Abstract. The unidentified TeV gamma-ray source MGRO J1908+06/HESS J1908+063 was observed with the VERITAS Imaging Atmospheric Cherenkov Array during October 2007 and May-June 2008. This extended source is located on the galactic plane at a galactic longitude of 40.45 degrees and has a hard TeV spectrum with an index of $\Gamma \approx 2.08$. The Very High Energy (VHE) gamma-ray flux was measured by H.E.S.S. out to energies greater than 30 TeV which along with its unidentified nature makes it an interesting hard-spectrum extended source for study. We confirm the detection of VHE gamma-ray emission from this source using VERITAS.

Keywords: Gamma rays, Unidentified, Milagro Sources, VERITAS

INTRODUCTION

The Milagro collaboration reported the detections of several $\gamma$-ray sources in 2007 which included the unidentified source MGRO J1908+06 at an 8.3$\sigma$ (pre-trials) level. Milagro report a source extension up to 2.6$^\circ$ with 90% confidence.

The H.E.S.S. experiment’s extended Galactic plane survey has confirmed this source with a post-trials estimate of 5.7$\sigma$. H.E.S.S. reported a flux above 300 GeV of 14% of the Crab Nebula flux, a best-fit position for the emission region of $l=40.45\pm0.06^\circ_{stat}\pm0.06^\circ_{sys}$ (19$^{h}08^m04.39^s$) and $b=0.8\pm0.05^\circ_{stat}\pm0.06^\circ_{sys}$ (06$^{d}19^h09.1^m$) along with an intrinsic source extension of $\sigma_{src}=0.21^\circ_{stat}\pm0.05^\circ_{sys}$.

The source may be associated with the radio-bright SNR G40.5-0.5 or possibly the EGRET sources 3EG J1903+063 and GeV J1907+0557. However, the possibility of TeV emission from nearby unresolved sources and/or cosmic-ray interaction with nearby CO molecular clouds cannot be discounted. The VERITAS measurements of the source position and size along with a discussion on possible counterpart sources are presented here.

The extended nature of this source, along with its relative strength make it an excellent analysis calibration source for the VERITAS sky survey.

OBSERVATIONS

VERITAS first observed the quoted H.E.S.S. position for TeV emission in October and November 2007 with further follow-up observations taken in May and June 2008. Two differing modes of observation were used to observe this source. The first observations were made using the concept of a "mini-survey". A grid of pointed array observations with multiple camera off-sets (from the reported H.E.S.S. position) was created to emulate the conditions of the main VERITAS sky survey.

A second set of observations were then undertaken that consisted purely of "Wobble" runs with offsets of 0.5$^\circ$ and 0.7$^\circ$ from the reported H.E.S.S. position. The average camera off-set for all the taken data is 0.65$^\circ$.

All data used in the analysis have passed data-quality cuts (very good weather coupled with no hardware issues) giving a total of $\sim$1300 minutes of live-time data. A table containing a break-down of the total time into its constituent modes is shown (Table 1.). The zenith angles of observations ranged from 25 to 50$^\circ$ with an average zenith of 34$^\circ$.

ANALYSIS AND RESULTS

VERITAS analysis

The VERITAS data analysis steps consist of

- Calibration and integration of the flash-ADC traces recorded when the array is triggered by a Cherenkov flash

| TABLE 1. Breakdown of VERITAS observations |
|--------------------------------------------|
| Survey-style pointings | 0.5$^\circ$ wobble | 0.7$^\circ$ wobble | Total |
| Time(min) | 340 | 300 | 660 | 1300 |
• Individual telescope Cherenkov images are then cleaned and parameterized according to Hillas [7].
• Stereoscopic reconstruction of the event impact position and direction, hadronic background rejection and energy estimation are undertaken.
• Generation of photon maps.
• The Ring Background Model analysis [8] is then used to estimate the hadronic background in the source region.

Several changes were made to the standard VERITAS analysis for this source that are highly motivated by the published H.E.S.S. results (spectral index and extension values). Since both the H.E.S.S. and Milagro instruments detail that this source is not point-like, a larger background ring radius was chosen to avoid contamination of the background estimation. H.E.S.S. also quote a spectral index of $\alpha = 2.08$, making this a hard-spectral source in the TeV regime. Since the VERITAS observations of this source were on average taken at relatively low elevations, a harder size cut of 850 dc ($\approx 150$ p.e) is well motivated (studied with simulations) and is used in this analysis.

To avoid gamma-ray contamination in the background ring, an exclusion region of 0.6° radius was placed around the reported H.E.S.S. position.

