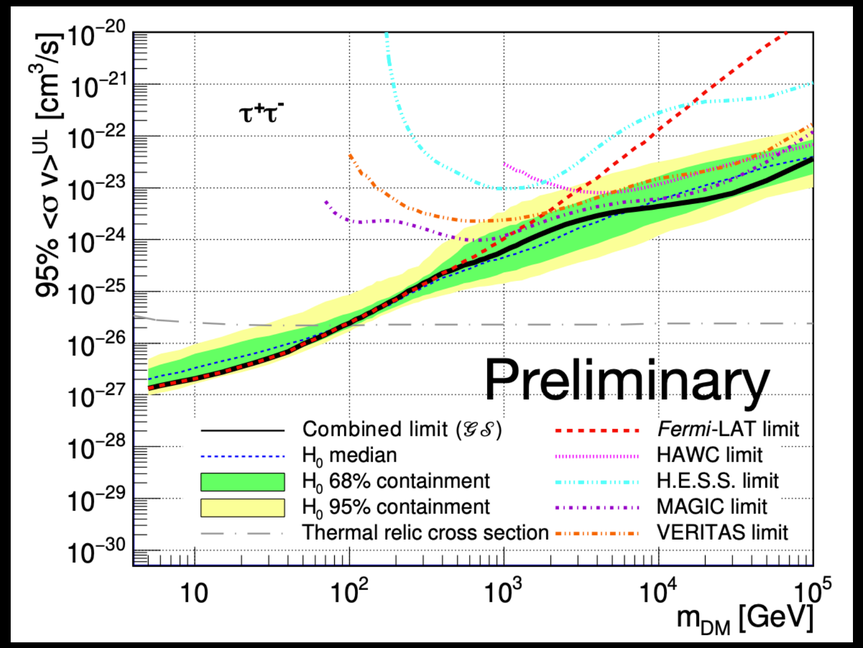
VERITAS Detection of Very-High-Energy Gamma-Ray Flaring Activity from OP 313: Atel #16993 (Jan 2025)

- z = 0.997.
- 1.7 hours of data with a 15σ detection and a flux of (7.8 ± 1.0) × 10^{-7} m^{-2} s^{-1} (>150 GeV), ~(21 ± 3)% Crab.
- The detection follows two weeks of GeV and optical flaring. activity reported by Fermi-LAT and multiple ATels, confirming OP 313's ongoing high state across energy bands.

Indirect Search for Dark Matter

A Joint Gamma-ray Search for Dark Matter in Dwarf Spheroidal Galaxies with Fermi-LAT, HAWC, H.E.S.S., MAGIC and VERITAS





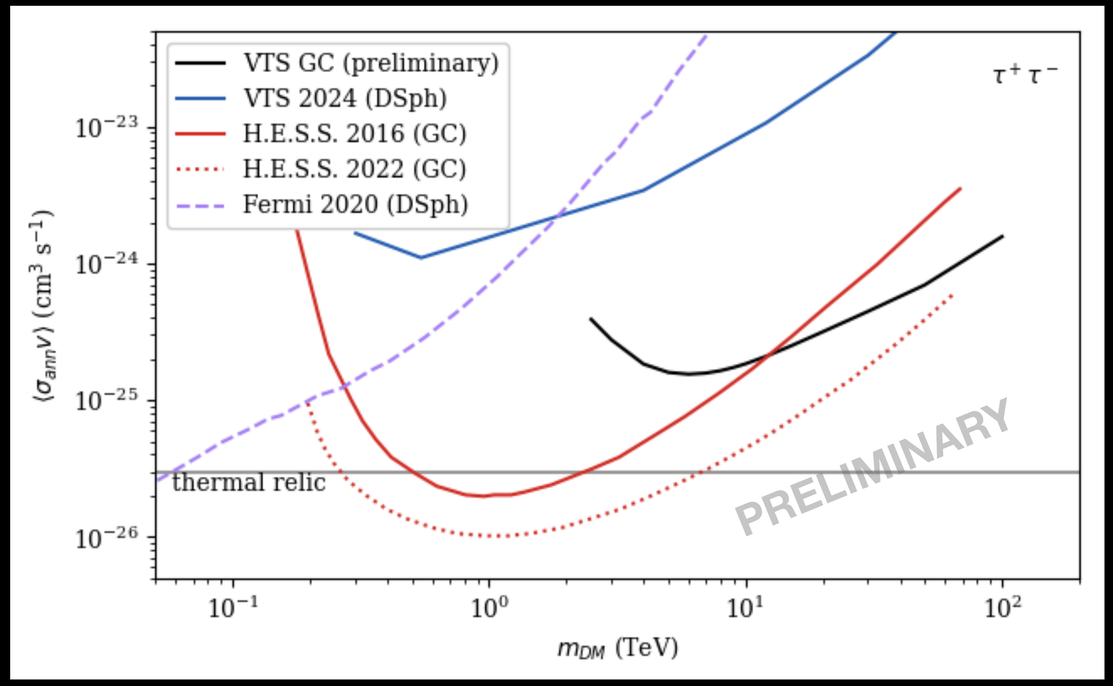
Javier Rico et al, ICRC 2025.

- A search for dark matter annihilation within 20 dSphs from a joint analysis of the combined datasets of five gamma-ray telescopes (VERITAS, H.E.S.S., MAGIC, HAWC and Fermi-LAT).
- Two different J-factor parameterizations ($\mathcal{GS}$ & $\mathcal{B}$ set).
- No positive signal for any dSph individually or altogether.

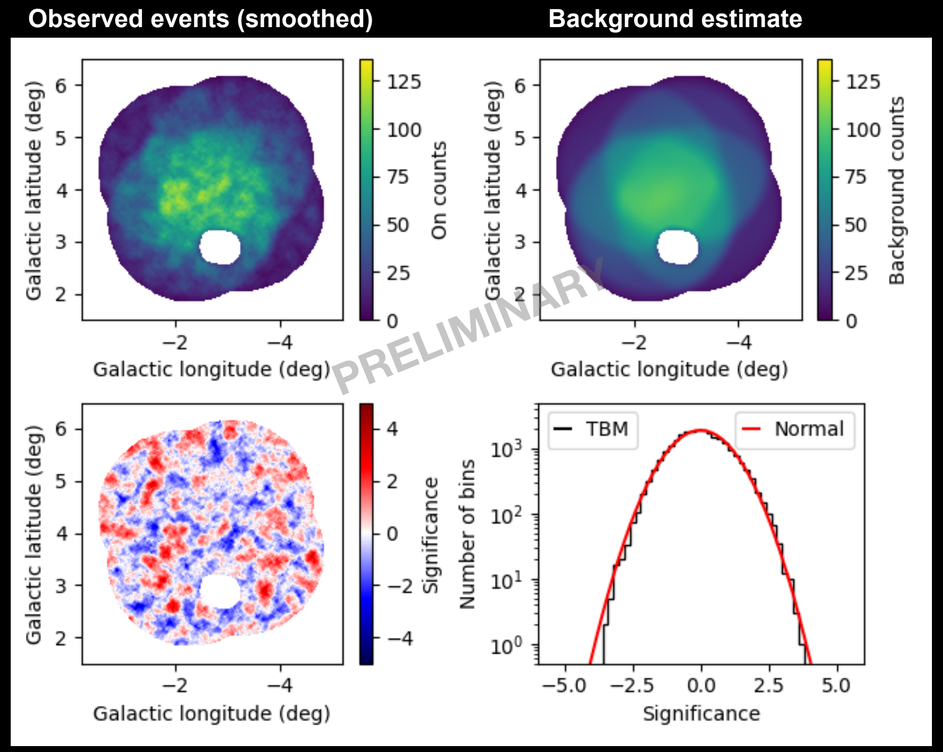
- Wide WIMP mass range (5 GeV to 100 TeV), improve <σv> by a factor of 2–3 at multi-TeV domain.
- Set some of the most stringent constraints on DM annihilation in dSphs to date, showcasing the power of multi-instrument synergy.
- The work is a tour de force — JCAP editor report.

VERITAS corresponding author Elisa Pueschel, Chiara Giuri. JCAP accepted.

