Recent VERITAS Highlights

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Alisha Chrome for the VERITAS Collaboration
Talk Outline

- Current VERITAS performance
- Major science highlights
  - Galactic
    - High energy binary+plerion PSR J2032+4127
    - High energy binary HESS J0632
  - Active Galactic Nuclei
    - Detection of blazar B2 1811+31
    - Detection of radio galaxy 3C 264
  - Other
    - Galactic Center
    - Stellar angular diameters
- Summary and future of VERITAS

Current VERITAS Performance

- Four 12m Cherenkov telescopes in southern Arizona, at the Fred Lawrence Whipple Observatory.
- Full-scale operations began: September 2007
- Sensitivity: detect 1% of the Crab flux in < 25 hours
- Energy Range: ~85 GeV to ~30 TeV
- Angular resolution: ~0.08 degree at 1 TeV.
- Field of view: 3.5 degrees
- Observing time: ~1,300 hours per season
- About 80 members from ~20 institutions
Current status and future projections

VERITAS observatory
Highlights: Galactic, AGN, Other
Project Future

64 total sources
newest source (Oct. 2020): B2 1811+31

> Shutdown due to COVID-19 from March-June 2020.

> Since operations resumed, we operate with local technical staff, with remote observers.

> VERITAS site operations are fully funded through 2022. The Collaboration has committed to seek funding to operate the array until 2025.
PSR J2032+4127 is a pulsar/Be star binary system, period approximately 50 years. The pulsar also powers a pulsar wind nebula, visible in gamma-rays.

November 13 2017 was the most recent periastron. Multiple telescopes dedicated observing in the months leading to and following periastron, including gamma-rays and X-rays.

VERITAS spectrum, high (periastron) & low states (June-Oct)

Science Highlights: New Surveys of HESS J0632+507

Archer et al. 2019 (ApJ 888, 115) conclude that a leptonic model is a good fit to the joint X-ray and gamma SED, further supporting the pulsar scenario.

- Binary system is a B0pe star, surrounded by a thick equatorial disk, and an unknown compact object, no pulsations detected.
- Orbital period from long-term Swift observations: 315 (+6/-4) days. Two orbital solutions exist.
- The paper reports joint analysis of simultaneous VERITAS and NuSTAR (hard X-rays) observations in November and December 2017.
- Two other joint collaboration articles on the long-term light curve are under internal review:
  - Another joint paper with NuSTAR
  - VERITAS, HESS, and MAGIC observations, 2004-2019

The upcoming joint H.E.S.S., VERITAS, and MAGIC article consists of 450 hours of exposure, the deepest study at TeV energies. Preliminary results were shown at ICRC 2019

- VERITAS has over 250 hours of exposure.
- Measured orbital period with gamma-ray data and two methods: $318.7 \pm 3.4$ days and $316.3 \pm 4.3$ days. Consistent with X-ray measurement: $315 (+6/-4)$ days
- Upcoming joint TeV publication:
  - looks for orbit-to-orbit variability
  - isolates outbursts for separate analysis
  - spectral analysis between phases and orbits
  - looks for correlation across X-ray, gamma, and optical


• B2 1811+31 is a BL Lac-type blazar at a redshift of 0.117.

• B2 1811+31 showed high levels of activity at optical wavelengths and in Fermi-LAT’s GeV band during the first half of October 2020.

• After reported detection by MAGIC (ATel #14090), VERITAS observed B2 1811+31, from October 15-19 2020.

• Detected with a statistical significance level of 7 standard deviations after 4.3 hours of livetime.

• Preliminary VERITAS soft photon index: 4.09 +/- 0.6

• Preliminary VERITAS mean flux (E>250 GeV): 6 +/- 1 % Crab
Science Highlights: new VERITAS source 3C 264

- Most distant radio galaxy seen at very high energies.
- Statistical significance of 7.8 standard deviations after ~57 hours of live time.
- VHE flux is variable. Highest flux observed in 2018 coincided with modestly elevated fluxes observed in other wavelengths.
- VERITAS continues to monitor this source.

VHE spectrum observed by VERITAS in 2018

Index = 2.20 +/- 0.27
Flux ~ 0.7% Crab above 315 GeV

Light curves measured by VERITAS and Swift-XRT

Science Highlights: Galactic Center

- Submitted journal article for publication, currently under review.
- **155 hours** of large zenith angle of galactic center observations.
- Spectral analysis: diffuse ridge emission, VER J1745-290, SNR G0.9+0.1, and HESS J1746-285
- The galactic center is a regular observing target for VERITAS.

