The TACTIC Telescope

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The TACTIC (TeV Atmospheric Cherenkov Telescope with Imaging Camera) is a ground-based gamma-ray telescope in India. The telescope was set up at Mount Abu (24.6∘ N, 72.7∘ E, 1300 m above sea level) in 1997. The operating principle of TACTIC is based on the imaging atmospheric Cherenkov technique for indirect observation of the gamma-ray sky. Since its first light in 1997, the TACTIC telescope has been employed to explore the Universe at TeV energies and several outstanding results are derived from the TACTIC data.

TACTIC Telescope Gamma Ray Astronomy Imaging Air Cherenkov Technique

1. Introduction

The TACTIC telescope was set up at Mount Abu (24.6∘ N, 72.7∘ E, 1300 m above sea level) in 1997. A comprehensive site survey was performed in 1993, and Gurushikhar in Mount Abu turned out to be the best-known location for GRA research using imaging the Cherenkov technique [1]. This site offered a very significant enhancement in the observation time (∼1200 h per year) more or less evenly spaced throughout the year with respect to the Gulmarg observatory. Mount Abu is a hill resort with good logistics, mild climate, dust-free atmosphere and offers ready accessibility to major Indian cities. The site is located at nearly the same longitudinal belt in which several major astronomical experiments in India were operational during that period. This fortuitous longitude clustering was greatly helpful in time-coordinated multi-band observations on candidate γ-ray sources. The longitude of the Mount Abu site is also important in long-term monitoring of the γ-ray sources as compared to other GRA observatories around the world.

2. TACTIC Telescope

The design of TACTIC telescope is based on imaging atmospheric Cherenkov technique for indirect detection of TeV photons from the cosmic sources [2]. A photograph of the observatory at Mount Abu is depicted in Figure 1. The instrument at the center of the array has been deployed as an imaging unit for TeV γ-ray observations since 1997. The imaging element is equipped with an altitude-azimuth mounted light collector of ∼4.0 m diameter and ∼3.8 m focal length. The light collector employs 34 front facing. aluminum-coated, glass spherical mirrors of 0.6 m diameter, each providing a light collection area of ∼10 m2. When all the 34 mirror-facets are properly aligned on the basket, the overall light reflector corresponds to a quasi-paraboloid surface. With focal length-to-diameter ratio ∼1, hybrid design of light collector is close to the Davies-Cotton design. This was achieved by deploying the shorter focal length mirror facets close to the principal axis of basket, while mirrors with longer focal lengths are placed around the periphery using longer studs on the frame structure to raise their pole position. This arrangement minimizes the off-axis effects on overall spot size of the reflector. A maximum spot size of ∼4 arcmin can be expected in the image plane of the telescope. The imaging camera at the focal plane uses an array of photomultiplier tubes (pixels) to detect the Cherenkov light flash with a resolution of 0.31∘. Initially, source observations using TACTIC started with only 81-pixel imaging camera covering a field of view of ∼2.8∘×2.8∘ in early 1997. Within a few days of its first light in 1997, the telescope with its prototype 81-pixel camera successfully detected a flaring activity from the blazar Mrk 501 during April–May 1997. This observation was almost synchronized by five other gamma-ray telescopes operating around the globe [3]. The prototype camera was first upgraded to 144 pixels, and the final camera configuration of 349-pixels with a field of view of ∼6∘×6∘ was attained in December 2000. The simulation studies using CORSIKA [4] suggested threshold energy of the TACTIC imaging telescope for γ-rays and protons to be ∼1.0 TeV and ∼1.8 TeV, respectively. The sensitivity of the telescope was estimated as detection of 5σ steady signal from the standard candle Crab Nebula in 25 h. A detailed description of the TACTIC telescope design and instrumentation can be found in [5][6][7][8][9][10]. The data recorded by the TACTIC telescope are first corrected for inter-pixel gain variation and then subjected to the standard image cleaning procedure [11]. The image cleaning threshold levels (for boundary and core pixels) are optimized on the Crab Nebula data. The clean images are characterized by calculating their Hillas parameters [12] followed by the application of standard Dynamic Supercuts procedure [13] to segregate γ-ray like events from the huge cosmic-ray background events. The significance γ-ray like excess events is estimated using the maximum-likelihood ratio method proposed by Li and Ma [14].

Figure 1. The TeV Atmospheric Cherenkov Telescope with Imaging Camera (TACTIC) telescope array operational since 2001 at Mount Abu, India. Single telescope at the center is being used as an imaging unit for TeV γ-ray observations.

A major upgrade program was taken up in 2011 to improve the overall performance of the telescope. The main motivation for the hardware and software upgrade of the system was to increase its sensitivity and lower the threshold energy. This translated to the reduction in the threshold energy of the telescope for cosmic rays from 1.8 TeV to 1.4 TeV and from 1.2 TeV to 0.8 TeV for the γ-ray events[1][2]. Application of gamma/hadron separation strategies using artificial neural networks and random forest classification further enhanced the performance of the telescope after upgrade [15][16]. The upgraded telescope has an improved sensitivity to detect the TeV γ-ray emission from the Crab Nebula at 5σ statistical significance level in an observation time of 12 h as compared to 25 h earlier. The γ-ray detection rate from the Crab Nebula also increased from ∼10 h−1 to ∼15 h−1 (defined as one Crab Unit for TACTIC). The TACTIC telescope with significant improvement in its performance has greatly helped in the monitoring of potential γ-ray sources in multi-TeV energy range during flaring activities for a short period and in low state for a long duration.

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