Search for Dark Matter at the Galactic Center

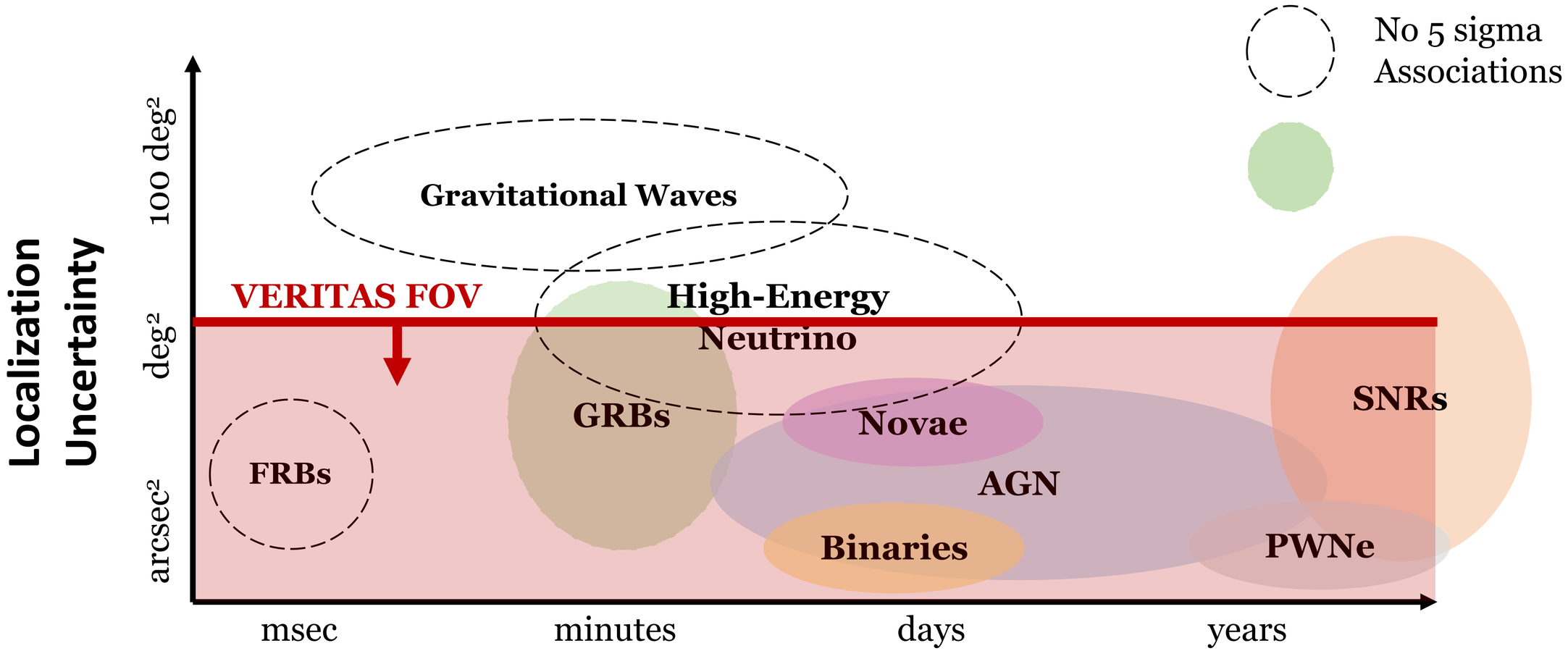


- The strongest γ-ray DM signal is expected towards the GC.
- VERITAS conducted 177.8 hr of GC observations between 2010 and 2022.
- Limits are placed on the dark matter annihilation cross section and compared with H.E.S.S. GC results and Fermi DSph results.



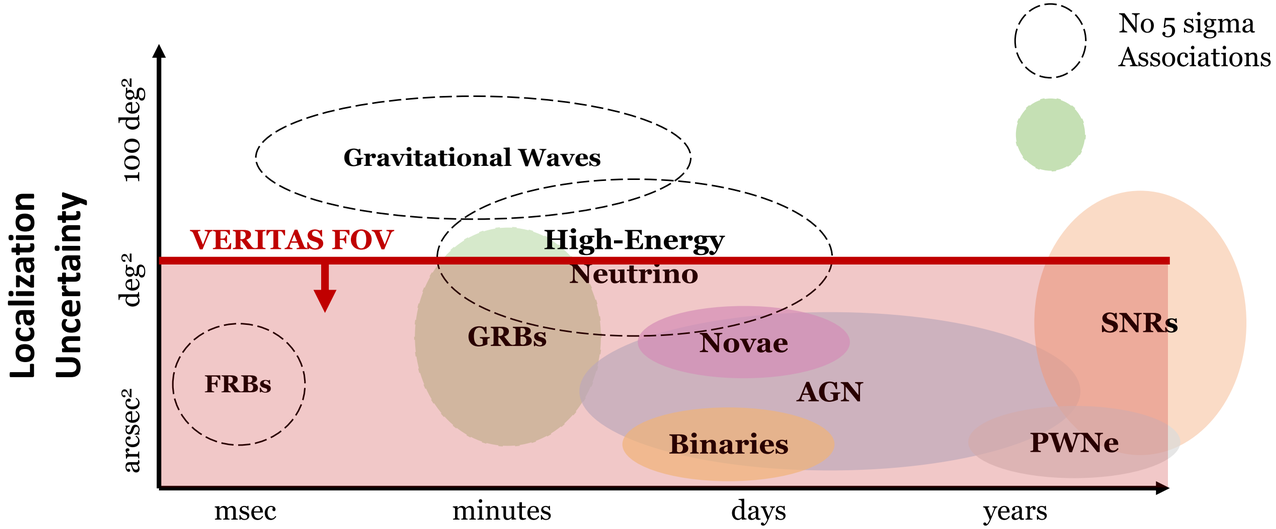
- Einasto profile used.
- DM-induced gamma-ray fluxes from "PPPC4" (Cirelli et al. 2011).
- Same signal bins as HESS analyses.
- Template background method applied to a blank field.

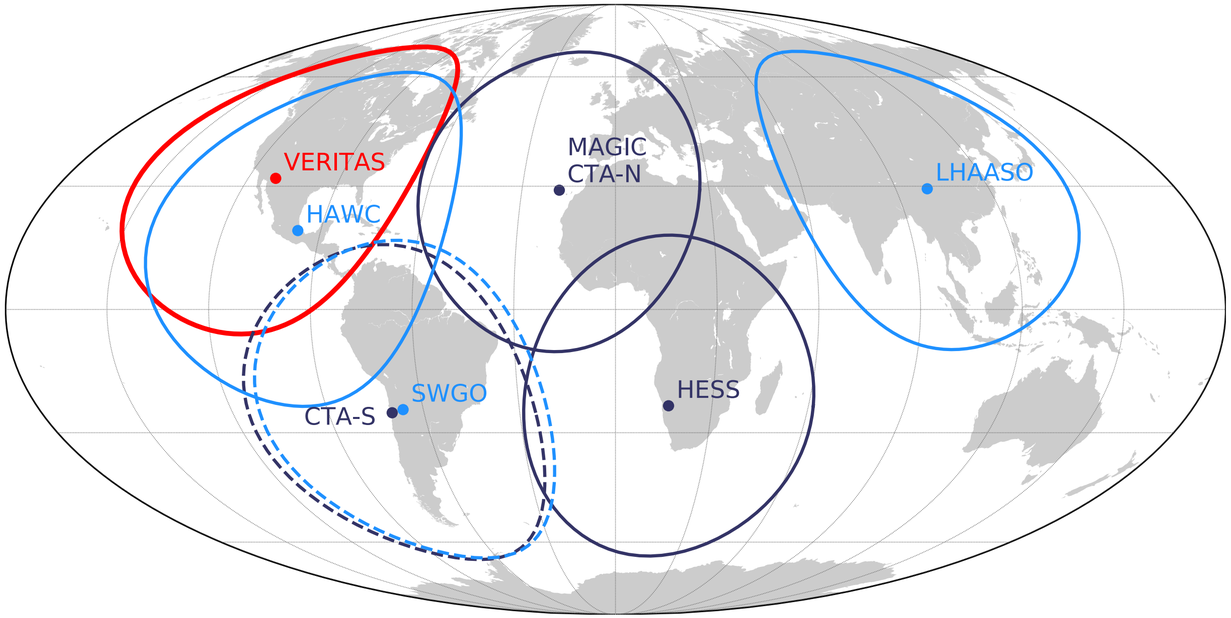
Multimessenger Transients Follow-Up



- ~10 deg2 FoV, + high sensitivity allow VERITAS to observe a wide variety of VHE sources and candidate emitters.

