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Results from the first two years of VERITAS observations

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ABSTRACT

The VERITAS observatory is an imaging atmospheric Cherenkov telescope array located in southern Arizona and covers an energy range between 100 GeV and 30 TeV. The VERITAS collaboration pursues a rigorous observing program that targets a range of key science objectives in astrophysics and particle physics; the understanding of the origin of cosmic rays, the search for supersymmetric dark matter self-annihilation, illuminating the connection between black holes and relativistic jets and constraints to the cosmological diffuse infrared background. We provide a summary of results from the first two years of observations with the full 4-telecope array reported at RICAP09.

1. Introduction

The VERITAS (Very Energetic Radiation Imaging Telescope Array System) concept was the first to be proposed among the current generation of atmospheric Cherenkov telescope arrays, was funded in 2003 and swiftly constructed at Fred Lawrence Whipple observatory, 40 km south of Tucson at an elevation of 1.3 km. Regular observations with all four telescopes started in Fall 2007. The instruments are operated 95% of all time during moonless nights and weather permitting, demonstrating the high reliability of the system. The duty cycle of the instrument is extended through partial moon observations that provide 30% more observing time at slightly lower sensitivity.

VERITAS provides an angular resolution of 0.1° per $\gamma-$ray event, an energy resolution of 15–20% and a flux sensitivity of 1% of the Crab in less than 50 h exposure (5σ detection). The excellent sensitivity combined with state-of-the-art angular resolution and source localization capabilities at gamma-ray energies provides good prospects for a highly sensitive coverage of the northern TeV sky.

The VERITAS key science projects ($\approx 50\%$ observing time) are: a sky survey of the Cygnus region, a blazar program, a survey of supernova remnants and pulsar wind nebulae and a search for dark matter.

Other targets for TeV observations are determined through individual observing proposals ($\approx 40\%$ observing time) while 10% of discretionary time is set aside for Targets of Opportunity. In the

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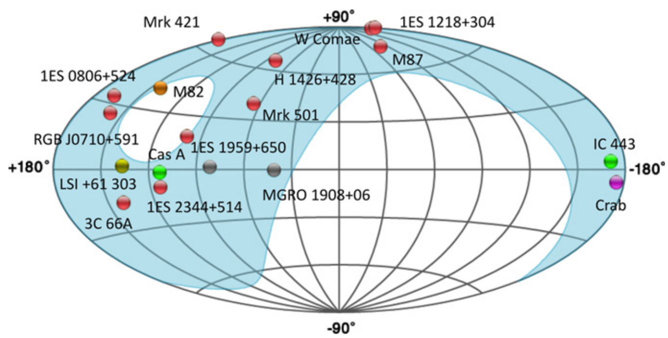

Fig. 1. The skymap shows the gamma-ray source catalog detected by VERITAS in the first two years of operation. The red dots indicate extragalactic sources, including active galactic nuclei with their jets pointing at us, radio galaxies and orange indicates a starburst galaxy. The green dots represent supernova remnants and violet indicates pulsar wind nebulae. Blue stands for unidentified sources. The dark green dot marks a binary system. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

first two years of the VERITAS science program more than 20 sources have been detected (see skymap in Fig. 1).

In this paper we will give some of the highlights of the VERITAS results from the first two years that were reported at RICAP09. For a more comprehensive and recent update see the VERITAS contributions [1] to the International Cosmic-Ray Conference 2009.

2. Galactic sources

A targeted program to probe for TeV emission from supernova remnants has resulted in several detections and interesting upper limits. This yielded the discovery of extended emission from the direction of the middle aged SNRs IC 443 and a detection of the prominent object Cas A.

2.1. Supernova remnants & pulsar wind nebulae: IC443, Cas A

Terraelectonvolt (TeV) observations of shell-type supernova remnants and pulsar wind nebulae are critical in the study of the long standing paradigm that supernova remnants are the dominant galactic cosmic-ray accelerators, and responsible for sustaining the observed cosmic-ray flux up to PeV energies. While pulsar wind nebulae are laboratories for studying relativistic electrons in a bubble surrounding a pulsar, the molecular gas found in the proximity of a shell-type supernova remnant, provides a target for relativistic protons accelerated in a supernova shock. Subsequent pionization and GeV–TeV gamma rays provide a tracer for studying cosmic particle acceleration sites.

