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Discovery of the Gamma-Ray source LHAASO J0534+3533

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We report the observation of an extended -ray source named LHAASO J0534+3535 with a significance of more than 10 standard deviations for energy from TeVs to tens of TeVs. In addition to the -ray source detected by LHAASO, there is one old supernova remnant candidate, G172.8+1.5, and some GeV sources nearby. G172.8+1.5 is located in one of the largest star-forming regions in the outer Galaxy, characterized by HI gas that extends to velocities beyond those allowed by Galactic rotation, spanning an area of 4.4 degrees by 3.4 degrees at a distance of 1.8 kpc. LHAASO J0534+3535 is detected near the center of the supernova remnant G172.8+1.5, with an extension of approximately 0.5 degrees. Some results of the data analysis for J0534+3533 will be presented.

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1. Introduction

A new gamma ray source is measured with LHAASO data analysis at J0534+3533 region[1], near the region of an old supernova remnant (SNR), G172.8+1.5[2]. This region is one of the largest star forming regions in the outer Galaxy. The SNR was first reported by the observations of high velocity HI gas that extends to the velocities beyond those allowed by Galactic rotation[2]. The extension size of the HI shell is correlated with the radio continuum loop, part of them are associated with a giant molecular cloud at the distance around 1.8 kpc[5]. Several point-like sources are listed in 4FGL-DR4 catalog released by Fermi-LAT[3], while none of them is spatial coincidence with the position of LHAASO J0534+3533.

2. The LHAASO Experiment

The primary objectives of LHAASO are to study gamma-ray astronomy, charged cosmic rays, and new physics[4]. LHAASO is located at Haizi Mountain (4410 meters above sea level in Sichuan, China). It consists of three sub-arrays: the square kilometer array (KM2A), a 78,000 m² water Cherenkov detector array (WCDA), and 18 wide-field air Cherenkov/fluorescence telescope array (WFCTA). The KM2A consists of 5216 electromagnetic detectors (EDs) and 1188 muon detectors (MDs), covering an area of approximately 1.3 km^2. A comprehensive performance study of the WCDA and KM2A detectors, is presented in the paper about observations of the Crab Nebula with LHAASO[6].

3. Analysis and Results

The WCDA data used in this analysis were collected from 5th March 2021 to 31st July 2024, and the KM2A data used were collected from 20th July 2021 to 31st July 2024. The WCDA covers an observation energy range from ~1 TeV to several tens of TeV, while the KM2A covers an observation energy range of greater than 10 TeV. After data reconstruction, the sky map in celestial coordinates is divided into a grid of 0.1°×0.1° pixels. Each pixel is filled with the number of detected events based on their reconstructed arrival directions. The "direct integration method" is used to estimate the number of cosmic-ray background events in each grid.

In this work, both separate and joint analysis were done with the data from KM2A and WCDA, and the analysis methods are identical. The significance of the source is evaluated using a test statistic, defined as $TS = \frac{\mathcal{L}_{s+b}}{\mathcal{L}_b}$, where $\mathcal{L}_{s+b}$ or $\mathcal{L}_b$ is obtained by comparing the observed event counts with the expected counts. For $\mathcal{L}_b$, the expected counts are derived from the background maps extracted from the data. For $\mathcal{L}_s$, the expected counts correspond to the signal contribution of the source plus the background hypothesis.

For the determination of the morphology and flux of the source, we use a 3D Likelihood method. The first step is to build the morphology and spectrum of each source in the ROI. The range of seven to seven degree aroud G172.8+01.5 is analyze. Direct Integration Method and standard 3D Likelihood analysis pipeline based on LHAASO official method is used. The Plank dust column denisity is used for the Galactic Diffuse Emission background, while the energy spectrum is fitted with power law. In this work, different spectrum distribution different morphology models for the source is used to fit. The spectrum distribution of simple power-law, Log power-law and power-law with energy cut are compared. The morphology models compared gaussian distribution, ellipse gaussian, point and disk model. For joint analysis of WCDA and KM2A, the power-law with energy cut and diffusion morphology models got the highest TS value for fitting this region with one source, while the TS value for the fitting with Log power-law and diffusion morphology model is similar. Fig .1 is the TS value distribution for fitting with PEC spectrum and diffusion morphology model, while Fig .1 is the residual distribution for fitting with one source. The fitting with two source were also tried with TS a little higher than fitting with one source, but there needs more analysis to confirm.