Multimessenger Transients Follow-Up

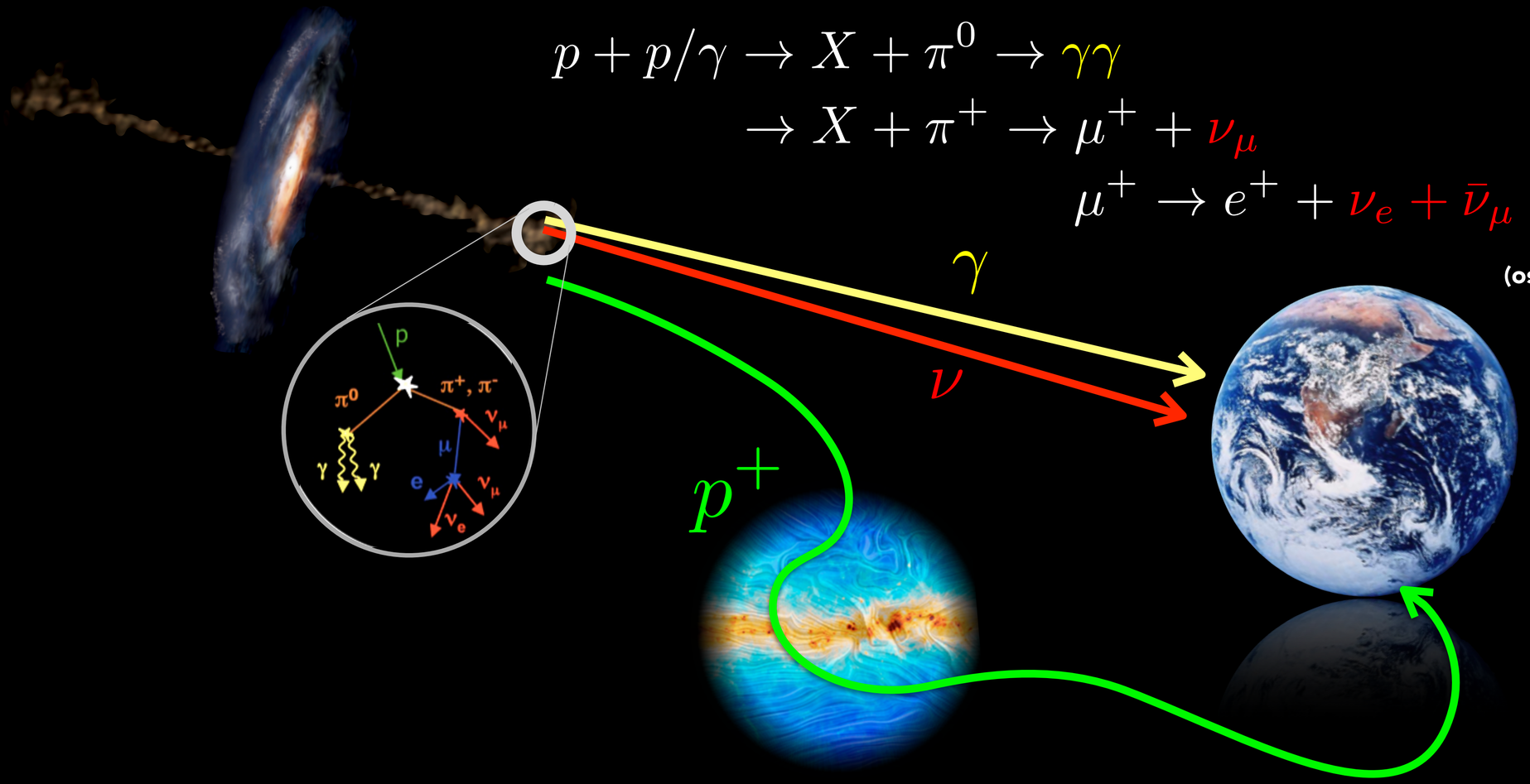




- ~10 deg2 FoV, + high sensitivity allow VERITAS to observe a wide variety of VHE sources and candidate emitters.
- **Collaborations with other imaging atmospheric Cherenkov telescopes and air-shower arrays enable coordinated target-of-opportunity observations.**

Prompt Searches for Very-High-Energy γ-Ray Counterparts to IceCube Astrophysical Neutrino Alerts

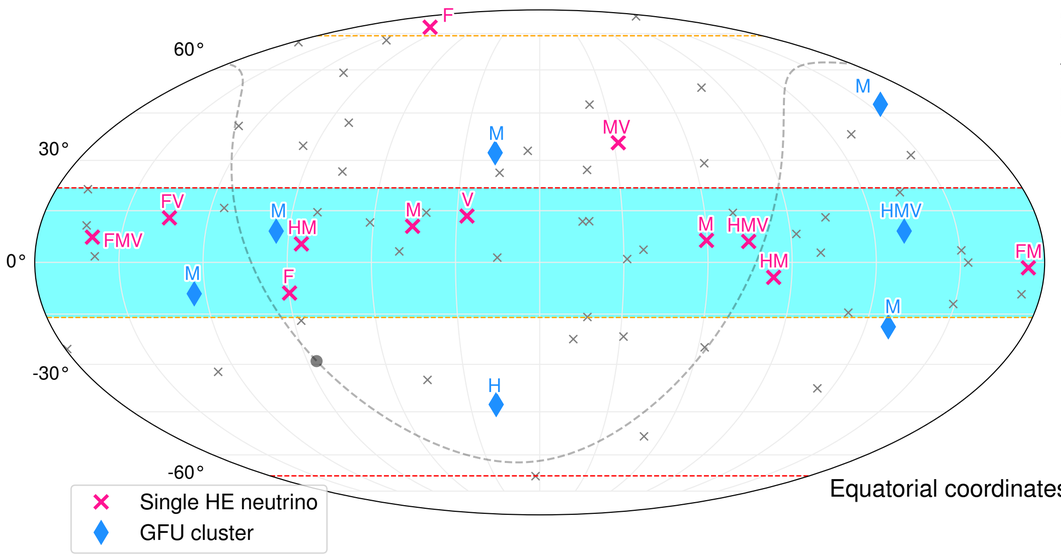
$$p + p/\gamma \rightarrow X + \pi^0 \rightarrow \gamma\gamma$$
$$\rightarrow X + \pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$



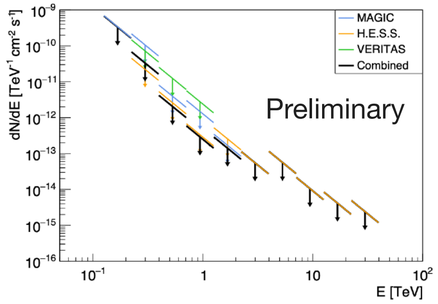
See Mauricio Bustamante's plenary talk.

Prompt Searches for Very-High-Energy γ-Ray Counterparts to IceCube Astrophysical Neutrino Alerts

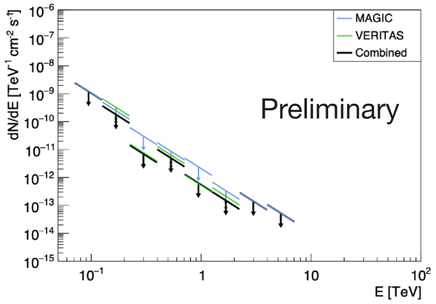
Name (GCN Circular)		Energy [TeV]
IC-171106A	E	230
IC-181023A	E	120
IC-190503A	E	100
IC-190529A†	H	—
IC-190730A	G	299
IC-190922B	G	187
IC-191001A	G	217
IC-200107A‡	—	—
IC-200926A	G	670
IC-201007A	G	683
IC-201114A	G	214
IC-201222A	G	186



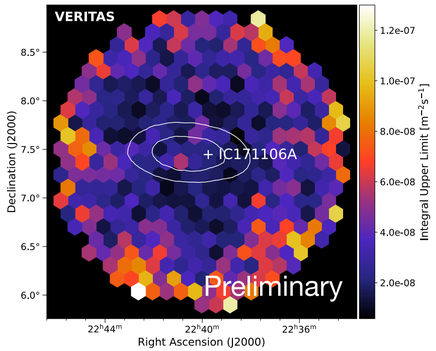
Skymap in equatorial coordinates showing IceCube alert positions in the period from September 2017 to January 2021. Letters indicate which IACTs participated in the observations (F - FACT, H - H.E.S.S., M - MAGIC, V - VERITAS). The latitude band between two dashed orange lines and two dashed red lines indicate regions of the sky that are potentially observable at zenith angles less than 45° from the northern (FACT, MAGIC, VERITAS) and southern (H.E.S.S.) IACTs, respectively. The light cyan band represents the overlapping visibility window for instruments in both hemispheres around the celestial equator, where the IceCube sensitivity to neutrinos in the ~100$ TeV energy range is at its best.

