VERITAS follow-up observation of the blazar TXS 0506+056

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Abstract

The gamma-ray blazar TXS 0506+056 was found with an enhanced gamma-ray emission state in spatial and temporal coincidence with the IceCube high energy neutrino event IC170922A [1]. This is the most significant association by far between a high-energy neutrino event and a blazar in a flaring state. Studying the time evolution and spectral behavior of the blazar emission may help in identifying the sources of the diffuse neutrino flux observed by IceCube and the origin of energetic cosmic rays. Here we will present results from recent VERITAS observations of TXS 0506+056 and an associated multiwavelength campaign, collected between **October 10, 2018 to March 1, 2021.** A relatively quiet very high energy gamma-ray emission state was observed during this time period, and flux upper limits are used to constrain the potential variability of this blazar.

The VERITAS Observatory [2]

- Location: Fred Lawrence Whipple Observatory (FLWO) in southern Arizona (31° 40'N, 110° 57'W, 1.3 km a.s.l.)
- Energy range: 85 GeV - 30 TeV. 15-25% energy resolution
- Sensitivity: 1% Crab in ~25h
- Angular resolution: < 0.1° at 1 TeV (68% containment radius).
- Observation time: ~750 h dark time + ~200 h moonlight per year.

Figure 1: Current configuration of VERITAS

Motivation.

- Since 2017, TXS 0506+056 remains the most significant correlation between a blazar and a high-energy neutrino.
- Time evolution and spectral behavior: identifying the sources of the diffuse neutrino flux observed by IceCube and the origin of energetic cosmic rays.

Multiwavelength observations

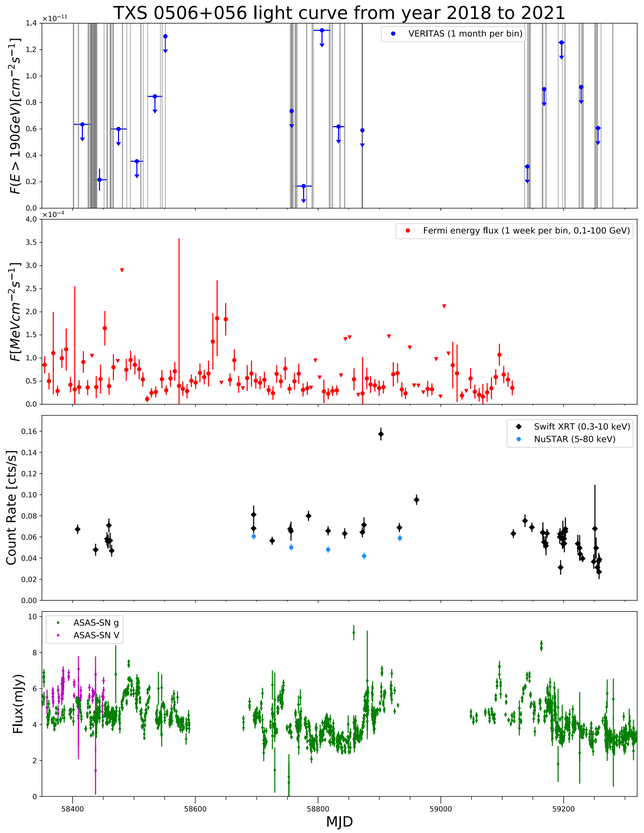

Figure 2: Multiwavelength light curves of blazar TXS 0506+056 from Oct 10, 2018 to March 7, 2021. The data set is composed of very-high-energy gamma-ray data from VERITAS, high-energy gamma-ray data from *Fermi*-LAT LCR[1], X-ray data from *Swift*[2] [3] and NuSTAR, and optical data from ASAS-SN Sky Patrol[3] [4].

1. https://fermi.gsfc.nasa.gov/ssc/data/access/lat/LightCurveRepository/
2. https://www.swift.ac.uk/user_objects/
3. https://asas-sn.osu.edu/

VERITAS observation of blazar TXS 0506+056 from 2018 to 2021

- VERITAS collected 61 hrs of quality-selected data from Oct 10, 2018 (MJD 58401) to March 7 , 2021 (MJD 59280)
- Average zenith angle of 28.8°
- The integral flux above an energy threshold of 190 GeV is $(1.34\pm0.40)\times10^{-12}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, corresponds to **0.52% ± 0.16% of the C.U.**
- The analysis yield a detection of the source above 190 GeV with a statistical significance of **3.4σ.**

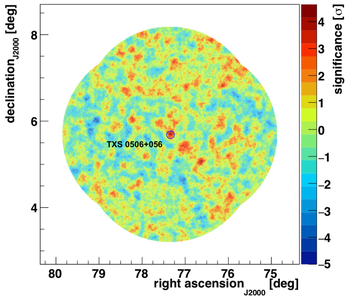

Figure 3: VERITAS significance sky map with TXS 0506+056 in the center.

Summary and outlook

- TXS 0506+056 is in a quiet state from year 2018 to 2021 and shows a **consistent flux level** compare to previous VERITAS observations collected in 2017-2018.
- An enhanced VHE gamma-ray emission detected by MAGIC on Dec1st (MJD 58453) and 3rd 2018 (MJD 58455) [5], no observation was made by VERITAS.
- A X-ray flare (higher than average flux by a factor of ~2) was observed on MJD 58902.
- **Clear variability** is observed in optical, X-ray and high energy gamma-ray bands. Quantitative analysis will be presented in an upcoming publication.

References:

[1] The IceCube Collaboration et al *Science* 361 no. 6398, (2018) .

[2] J. Holder et al. *Astroparticle Physics* 25 no. 6, (July, 2006) 391–40.

[3] P. A. Evans et al. *Monthly Notices of the Royal Astronomical Society* 397 no. 3, (Aug, 2009) 1177–1201.

[4] S. Kochanek, et al. *Publications of the Astronomical Society of the Pacific* 129.980 (2017): 104502.

[5] K. Satalecka, et al. *PoS (ICRC2019)* , vol. 358, p. 783. 2019.

Acknowledgements

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