IDENTIFICATION OF NEW GAMMA-RAY BLAZARS USING FERMI-LAT

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Abstract

We study sources with WISE-IR colours similar to those of known blazars and with radio counterparts from NVSS and SUMSS catalogues (WIBR catalogue). In addition, we study gamma-ray blazars which are part of the upcoming 2BIGB catalogue. Most of these sources have not yet been detected in any of the current Fermi-LAT catalogues including the 4FGL. This study, therefore, aimed at identifying new gamma-ray blazars by using Fermi science tools. The new blazar candidates were identified by analysing their spectral energy distribution. From the WIBR catalogue, a total of 230 sources (WIBR-Selection) were analysed for their spectral energy distribution (SED) to identify blazar candidates from which we selected 40 sources for the gamma-ray analysis. A binned likelihood analysis (at the 500 MeV–500 GeV energy band) integrating over 10 years of Fermi-LAT observations was performed to determine the statistical significance of the gamma-ray detections. By studying the test statistics (TS) maps, we confirm the new gamma-ray detections and also solve cases of source confusion. Out of the subsample of 40 WIBR sources, 26 sources (65%) have shown significant gamma-ray signatures $\geq 3\sigma$. Among the significant detections from WIBR sources, 8 sources are completely new gamma-ray sources from the TS map analysis and 18 sources were found to be spurious detections. Given a large number of sky regions studied with TS maps, we also identified 25 new unknown gamma-ray sources which happen to be close to our seed positions. These results show that a multi-frequency approach improves our current description of the gamma-ray sky, making it a powerful tool to explore very high energy (VHE) phenomena in astrophysics.

Introduction

Despite the fact that blazars whose relativistic jets are directed towards the Earth [7] are rare sources in extragalactic astronomy, they cover the largest fraction of gamma-ray sources [3]. As a consequence, they are the most likely sources that contribute to the extragalactic gamma-ray background (EGB) [2, 4, 5]. The origin of EGB could be related to:

(i) physical processes like the decay or annihilation of putative dark matter particles that produce gamma rays.
(ii) gamma rays produced by particles through induced shock waves during the formation of the universe.
(iii) unidentified sources, for example, normal galaxies, starbursts and AGNs (mostly blazars).

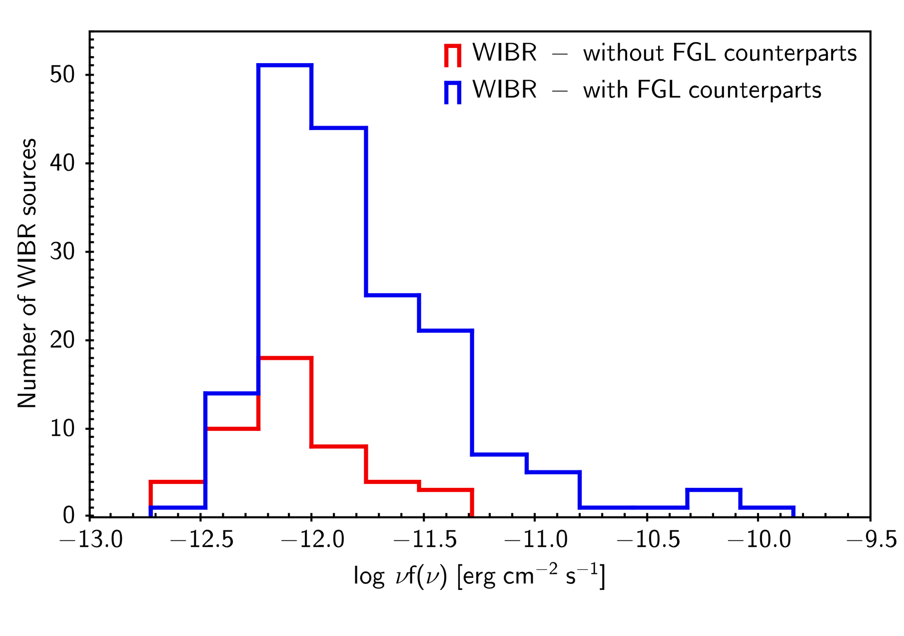
Unveiling new gamma-ray sources helps to solve isotropic emissions into point-like sources. This, in turn, helps to better describe the gamma-ray sky [1] and constrain the available parameter space for dark matter models. In addition, identifying new gamma-ray sources shades light over potential candidates for observations with the Very High Energy (VHE) observatories such as the Cherenkov Telescope Array (CTA).