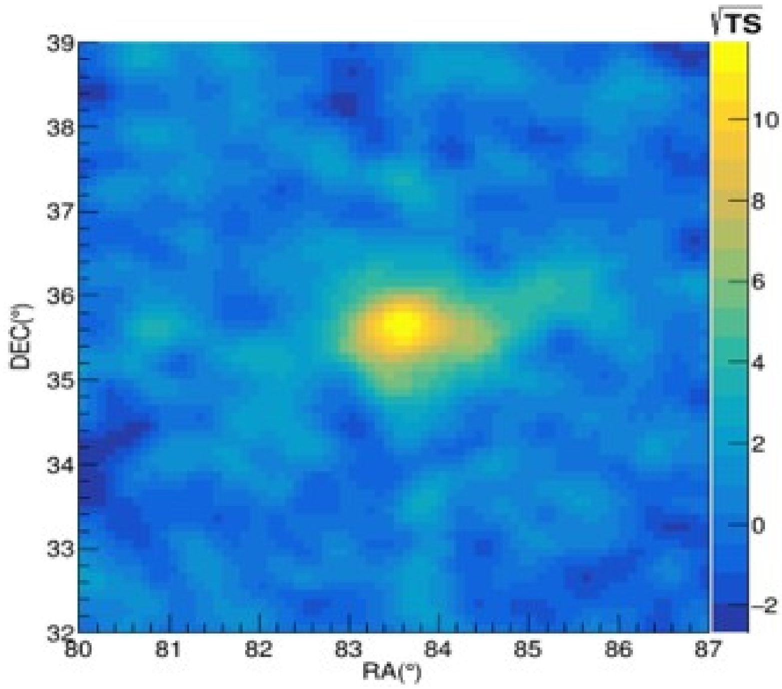

Figure 1: The significance maps of all data (left) and The significance maps of the fitted source (right).

References

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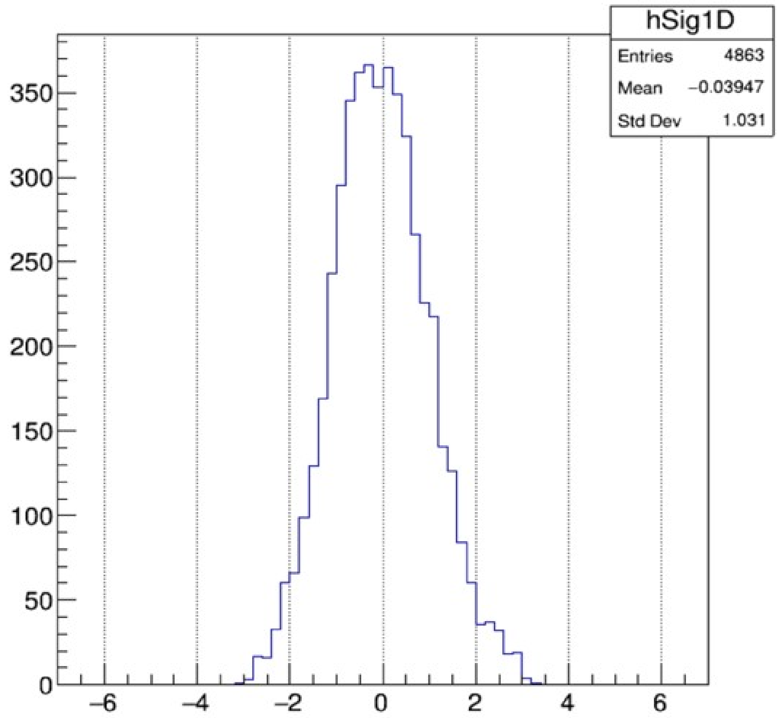

Figure 2: (left) and (right).

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