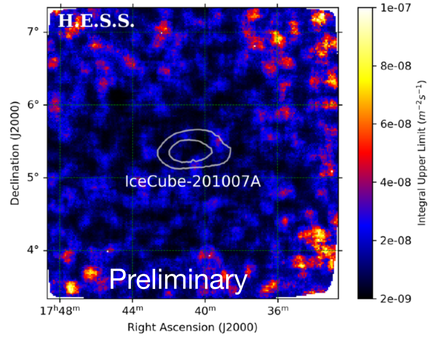


(e) GB6 J0316+0904 (Section 5.6)



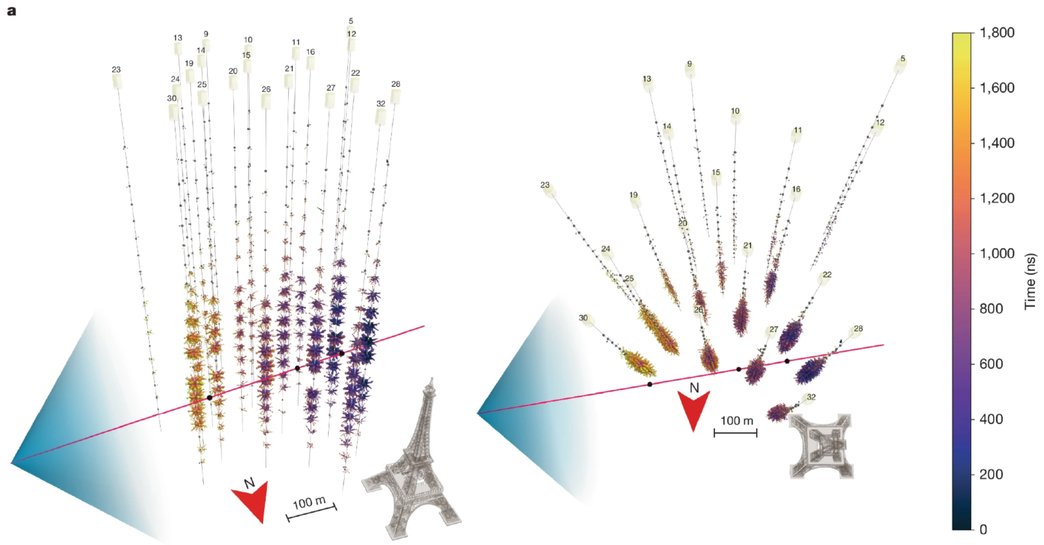
(f) IceCube-200107A/4FGL J0955.1+3551 (Section 6.7)



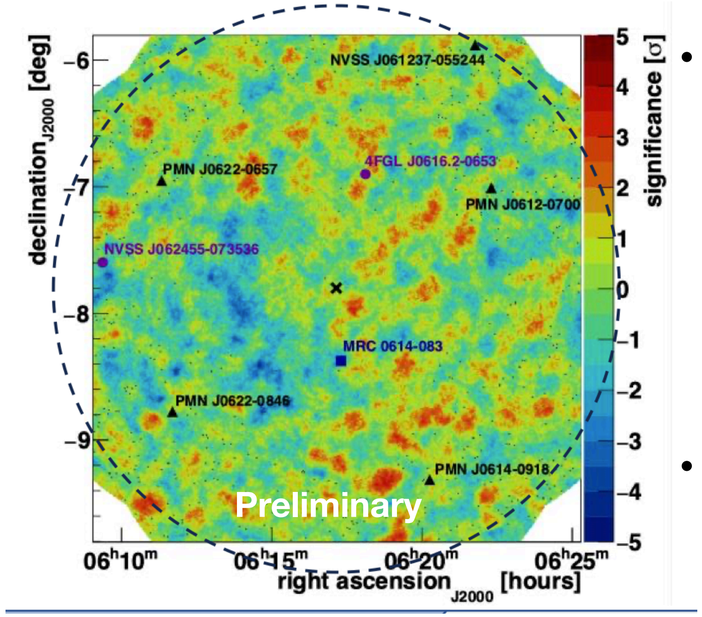


- A comprehensive analysis of follow-up observations of high-energy neutrino events observed by the four IACTs between September 2017 and January 2021.
- Our study found no associations between γ-ray sources and the observed neutrino events. We provide a detailed overview of each neutrino event and its potential counterparts.
- A joint analysis of all IACT data is included, yielding combined upper limits on the VHE γ-ray flux.

Probing for Gamma-Ray Emission near KM3-230213A Neutrino Event with VERITAS



Credit: KM3NeT Collaboration. Nature, 638, 376.



Connor Mooney, ICRC 2025.

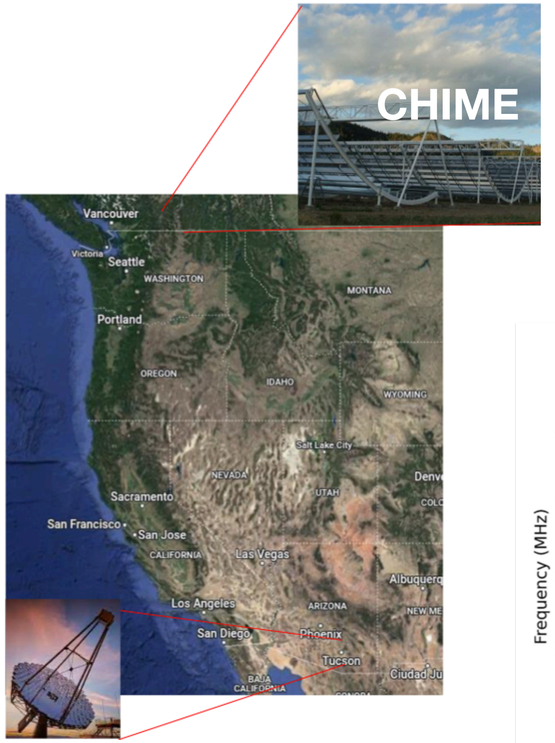
- **MRC 0614-083 is one of the most promising candidate:**
  - Closest (0.6°) to best-fit position
  - Soft X-ray flare buildup around time of neutrino detection.
- **Standard point-source analysis yield integral flux U.L (E > 550 GeV):**
  - **At best-fit position:** 1.2×10^{-12} erg cm^{-2} s^{-1} = 1.8% C.U.

- **Detected on Feb. 13, 2023 by KM3NeT/ARCA.**
- **The Most Energetic Neutrino Detected:**
  - Triggered 3,672 PMTs (~35%).
  - Parent neutrino energy: 220 PeV +570 / -150 PeV (90% C.L).
- **Angular uncertainty 2.2° radius (90% C.L.)**
- **IceCube has no reported events above 10 PeV.**
- **See Piera Sapienza's plenary talk.**

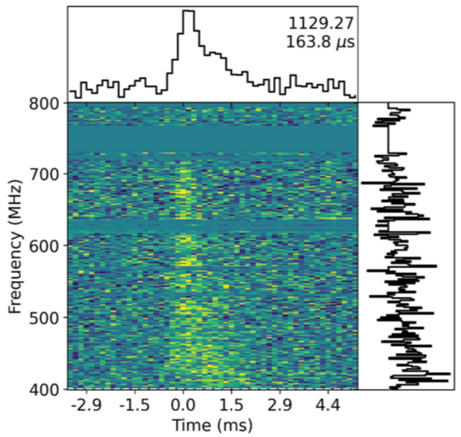
- **VERITAS observations were conducted for two weeks beginning Feb. 18, 2025 (17.62 hours).**
- **Region spans 4.4° diameter, contains 8 cataloged blazar candidates.**