![diffuse ridge emission spectra](image)

**Preliminary**

- $E^2 dN/dE$ (TeV cm$^{-2}$ s$^{-1}$) plot
- Power law
- Index: $2.19 \pm 0.20$

**Significance map > 2 TeV**

![significance map](image)

**Significance map > 10 TeV**

![significance map](image)

Credit: NASA/DOE/Fermi LAT Collaboration

Alisha Chromey : 9th Fermi Symposium (Virtual)
Science Highlights: New gamma-ray targets and beyond

VERITAS operates foremost as a gamma-ray telescope. However, with multiple multi-messenger discoveries since 2007 and new optical applications of telescope hardware, VERITAS has a diverse list of science targets, including:

- **Gamma-ray follow-up**
  - Fast Radio Bursts: observing repeating FRBs, time-coincident with radio observations
  - LIGO and IceCube: follow up observations on alerts (ex: TXS 0506+056)
    - Details in Wei-dong Jin Parallel-7

- **Optical**
  - Fast Radio Bursts: also searching for optical signal
  - Stellar angular measurement: stellar intensity interferometry and asteroid occultation
  - Optical SETI: searching for nanosecond optical flashes, consistent with artificial origin
VERITAS has two publications in Nature Astronomy reporting on the angular sizes of multiple stars.

**Stellar Intensity Interferometry (SII)**
- angular diameters of β Canis Major and ε Orionis with precision better than 5%
- current SII limiting magnitude: $m_V \approx 3.5$
- over 100 hours of SII observations of OBA stars

**Asteroid occultations**
- angular diameters of two stars 10.2 and 9.9 V-magnitude
- can view ~5 occultations per year

Direct measurement of star angular diameter at < 0.1 milliarcsecond scale!

Comparison of VERITAS asteroid occultation results to other directly measured stellar angular sizes.
Future of VERITAS

- This is VERITAS’s 14th season of full-scale operation!
- The scientific output remains strong; twenty papers have been published from 2018 to now, with a few coming up soon for publication, including joint collaboration projects.
- Telescope operations guaranteed to continue through 2022
- The prototype SCT telescope for CTA, also at the Whipple observatory with VERITAS, has detected the Crab Nebula, and is undergoing further development.

Operating beyond 2022
- Joint science between VERITAS and pSCT
- Analysis methods to improve source sensitivity
- Telescope operation until surpassed by CTA (~2025)
- SII upgrade proposal

CTA prototype, pSCT, inaugurated in Jan. 2019
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References

10. VERITAS, ATel #14104
Backup Highlights

VERITAS observatory

Highlights: Galactic, AGN, Other

Project Future
Science Highlights: Electron and Iron Spectrum

Electron spectrum 300 GeV to 5 TeV

- About 300 hours of observation
- Broken power law with break at ~710 GeV

Iron spectrum 20 TeV to 500 TeV

Power law with:
\[ \gamma = 2.82 \pm 0.30 \text{(stat)}\pm 0.24 \text{(sys.)} \]
\[ f_0 = (4.82 \pm 0.98 \text{(stat.)})^{+2.12}_{-2.70} \text{(sys.)}) \cdot 10^{-7} \text{m}^{-2} \text{s}^{-1} \text{TeV}^{-1} \text{sr}^{-1} \]
\[ E_0 = 50 \text{ TeV} \]
Science Highlights: TXS 0506+506

- On September 22 2017, IceCube reported detection of a high-energy astrophysical neutrino candidate event
- VERITAS performed observation of the blazar between 2017 September and 2018 February
- 5.8 sigma detection by VERITAS after 35 hours of observation
- ~1.6% Crab (E>110 GeV)
- VERITAS continues to perform follow-up observations
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SED data-model comparison for the two orbital solutions in red and blue, overlay on the Dec. 2017 data.
Science Highlights: Galactic Center

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Spectra coincident with Sgr A*

HESS J1746-285 spectra

SNR G0.9+0.1 spectra

Preliminary

C.B. Adams et al. (submitted for publication)
Science Highlights: Stellar Angular Diameters

Ingress and egress light curves for asteroid occultations

Comparison of angular size measurements and stellar radius estimates, compared to others available in the literature.

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