Objectives

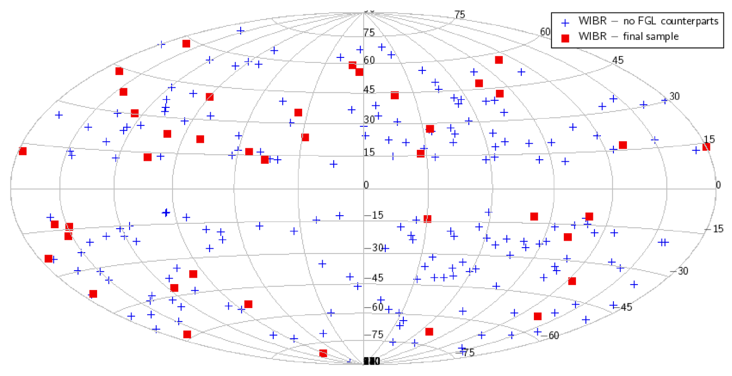
The objectives of this study were to:

(i) identify potential blazar candidates by using their SED and multifrequency properties.
(ii) determine the significance of the detection of the sources using likelihood analysis.
(iii) validate the new gamma-ray detections using Test Statistic (TS) maps.

Sample



$\log(\nu f_\nu)$ distribution of the WIBR sources. The blue distribution represents the WIBR-Selection sources that have been detected in the Fermi LAT catalogues. The red distribution represents the WIBR-Selection sources which have not yet been detected in the Fermi-LAT catalogues. The intersection of these two samples indicate that there are still WIBR sources close to the detection of the Fermi LAT



Red squares indicate the final WIBR sample outside the Galactic plane.

Methods

(i) The SEDs were analysed using the ASDC SEDbuilder tool.
(ii) The gamma-ray analysis was performed using Fermi science tools. The significance of the detections was determined using the Test Statistic (TS) parameter defined as;

$$\mathrm{TS} = -2(\ln \mathrm{L}_{no\text{-}source} - \ln \mathrm{L}_{source}) \qquad (1)$$

where $L_{no\text{-}source}$ is the null hypothesis, and L_{source} is the likelihood value for a model with the additional candidate source at the same position[6]

$$\text{significance} \sim \sqrt{\mathrm{TS}}\,\sigma \qquad (2)$$

The gamma-ray spectrum of the sources was assumed to be described by a power law model given by;

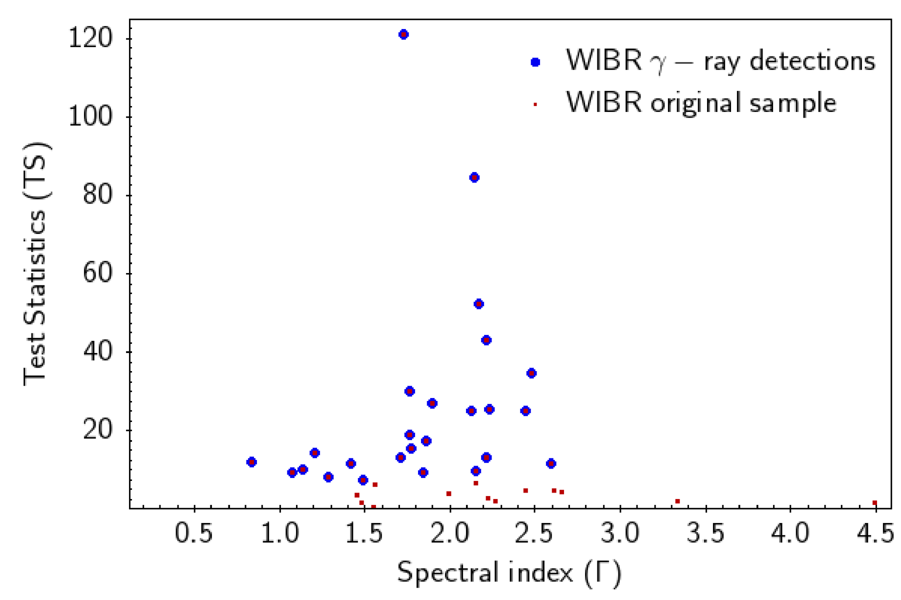
$$\frac{\mathrm{dN}}{\mathrm{dE}} = \mathrm{N_o}\left(\frac{\mathrm{E}}{\mathrm{E_o}}\right)^{-\Gamma} \qquad (3)$$

$\mathrm{E_o}$ is pivot energy, $\mathrm{N_o}$ is the prefactor (corresponding to the flux density in $\mathrm{ph/cm^2/s/MeV}$) at $\mathrm{E_o}$ and Γ is the photon spectral index for a given energy range.

(ii) TS maps were obtained by performing an unbinned likelihood analysis using Fermi science tools.