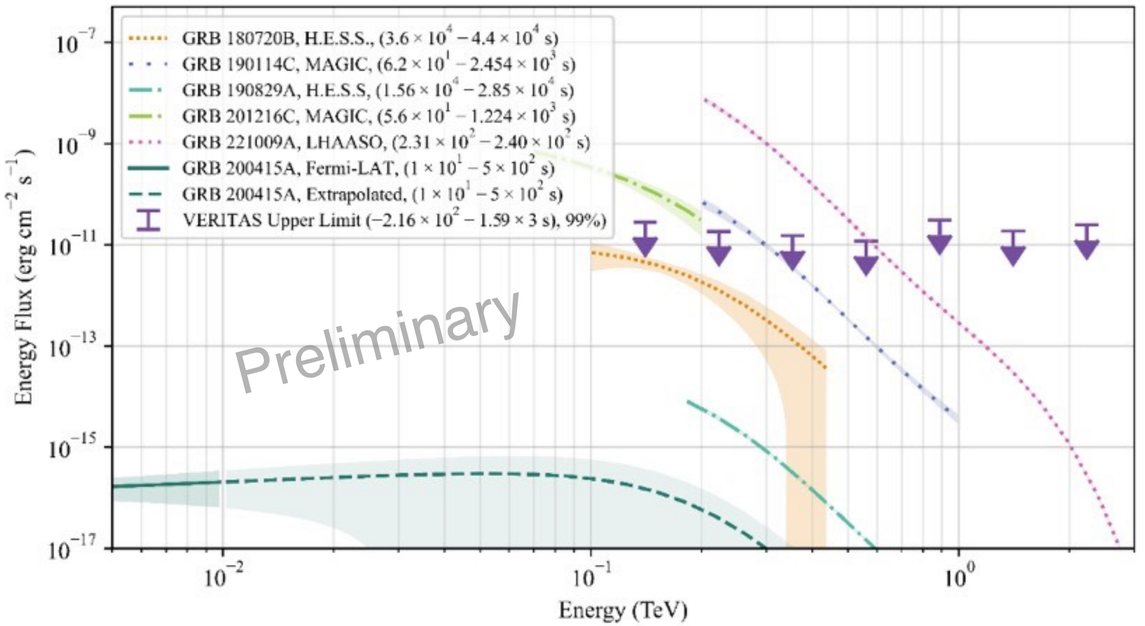
Name	RA (°)	Dec (°)	Significance (σ)	Emission Bands
MRC 0614-083	94.2623	-8.3749	-1.6	Radio, IR, Optical, X-ray
4FGL J0616.2-0653	94.06	-6.9	1.1	Fermi
PMN J0622-0657	95.7419	-6.9478	0.2	Radio, IR
NVSS J062455-073536	96.2306	-7.5936	-0.6	Fermi, Radio, IR
PMN J0612-0700	93.0202	-7.00635	-0.5	Radio, IR
PMN J0614-0918	93.5252	-9.31053	0.7	Radio, IR
PMN J0622-0846	95.6583	-8.77174	0.7	Radio, IR
NVSS J061237-055244	93.1557	-5.879	-0.9	Radio

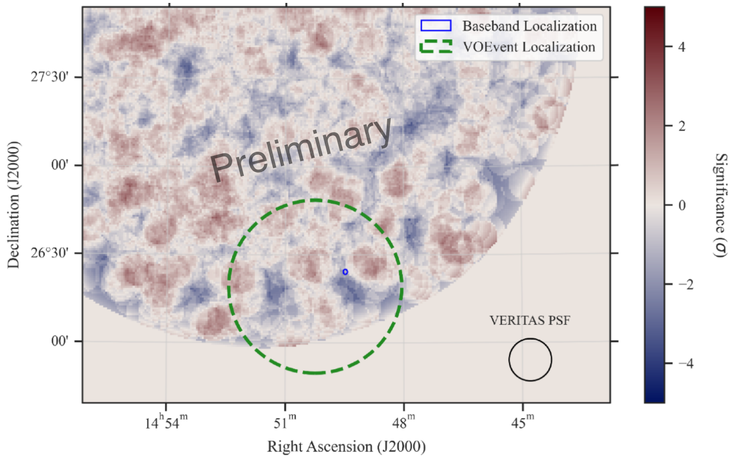
Fast Radio Bursts Counterpart Searches with VERITAS



- CHIME is a low frequency, large FoV radio telescope located in Penticton, BC, Canada.
- 400-800 MHz
- FoV ~ 2° x 120°





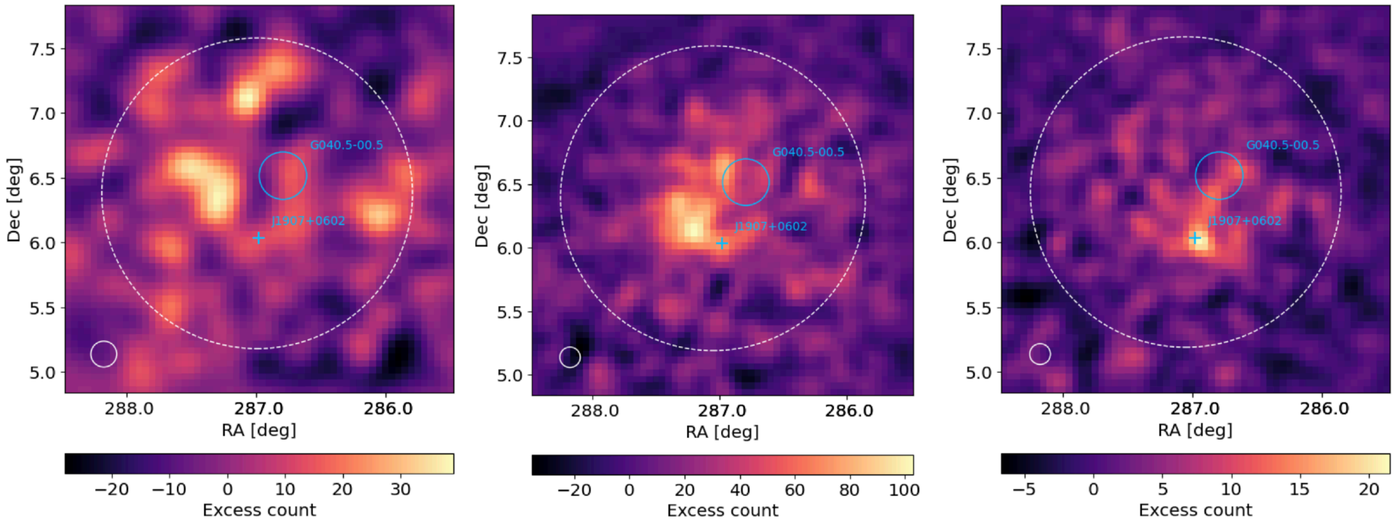


- FRB is characterized by bright, coherent, millisecond-duration radio pulses of as-yet-unidentified origin(s).
- The baseband localization error is below our point-spread function (~0.1 deg).
- The dispersion measure is suggestive of a redshift of ~0.9, assuming a negligible host contribution.
- VERITAS present the first simultaneous TeV observations with a known non-repeating **FRB 20240509A** (4 minutes before the FRB was detected by CHIME). This places constraints on many cataclysmic models of non-repeater emission **($\eta_{r\gamma}$>3.3×10^{-10})**.

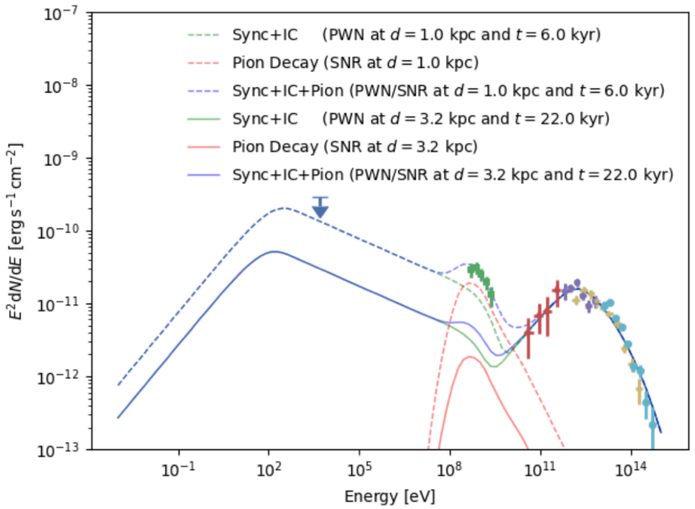
Galactic Science

Multiwavelength Investigation of γ-ray Source MGRO J1908+06 Emission Using Fermi-LAT, VERITAS and HAWC

- An extended TeV gamma-ray source in the Galactic plane, was originally discovered by the Milagro detector (~20 TeV).
- First application of a newly-developed VERITAS data analysis method for extended sources.
- Energy-dependent morphology.
- Observations support scenario that inverse-Compton emission of an evolved pulsar wind nebula (PWN) undergoing an interaction with the SNR reverse shock.
- At lower γ-ray energies (cooling break Eγ <1.5 TeV), the emission comes from older, cooled electrons left behind in the relic PWN. This produces asymmetric, extended γ-ray emission offset from the PSR J1907+0602's position.
  - Best-fit true age of 22 ± 9 kyr and magnetic field of 5.4 ± 0.8 μG



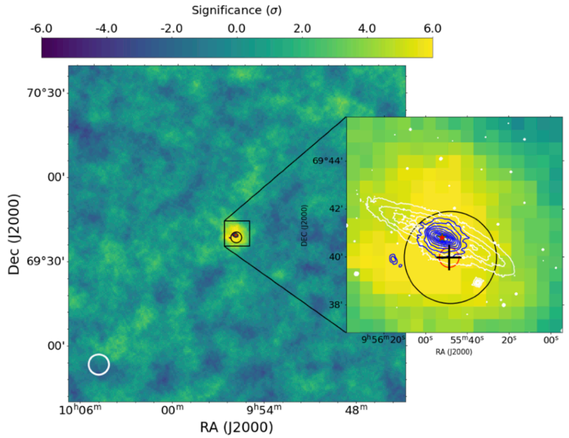
(a) Fermi–LAT γ-ray residual map in the energy range [30,300] GeV. (b) VERITAS γ-ray residual map in the energy range [0.5, 2.0] TeV (c) VERITAS γ-ray residual map in the energy range [2.0, 7.9] TeV.

