VERITAS Observations of HESS J1943+213

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HESS J1943+213 is a very-high-energy (VHE; >100 GeV) γ-ray point source detected during the H.E.S.S. Galactic Plane Survey. Radio, infrared, X-ray, and GeV γ-ray counterparts have been identified for HESS J1943+213; however, the classification of the source is still uncertain. Recent publications have argued primarily in favor of an extreme BL Lac object behind the Galactic plane, though the scenario that HESS J1943+213 is a young pulsar wind nebula is viable as well. We present deep VERITAS observations of HESS J1943+213, which provide the most significant VHE detection of the source so far, with ~18σ excess. The source is detected at ~2% Crab Nebula flux above 200 GeV, with the source spectrum well fit by a power-law function and showing agreement with the H.E.S.S. detection. We also include *Swift*-XRT observations contemporaneous with VERITAS. No significant flux or spectral variability is detected with VERITAS or *Swift*-XRT observations. We place the VERITAS results in a multi-wavelength context to comment on the HESS J1943+213 classification.

HESS J1943+213 Classification

HESS J1943+213 was discovered in very-high-energy (VHE; E > 100 GeV) γ-rays during the H.E.S.S. Galactic plane scan [1].

The classification of HESS J1943+213 is still uncertain, with BL Lac object (blazar) behind the Galactic plane and young pulsar wind nebula (PWN) as the leading candidates. Recent evidence has been stacking in favor of the blazar hypothesis.

*Evidence **for** the blazar (**against** the PWN) scenario*

- Point-like appearance in X-rays and VHE γ-rays
- Soft VHE spectrum (Γ = 3.1 ± 0.3) from ref. [1]
- Broadband spectral energy distribution is very similar to known extreme HBL, 1ES 0347-121 [3]
- Potential detection of an elliptical host galaxy in near-infrared (K-band) observations of HESS J1943+213 counterpart [4]
- 1.5 GHz and 5 GHz e-Multiple Element Remotely Linked Interferometer Network (e-MERLIN) observations exhibiting a flat spectrum and showing flux density variability in the 1.5 GHz band when compared with the EVN data [5]

*Evidence **against** the blazar (**for** the PWN) scenario*

- Lack of significant flux variability in the X-rays, infrared, and γ-rays [1].
- Low brightness temperature (7.7×10^7 K) from 1.6-GHz observations with the European VLBI Network (EVN) [2]
- 1′ feature observed in the 1.4-GHz VLA C-array configuration image is consistent with a Crab-like PWN placed at a distance of 17 kpc [2]

If HESS J1943+213 is a blazar, it would be categorized as an extreme high-synchrotron-peak BL Lac object (extreme HBL) based on lack of evidence of a cutoff in the INTEGRAL-IBIS and *Swift*-BAT spectra up to 195 keV [1], a class of blazars with the synchrotron peak located at energies >1 keV [2].

VERITAS Instrument

- The Very Energetic Radiation Telescope Array System (VERITAS)
- An array of four 12-m imaging atmospheric Cherenkov telescopes
- Located in Arizona, USA at 1270 m elevation
- Cameras with 499 photo-multiplier tube
- See [6] for more details
- **Field of view**: 3.5°
- **Energy coverage**: 85 GeV and >30 TeV, with
- **Energy resolution**: 15-25%
- **Angular resolution**: < 0.1° at 1 TeV
- **Sensitivity**: 1% Crab Nebula flux source detected at 5σ in 25 hours

VERITAS Observations of HESS J1943+213

- Observation dates: 27 May, 2014 – 2 July, 2014
- Total weather-cleaned live time: 22.5 hours
- Source elevation: 63° – 80°

Swift-XRT Observations of HESS J1943+213 Counterpart

- *Swift*-XRT observations of HESS J1943+213 were obtained on 17 June, 19 June, 21 June, contemporaneous with VERITAS observations.
- XRT data was analyzed with *XRTDAS v3.0.0* tools in *HEASoft package Version 6.15.1*, with spectral analysis performed using *Xspec.*
- XRT flux spectra were obtained by unfolding the counts spectra with instrument response functions included in *CALDB 1.0.2* and by assuming an absorbed power-law functional form for the intrinsic spectrum and for the fits.
- **No significant spectral or flux variability is detected between observations.**
- *The results are consistent with previous observations from Swift XRT and other X-ray instruments in the same energy regime [1].*

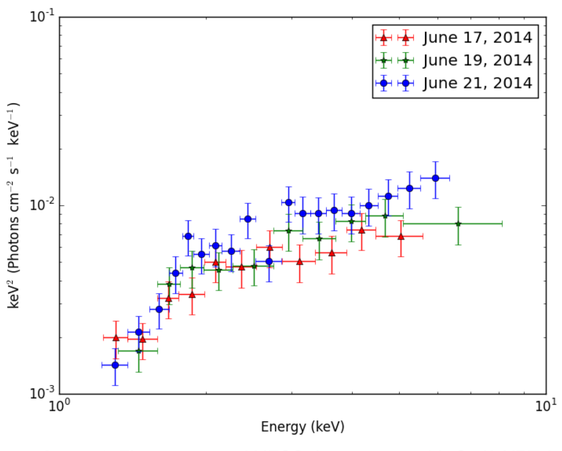

Figure 4. Flux spectra of HESS J1943+213 with *Swift* XRT for the three separate observations

Date	Observation ID	Exposure (seconds)	Log10[Flux] (2–10 keV) Log10 (erg cm^{-2} s^{-1})	Index	χ^2/NDF
2014-06-17	00033319001	967	-10.74±0.06	1.76±0.43	3.29/8
2014-06-19	00033319002	769	-10.66±0.05	1.98±0.37	3.25/7
2014-06-21	00033319003	1156	-10.52±0.04	1.65±0.28	11.93/16

Table 1: Summary of *Swift*–XRT observations.