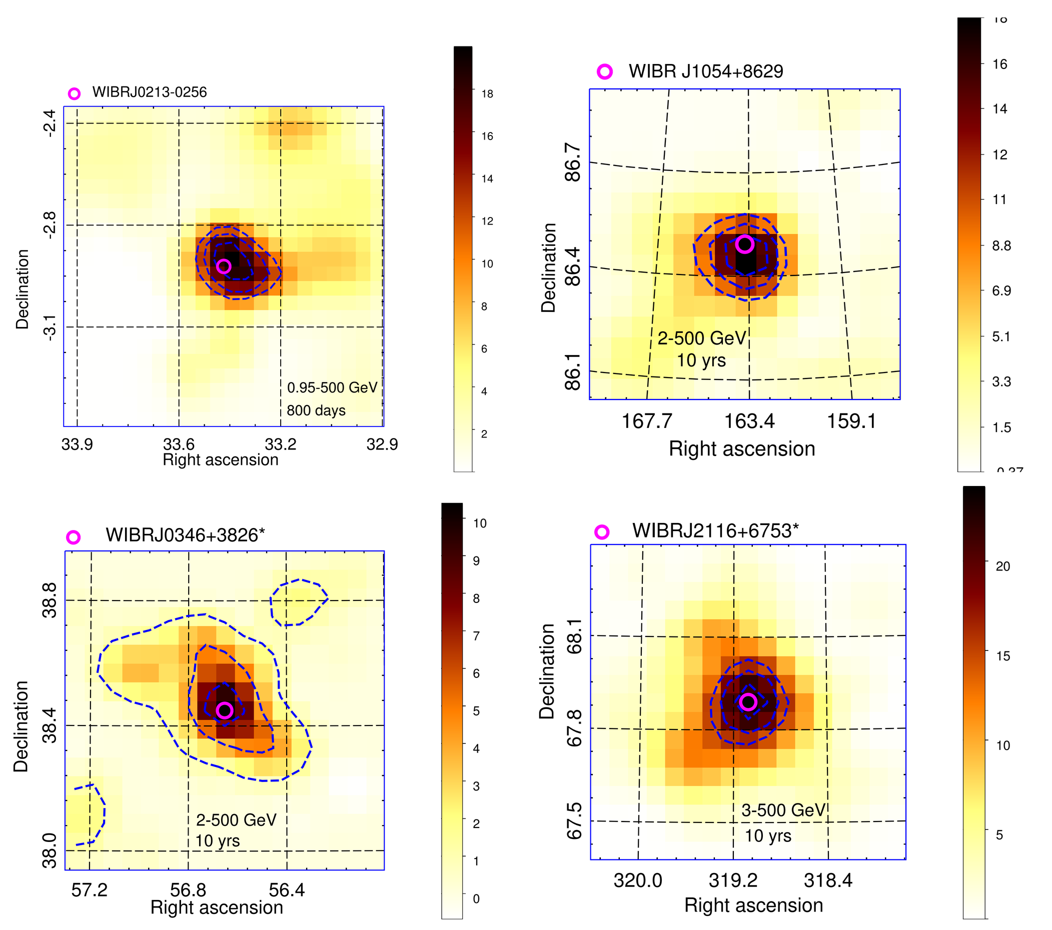
Results

Significant detections



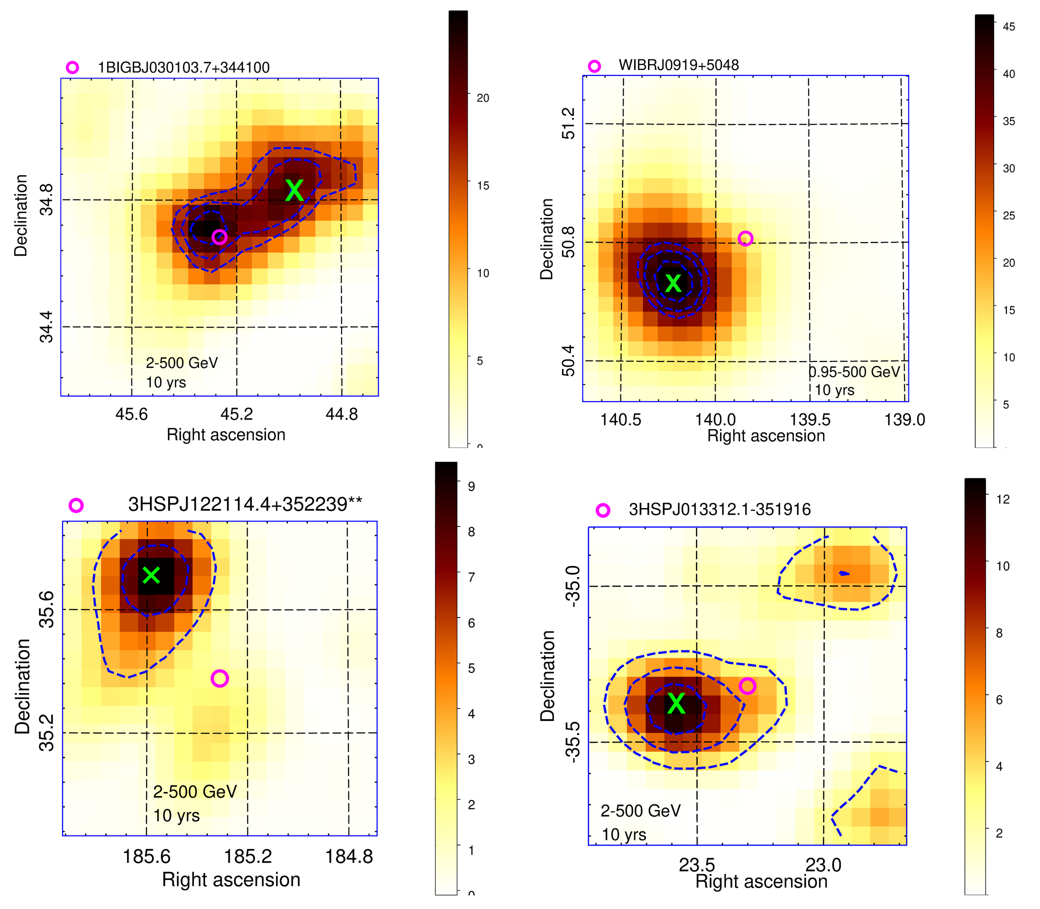
The blue circles indicate the 26 sources that showed significant gamma-ray signatures $\geq 3\sigma$

New WIBR gamma-ray detections



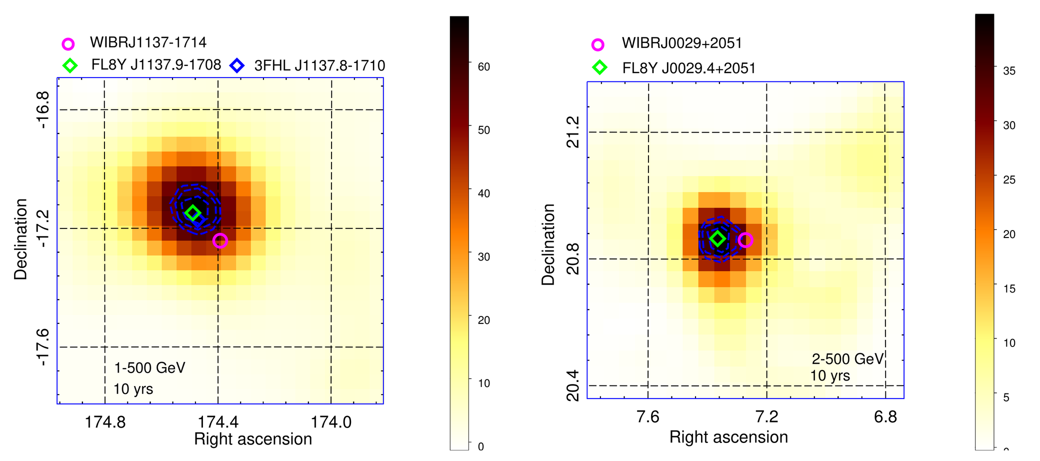
The WIBR seed positions are shown by the magenta circles. The blue dashed contour lines correspond to 68%, 95%, and 99% containment region for the gamma-ray signature position (from inner to outer lines) in both TS maps.

New unknown gamma-ray detections



The new unknown sources are shown by the green cross.

Spurious detections



Conclusions

(i) Out of 230 WIBR-Selection sources, 69 were classified as LSP, 98 as ISP and 22 as HSP. 41 sources were left unclassified due to limited data.
(ii) Out of 40 sources that were selected as the final sample, 16 were low significant detections with $8 < \mathrm{TS} < 25$ and 10 were high significant detections with $\mathrm{TS} > 25$. All these sources are completely new detections without counterparts in Fermi catalogues (4FGL).
(iii) Out of the 26 WIBR significant detections, we found 8 new gamma-ray detections, and 18 were spurious detections. Although these new detections only represent a small fraction of gamma-ray emitters, it contributes for a better description of the gamma-ray sky.
(iv) In addition to our seed positions considered, we have identified 25 (both WIBR and 2BIGB) more gamma-ray sources which were present in the sky-regions covered by the TS maps.

Contact information

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