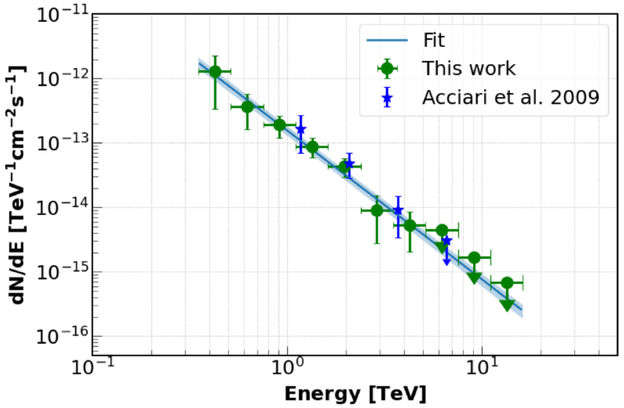


Adams, C. B., et al. *The Astrophysical Journal* 985.1 (2025): 90.

Starburst Galaxy

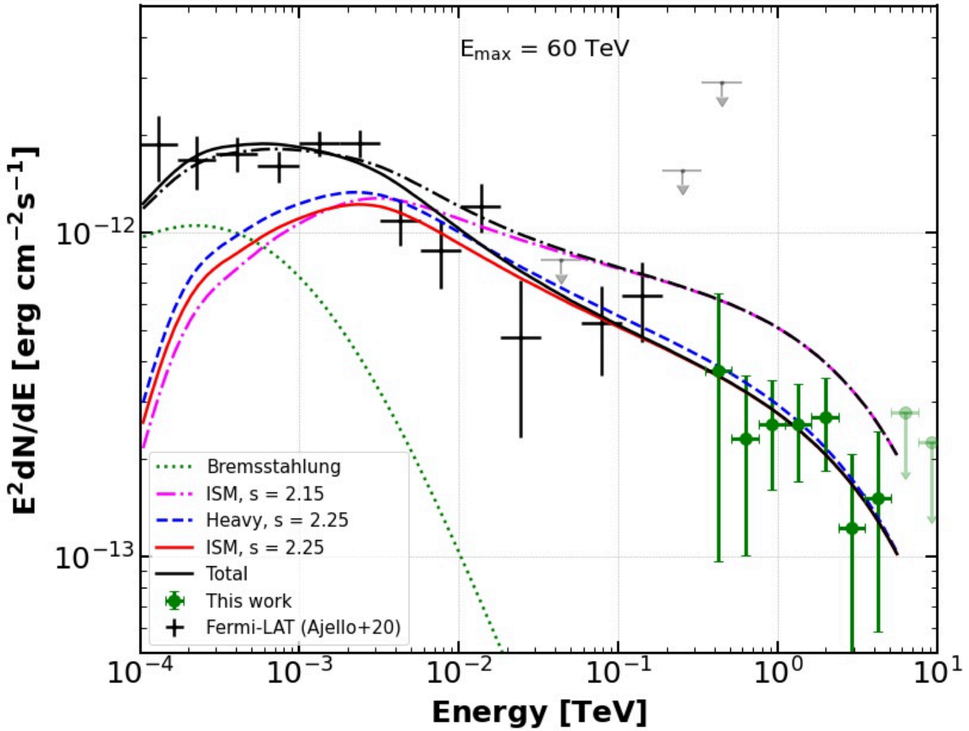
An in-depth study of Gamma rays from the Starburst Galaxy M82 with VERITAS





- Starburst galaxies are emerging as a prominent class of γ-ray emitters — massive stars (via supernovae and winds) drive exceptionally high CR densities.
- More good-quality data (254 h from 2008-2023) with 6.5 σ compared to previous VERITAS results from 2008-2009.
- More sensitive, lower-threshold analysis methodology.
- Improved spectrum: $\Gamma = 2.31 \pm 0.26$
  - Norm @ 1.4 TeV = (7.17 ± 1.23) x 10^{-10} TeV^{-1} m^{-2} s^{-1}.
  - c.f. $\Gamma = 2.5 \pm 0.6$ originally.
- Revised flux: F(>450 GeV) = (3.2 ± 0.6stat ± 0.6sys) × 10^{-13} cm^{-2} s^{-1} (~0.4% Crab).

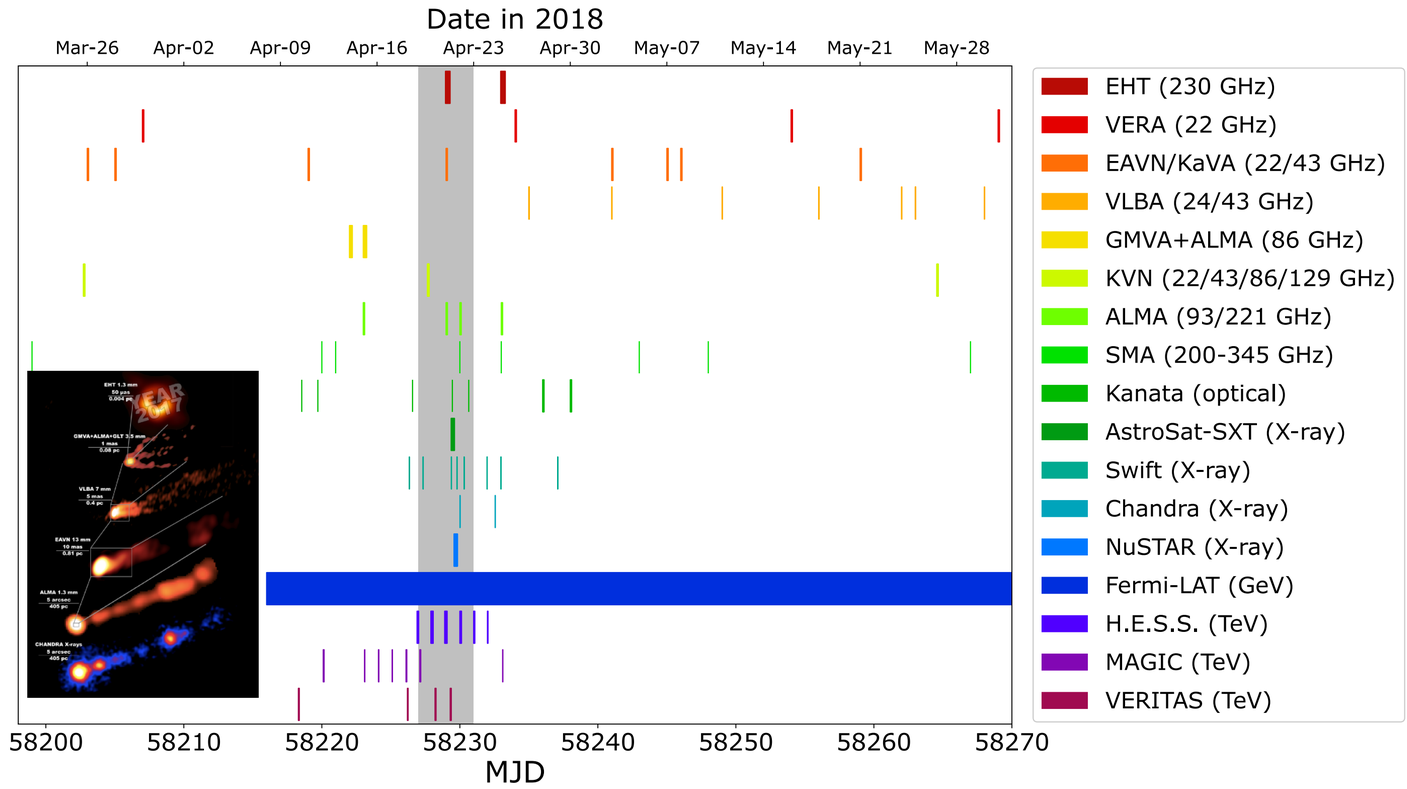
- A purely leptonic scenario for the SED of M82 is very unlikely.
- A lepto-hadronic scenario with a power-law spectrum & significant bremsstrahlung below 1 GeV, provides a good match to the observed SED.
- Spectral index s ≃ 2.25 in line with results for individual supernova remnants.