The TeV skymap of the young and nearby supernova remnant Cas A is shown in Fig. 2. Cas A is among the brightest and best studied supernova remnants and covered in the radio to X-ray waveband. However, it was not detected by EGRET and is not in the bright source catalog of he Fermi Gamma ray Space Telescope (FGST) [2]. Cas A was detected in the TeV waveband by the HEGRA collaboration based on 232 h of observations [3]. A subsequent confirmation by MAGIC [4] and the recent detection by VERITAS (8σ detection in 22 h) have established Cas A as a constant TeV source with a flux of $\approx 3\%$ of the Crab. While the small angular size (5 arcmin) prevents morphological studies with current generation Cherenkov telescopes, future arrays such as AGIS (www.agis-observatory.org) and CTA (www.cta-observatory.org) with arcminute angular resolution would allow one to map the TeV emission region.

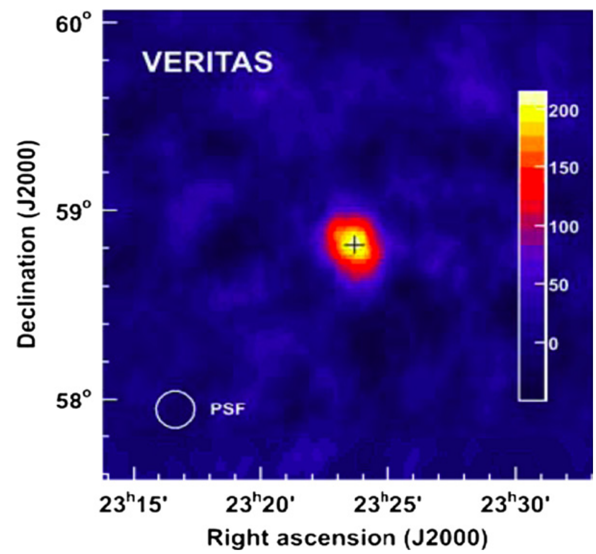

Fig. 2. The skymap of Cas A is shown indicating a point source [5].

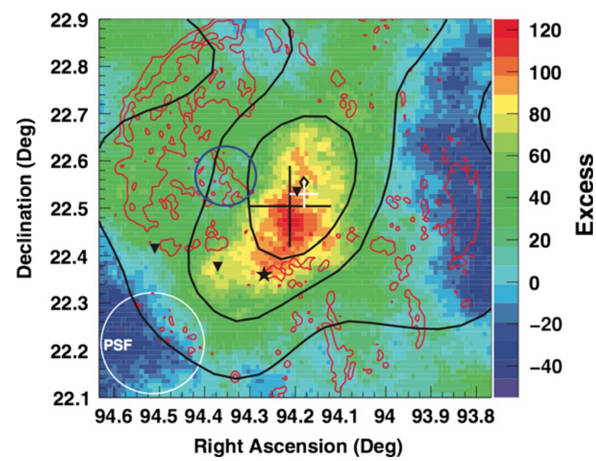

Fig. 3. The skymap of IC 443 exhibits a small ($0.16^\circ \pm 0.03^\circ$) but significantly extended emission region.

A prototype of a potential cosmic-ray accelerator is IC 443, a supernova remnant with a molecular cloud, Maser emission and favorable angular size (0.75° in diameter) to be resolved with current TeV telescopes. Its age is in the range of several thousand to 30 kyrs and its morphology has been studied in detail in the radio, optical and X-ray waveband. The initial TeV detections by MAGIC [6] and VERITAS [7] have motivated a range of detailed theoretical [8] and observational studies [9].

The VERITAS skymap of IC 443 in Fig. 3 clearly shows a slightly extended emission region of $0.16^\circ \pm 0.03^\circ_{stat} \pm 0.04^\circ_{sys}$. The TeV excess coincides with the CO-map indicated by the black contours in Fig. 3. The black star indicates the position of the pulsar wind nebula PWN CXOU J061705.3+222127 and is clearly offset from the TeV emission peak by 0.15°. Furthermore, the blue circle indicates the position of the Fermi source 0FGL J0617.4+2234 [2] which is displaced from the TeV excess by 0.15°, but maybe consistent with the same position, given the uncertainties in the angular position of the Fermi measurement.

The TeV emission is consistent with a scenario in which the VHE emission arises from inverse Compton scattering off electrons accelerated early in the pulsar wind nebula's career. A hadronic origin is also possible and would naturally explain the spatial coincidence between the TeV excess and the molecular