Results

MGRO J1908+06/HESS J1908+063 has been detected by VERITAS at the 4.9$\sigma$ level. This quoted significance value is at the reported H.E.S.S. position. Figure 1 shows the smoothed significance map of the region with the 4.9$\sigma$ VERITAS value at the H.E.S.S. position marked with a cross. Figure 2 shows the distribution of significances for the field of view around the source.

To investigate the position and extension of this source, a symmetrical two-dimensional Gaussian function was fitted to the uncorrelated excess map for this field. The best-fit position lies at RA=287.05° ±0.05° (19°08m12s) and DEC=6.37° ±0.04° (06°22′12″) with a 68% excess containment radius (Point Spread Function not deconvolved) of $\sigma_{68%} = 0.19° ±0.04°$ (the corresponding measurement for the Crab Nebula is $\sigma_{crab, 68%} = 0.07°$), these measurements indicate that the source is not point-like and that the VERITAS best-fit position is fully compatible with previous results.

Figure 3 displays the uncorrelated excess plot of the field of view with 2D Gaussian contours overlaid. The source appears to be asymmetric therefore the 2-Dimensional Gaussian fit values should be taken as first approximations. A more detailed study of source extension/morphology is ongoing.

Counterpart Discussion

Figure 4 displays the VERITAS $\gamma$-ray excess map with potential multi-wavelength counterpart sources overlaid. The Milagro 7$\sigma$ (outer) and 5$\sigma$ (inner) contours are shown overlain on the field along with the previously quoted H.E.S.S. position and extension value. Potential TeV $\gamma$-ray sources located in this region include the Supernova Remnant (SNR) G40.5-0.5 [9] which is located at a distance between 5.5-8.5 kpc, this remnant has been observed emitting non-thermal radio emission [4] and its level of extension somewhat overlaps with the VERITAS best-fit location. Two additional SNR are marked within the field-of-view but cannot be read-
FIGURE 3. 2-Dimensional Gaussian fit to uncorrelated excess map (0.2° bins)

... identified with the emission region. The ASCA X-ray source AX J1907+0557 and the ROSAT source 1RXSJ190859.7+0602426 are overlaid, with Roberts et al. [10] showing AX J1907+0557 as an extended X-ray source compatible with the EGRET GeV source.

CONCLUSIONS

VERITAS reports a detection of TeV gamma-rays from MGRO J1908+06/HESS J1908+063 at the 4.9σ level confirming that this is a Very High Energy gamma-ray emitter. The source location as measured by VERITAS is RA=287.05° (19h08m12s) and DEC=6.37° (06°22′12″) with an extended emission region. Further analysis of this source is ongoing with aims for flux/spectral measurements to be finalised for the possibility of future publication.

ACKNOWLEDGMENTS

This research is supported by grants from the U.S. Department of Energy, the U.S. National Science Foundation, and the Smithsonian Institution, by NSERC in Canada, by PPARC in the UK and by Science Foundation Ireland.

REFERENCES

1. A. Djannati-Atai, E. Ona-Wilhelmi, M. Renaud and S. Hoppe for the H. E. S. S. Collaboration. H.E.S.S. Galactic Plane Survey unveils a Milagro Hotspot. ArXiv e-prints 0710.2418, October 2007.

2. A. A. Abdo et al. Discovery of TeV Gamma-Ray Emission from the Cygnus Region of the Galaxy. ApJL, 658:L33–L36, March 2007.

3. S. Hoppe for the H. E. S. S. Collaboration. The H.E.S.S. survey of the inner Galactic plane. ArXiv e-prints 0710.3528, 710, October 2007.

4. A. J. B. Downes, C. J. Salter, and T. Pauls. G40.5-0.5 - A previously unrecognised supernova remnant in Aquila. AAP, 92:47–50, December 1980.

5. R. C. Hartman, et al. Third EGRET catalog (3EG). VizieR Online Data Catalog, 212, August 1999.

6. R. C. Lamb and D. J. Macomb. Point Sources of GeV Gamma Rays. ApJ, 488:872, October 1997.

7. A. M. Hillas. In Proc. 19th ICRC, 445, pages 445–448, 1985.

8. D. Berge, S. Funk, and J. Hinton. Background modeling in very-high-energy γ-ray astronomy. AAP, 466:1219–1229, May 2007.

9. A. D. Green. Galactic supernova remnants: an updated catalogue and some statistics. http://www.mrao.cam.ac.uk/surveys/snrs/, April 2004.

10. M. S. E. Roberts, R. W. Romani, and N. Kawai. The ASCA Catalog of Potential X-Ray Counterparts of GEV Sources. APJS, 133:451–465, April 2001.