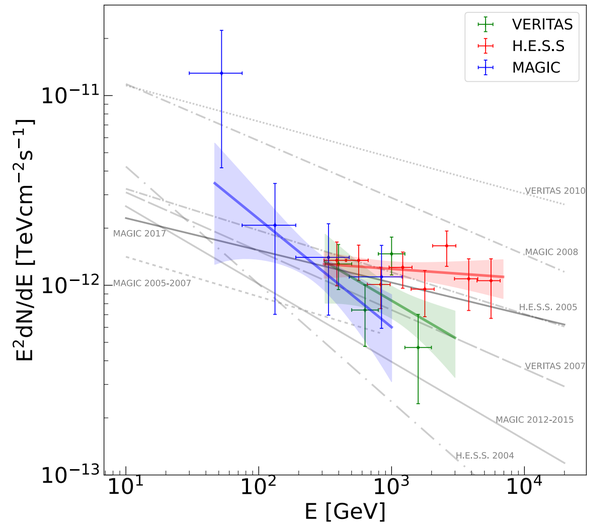


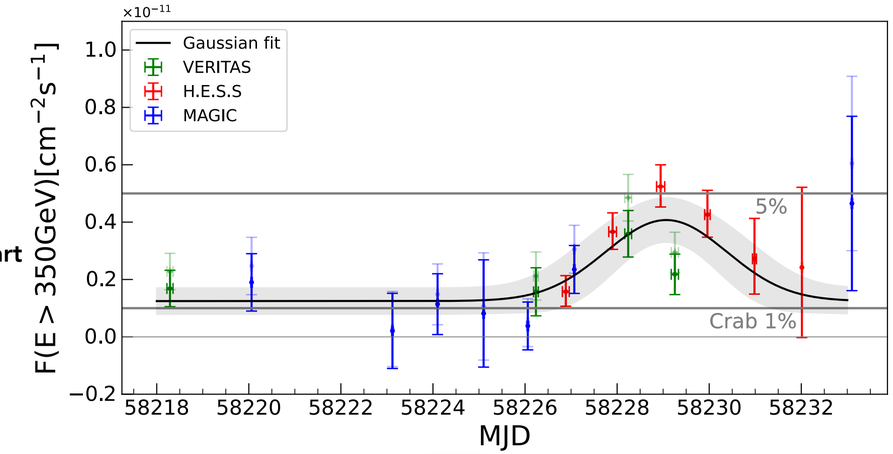
Acharyya, Atreya, et al. The Astrophysical Journal 981.2 (2025): 189.

Active Galactic Nuclei (AGNs) Results Highlights

Broadband Multi-wavelength Properties of M87 during the 2018 EHT Campaign including a Very High Energy Flaring Episode



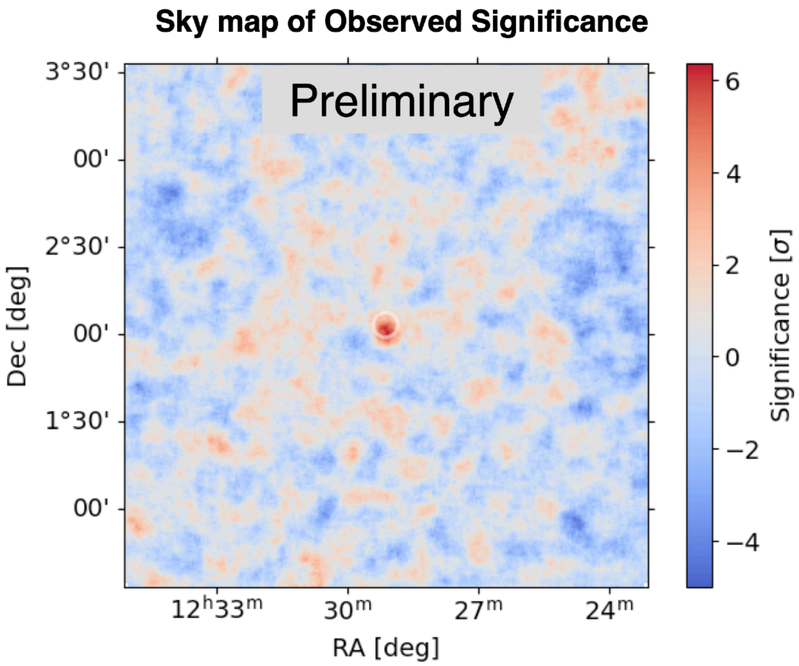




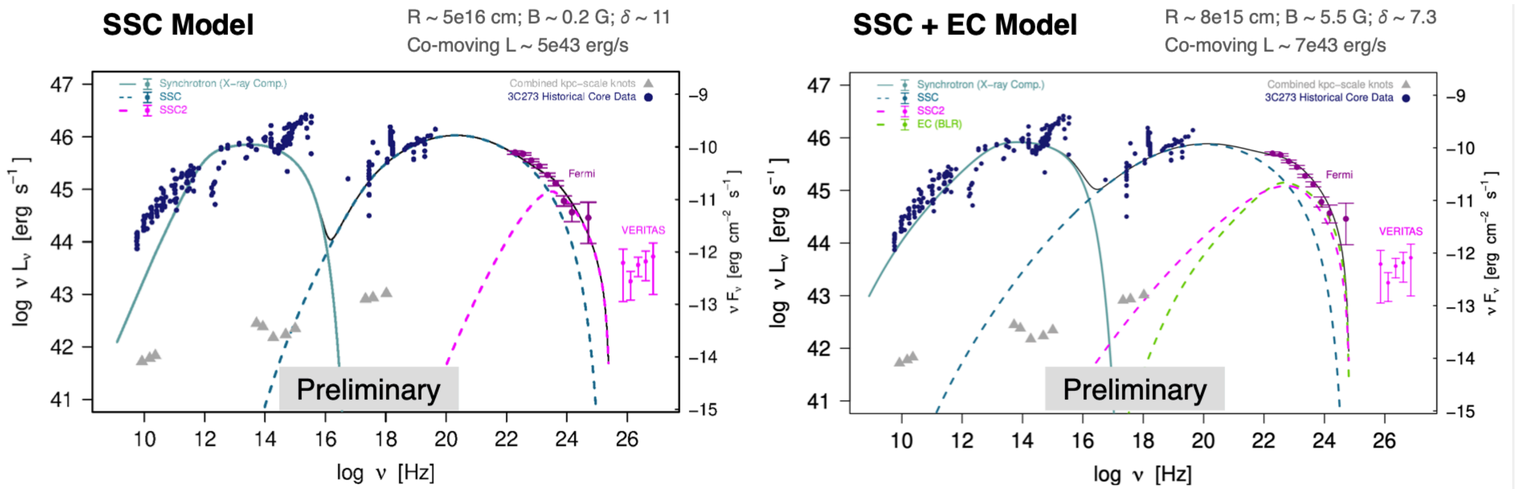
- In 2018, VERITAS, together with more than two dozen multi-wavelength (MWL) facilities (from radio to gamma-ray energies) took part in the 2nd M87 EHT campaign.
- A short (~ 3-days) VHE γ-ray flare was detected by IACTs from M87 since 2010.
- One-zone model is not able to model the broadband SED. Potential scenarios: magnetic reconnection in magnetized plasma, a structured, multi-zone scenario.
- We have acquired a full set of complementary, contemporaneous MWL observations for M87*, both to support the modeling and interpretation, as well as to provide a legacy dataset for the community.

Algaba, Juan Carlos, et al.,Astronomy & Astrophysics 692 (2024): A140.