VERITAS Detection of HESS J1943+213

- HESS J1943+213 is detected at **~17.5σ**
- Source location is consistent with the catalog position of HESS J1943+213 (black cross)
- Flux of (1.30 ± 0.20) × 10^{-12} cm^{-2} s^{-1} measured with VERITAS above 470 GeV is consistent with flux of (1.25 ± 0.20) × 10^{-12} cm^{-2} s^{-1} from the H.E.S.S. detection [1]
- VERITAS is able to observe HESS J1943+213 at a much higher elevation than H.E.S.S., leading to a significantly higher detection rate of ~**3.7σ/√hour** with VERITAS compared to ~**1.8σ/√hour** with H.E.S.S.

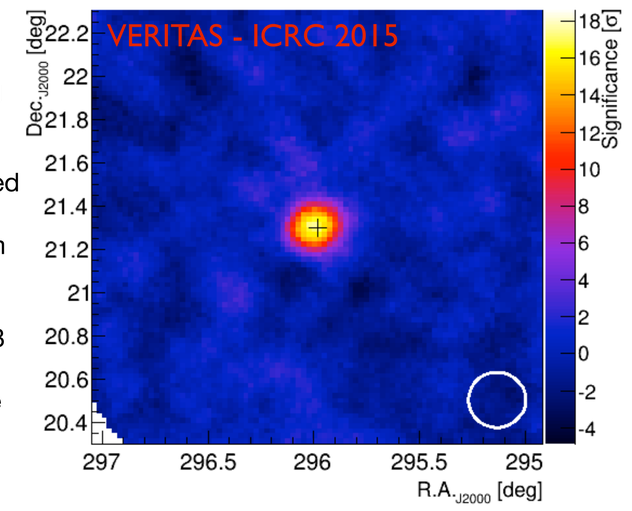

Figure 1. Significance sky map of VERITAS observations of HESS J1943+213

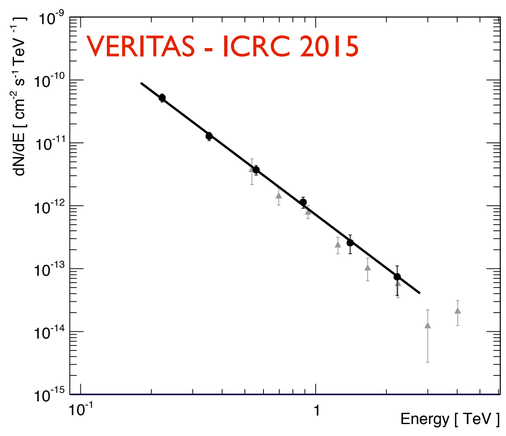

Figure 2. Differential energy spectrum of HESS J1943+213. The spectrum with VERITAS (black points) is between 200 GeV and 2 TeV and is fit to a power-law function. The spectral points from the H.E.S.S. result [1] are included for comparison (gray points).

- Low energy threshold of < 200 GeV (compared to 470 GeV for H.E.S.S.)
- HESS J1943+213 spectrum from VERITAS is well-fit by a power-law function with an index of **Γ = 2.82 ± 0.13** in the 200 GeV – 2 TeV energy range
- *The VERITAS spectrum of HESS J1943+213 is consistent with the spectrum from H.E.S.S.*

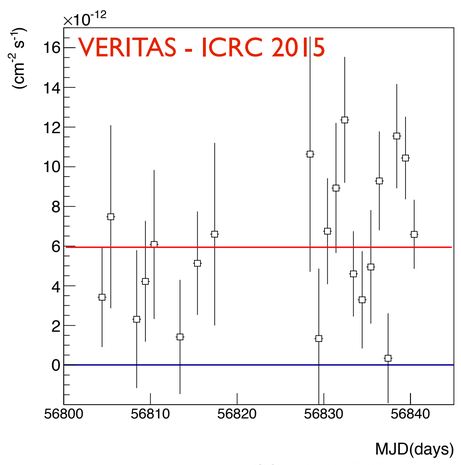

Figure 3. Daily light curve of HESS J1943+213 observations with VERITAS (showing only statistical uncertainties), with fluxes measured above 200 GeV. The red line is a constant flux fit to the data.

- Higher detection rate allows VERITAS to test for variability in HESS J1943+213 flux on a factor of four shorter timescales than H.E.S.S.
- The light curve is fit with a constant flux line resulting in a **χ^2/NDF = 31.34/20** or a **p-value of 0.05** for the constant flux hypothesis.
- With systematic uncertainties in flux included, *any hints of variability are not statistically significant*.

Discussion and Outlook

- If HESS J1943+213 is a blazar, the agreement between VHE fluxes and spectra from VERITAS and H.E.S.S. and the lack of flux variability in the X-rays is surprising, but not unusual.
- The detection of variability at 1.5-1.6 GHz by ref [5] is a strong piece of evidence for the blazar scenario and has weakened the lack of variability concerns.
- VERITAS can probe factor of four shorter timescales than H.E.S.S. for HESS J1943+213 and possesses one of the best VHE datasets available for searches of flux and spectral variability.
- Planned application of advanced analysis techniques, such as use of boosted decision trees for gamma-hadron separation will provide a better sensitivity and allow for an additional factor of two improvement in the minimum variability timescale that can be tested.
- The VERITAS spectrum, in conjunction with an improved *Fermi*-LAT spectrum using PASS 8 data will provide a more accurate measurement of the gamma-ray peak, which will be vital for future multi-wavelength studies of the source.

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