VERITAS discovery of complex TeV emission towards the Cyg OB1 region

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ABSTRACT

We report the discovery of a complex region of emission above 650 GeV towards the Cyg OB1 association using the VERITAS ground-based TeV observatory. This emission is positionally compatible with the brightest part of MGRO J2019+37 seen above 12 TeV, which has been interpreted as the nebula of the bright radio and gamma-ray pulsar PSR J2021+3651. By contrast, VERITAS resolves the MGRO emission into a complex gamma-ray emission region, likely composed of multiple sources, and distinct from nearby SNR CTB 87. A broadband study of this region with the available archival data in radio, X-rays and GeV gamma-rays has been performed and compared to these new TeV maps.

INTRODUCTION

The Cyg OB1 association is located at the edge of the Cygnus region. It is a less well studied and less massive OB association than the nearby Cyg OB2. Recently, this OB association has received some attention because MGRO J2019+37, the largest and most significant of the sources found in the large-scale Milagro TeV survey, overlaps with it [1].

MGRO J2019+37 extends over an area of 0.6°x1.0°. Its measured flux is about 80% of the Crab Nebula flux at 20 TeV. The origin of this gamma-ray emission has been subject of much speculation. Emission from the shocks driven by the WR stars contained in the young cluster Ber 87 in the Cyg OB1 has been proposed [2]. However, the PWN produced by the energetic young pulsar PSR J2021+3651 ($\dot{E}$ = 3.4x10^{36} erg/s) is still a common interpretation, given the observed offset between the emission maximum and the pulsar, an effect often seen in TeV PWNe.

VERITAS OBSERVATIONS

VERITAS is an array of four 12m diameter IACTs, located at the Fred Lawrence Whipple Observatory in Arizona [3,4]. VERITAS has an angular resolution better than 0.1 deg per event and a 5σ point-source sensitivity of 1% of the Crab Nebula flux above 300 GeV in less than 30 hr of observation.

Observations of the Cyg OB1 region span from May 2010 to December 2010, and amount to 75 hours after selection for good weather and absence of hardware problems. Wobble mode observations around PSR J2021+3651 were used in the first half of the observations with an offset of 0.7°. Motivated by the initial results, the wobble position was subsequently moved 0.5° to the west.

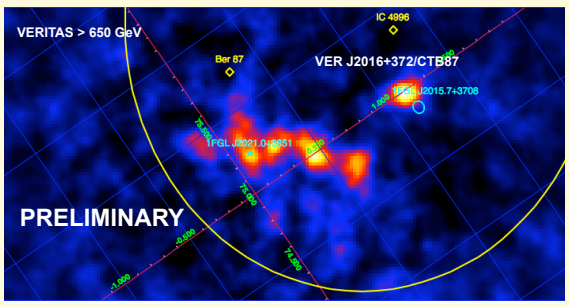
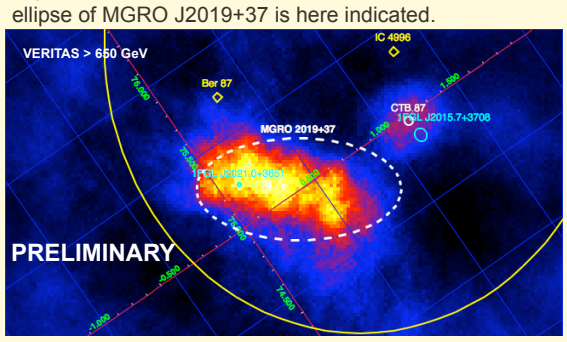


Fig 1. Excess-counts sky map towards the Cyg OB1 region (big yellow circle) above 650 GeV obtained with VERITAS. We used θ_{int}=0.09°(see text). Significant excesses post-trials are evident (see text). The positions of Ber 87 and IC4996 (young stellar clusters associated with Cyg OB1), are indicated, along with those of 1FGL sources in the region.

Fig 2. Same as above using an integration radius θ_{int}=0.23° to look for extended emission. The best-fit ellipse of MGRO J2019+37 is here indicated.



TEV ANALYSIS & RESULTS

Analysis: Events were reconstructed using the Hillas parameters. The γ-ray event selection was optimized for a hard-spectrum source at 1% Crab flux. The search for the γ-ray signal is performed with two fixed integration radii (θ_{int}=0.09° and θ_{int}=0.23°), to account for the possibility of finding both point-source and extended emission.

Trials: We defined a priori two source regions. One is at the location of CTB87, only 1.1° from PSR J2021+3651, and a good candidate for TeV emission. The true chance probability of any observed excess at CTB87 needs to be corrected for only 2 trials. The second source region we consider is the best-fit extension of MGRO J2019+37. In this case, the number of trials for any observed excess inside that region is estimated to be 734.

Results: The point-source search reveals significant (6.1σ post-trials) emission from the direction of CTB87 (VER J2016+372). In the larger search window, we find a significant (7.4σ post-trials) elongated and extended emission region, compatible with the best-fit extension of MGRO J2019+37. In the point-source search this extended region of TeV emission appears as a complex region of TeV emission with significances between 3σ to 6.2σ pre-trials.