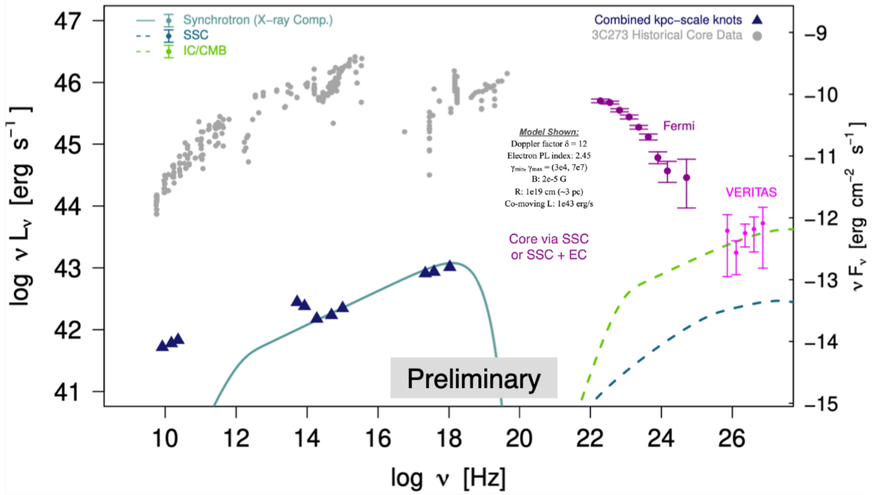
Discovery of 3C 273 in the Very-high-energy Regime



- Located in the direction of Virgo at a distance of 1.9 billion light years (z = 0.159).
- Data set: ~231 hours from 2008-2025 (Energy threshold ~ 350 GeV).
- Post trials probability of detection => 4.9σ; Confirmed by independent analyses.
- Constant flux; F(>350 GeV) = (2.3 ± 0.5) x 10^{-13} cm^{-2} s^{-1};

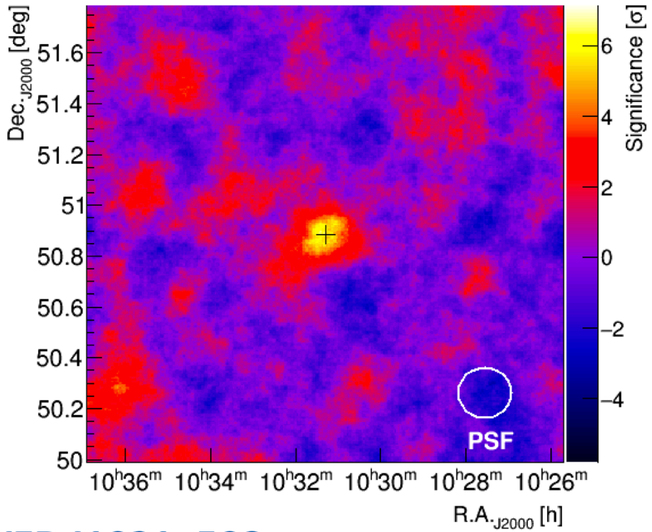


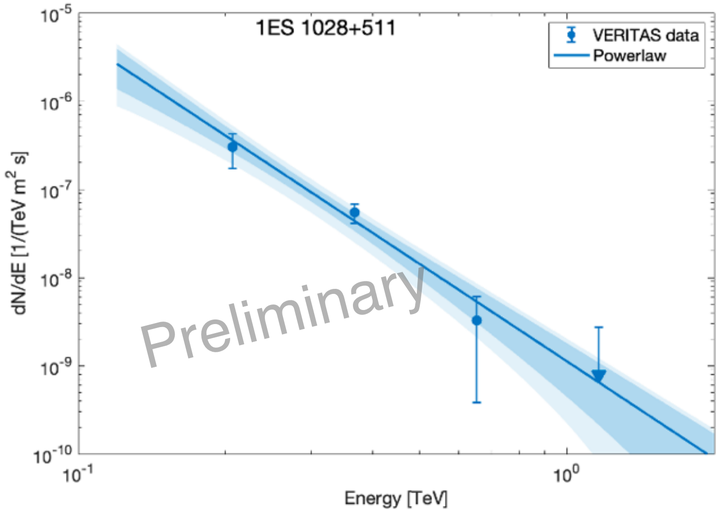
- SSC: Using typical parameters for 3C 273 is reasonable match for much of SED, but does not match VHE.
- SSC + EC: better match to much of SED, but VHE data are still problematic.



- Strong Possibility: IC/CMB from extended jet naturally explains the VERITAS excess.
- Parameters are reasonable; "small" size is to agree with year-scale variability constraints.

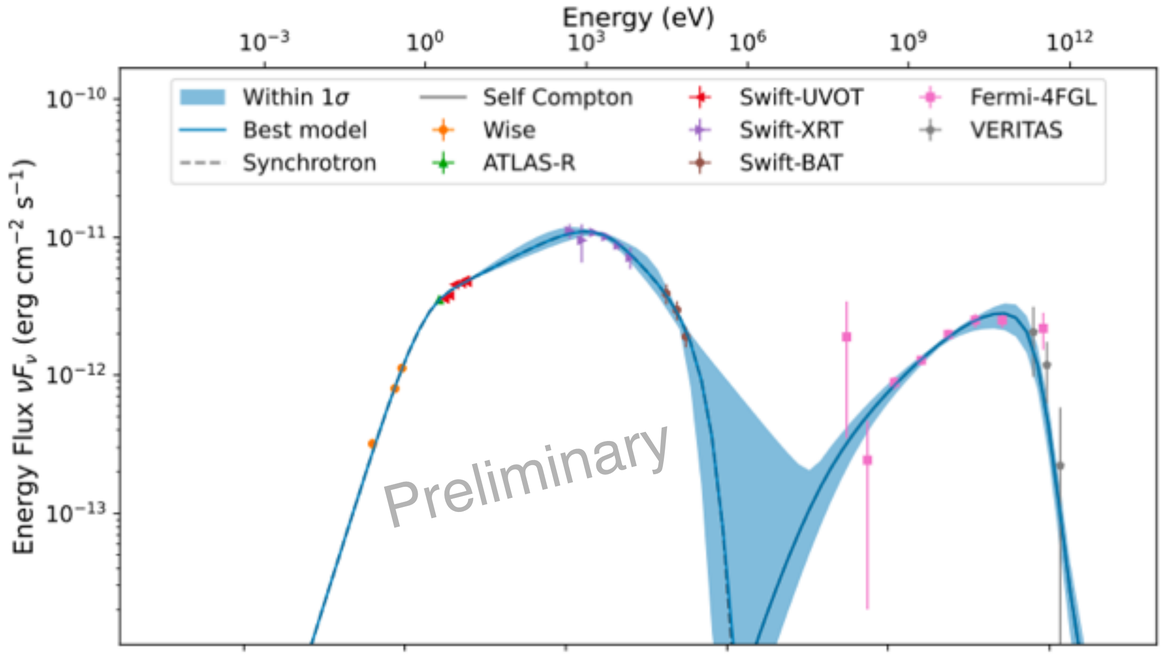
VERITAS Discovery and Multi-wavelength Observations of 1ES 1028+511





- Report on 48.5 hours of quality selected data with 6.4 σ.
- Flux(>200GeV): (2.50±0.45)x10^{-8}m^{-2}s^{-1} (~1% Crab).
- f_0 = (9.2 ± 2.0 (stat) ± 1.8 (sys))×10^{-8}/($TeV\ m^2 s$)
- Γ=−3.7±0.5 (stat) ±0.1(sys)

- Single-zone SSC model fits MWL fluxes well (Bjet_MCMC, Hervet et al. 2024, ApJ).
- 1ES 1028+511 is typical of EHBL with log10(synchrotron peak) =$17.4^{+0.3}_{-0.4}$ Hz.
- Out of equipartition: U_B/Ue < 0.1.
- High Doppler factor > 70.
- High γ_{min} > 2500.
- MWL fluxes shown are archival.

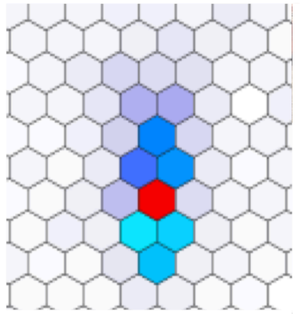


Looking Forward with VERITAS

- **Uninterrupted monitoring of variable galactic and extragalactic sources.**
  - Provide decade-scale light curves to connect smoothly with CTAO.
  - Spectrally and spatially resolve large scale emission and energy-dependent morphology studies.
- **Prompt follow-up on extraordinary transient events.**
  - Unique geographical location:
  - MMA: O4 and O5 GW events, IceCube neutrino alerts
  - Timely opportunities: TCrB, GRBs, flaring z > 1 blazars
  - New instrument triggered ToOs (LHAASO, Einstein Probe, SVOM, Glowbug, BurstCube, LSST, …)
- **Synergies with the pSCT:**
  - Compact wide **8° FoV** provides improved coverage of poorly-localized transients/multimessenger events.
  - Improved angular resolution for morphology studies.
- **Continue coordinated efforts to understand particle acceleration in extreme conditions (e.g. EHT, IXPE, NuSTAR, Fermi, Swift, CHIME, IceCube, HAWC, …)**

The 9.7 m prototype Schwarzschild-Couder telescope (pSCT) installed at the VERITAS site. Adams, C. B., et al. *Astroparticle Physics* 128 (2021): 102562.

1 TeV gamma-ray shower



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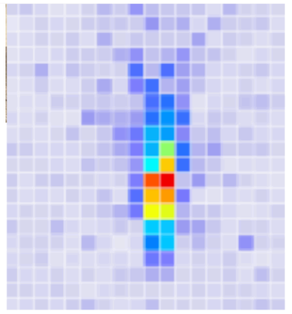

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Thank You!