VER Source	θ_{int}	Excess events	S pre-trial	S post-trial
J2016+372	0.09°	60.2	6.2σ	6.1σ
TeV Cyg OB1 complex	0.23°	230	8.3σ	7.4σ

Table 1. Emission detected above > 5σ post-trial

The Cisne pulsar & its surroundings

PSR J2021+3651, called the Cisne pulsar, has been for many years the only young and energetic pulsar known in this part of the Cygnus region[5]. Its GeV emission dominates this FoV [6,7]. It has also been proposed that it powers the large multi-TeV source MGRO J2019+37.

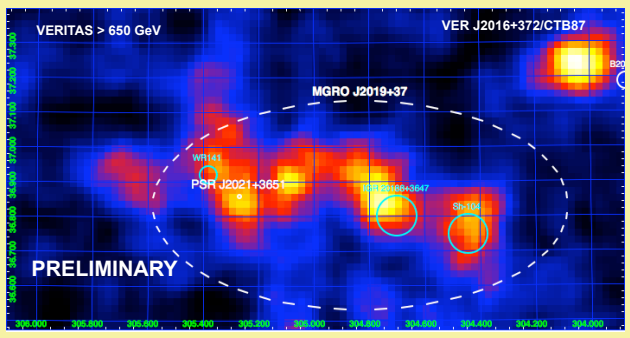


Fig 3. VERITAS observations show that MGRO J2019+37 is a complex TeV emitting-region. It is likely that multiple sources are the responsible for this emission. Among the candidates are PSR J2021+3651, WR 141, the transient IGR 20188+3647, the HII region Sh-104 and probably new ones not yet known. Deeper VERITAS observations are underway to try to disentangle these sources.

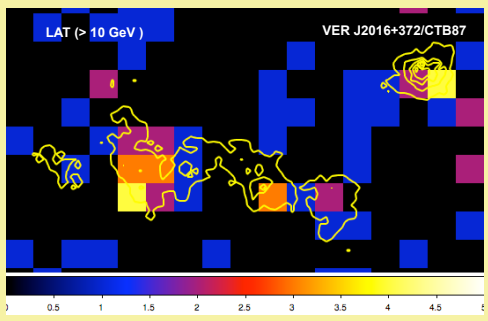


Fig 4. The diffuse galactic background and the large Fermi-LAT PSF at low energies make the analysis of the Cygnus region very challenging in the GeV regime. We have analyzed the 31 months of Fermi data in this region using the public tools. We have restricted the analysis to photons above 10 GeV and have binned the maps with the size of the smaller PSF at those energies (~0.15°). Clusters of two and three photons overlap some of the TeV emission (yellow contours). More detailed analysis, including subtraction of the diffuse background, will determine if the LAT observations provide support for the idea that the gamma-ray emission in the region is comprised of multiple sources.

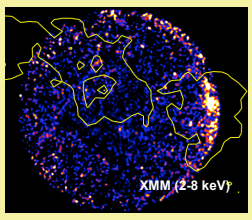


Fig 5. In this XMM observation, dedicated to a search for counterparts for MGRO J2019+37, an extended and non-thermal X-ray source is found at the edge of the FoV [9]. This source is located in the complex region of TeV emission seen by VERITAS (yellow contours). There is 2 LAT photons above 10 GeV in the same location. This also supports the idea that MGRO J2019+37 comprises multiple sources.

THE CTB 87 REGION

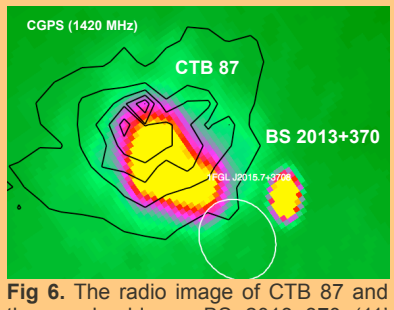


Fig 6. The radio image of CTB 87 and the nearby blazar, BS 2013+370 (11' away) . Black contours indicate the 3, 4, 5, 6 and 7σ contours at TeV. 1FGL J2015.7+3708 is a highly variable GeV source(V=139)[11]

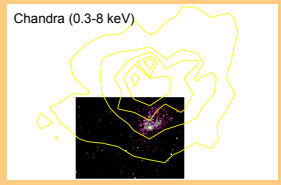


Fig 7. Recent public Chandra data reveals the location of the pulsar powering CTB 87: it lies inside the 4σ contour levels of the TeV emission.

CTB 87 is a PWN located at 6 kpc, in the Perseus arm, but in the line of sight of Cyg OB1. The properties and energetics of the underlying pulsar are not known.

The LAT source 1FGL J2015.7+3708 is compatible with the position of CTB 87, buts its high degree of variability would favor an association with the blazar BS 2013+370 [10].

VER J2016+372: the centroid of this new compact TeV gamma-ray source (RA, dec)=(304.02,+37.20) is compatible with the position of CTB87. We can exclude possible emission from the blazar with 99% probability.

The preliminary measured flux is ~0.8-1% of the Crab Nebula flux above 1 TeV, and the spectrum is best fitted with a power law with photon index Γ~2.1±0.5.

The measured spectrum and the absence of variability throughout the observations are properties similar to those of other PWNe, previously detected at TeV energies.

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