Sources above 10 GeV in the *Fermi* Sky

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Abstract

We searched for gamma-ray sources at energies above 10 GeV using data from the Large Area Telescope (LAT) accumulated during the first 3 years of the *Fermi Gamma-ray Space Telescope* mission. We found almost 500 sources, measured their spectra, quantified their variability, and studied their associations with cataloged sources at other wavelengths. A large fraction of these sources were found to be good Very High Energy (VHE) candidates to be detected with Cherenkov Telescopes. This search complements the Second Fermi LAT catalog, which was based on 2 years' data extending down to 100 MeV and included many sources with softer spectra. The complete list of the LAT sources detected above 10 GeV, as well as the characterization of the spectra, variability and population implications from these sources will be presented elsewhere.

Introduction

The Large Area Telescope (LAT) on the *Fermi Gamma-ray Space Telescope* operates in the energy range from 20 MeV to greater than 300 GeV. Its large field of view (2.4 sr) and the scanning mode operation of the satellite provide fairly uniform and continuous coverage of the entire sky, making the LAT data well suited for construction of source catalogs.

As a follow-on to the Second Fermi Large Area Telescope Catalog (2FGL, Abdo et al. 2012), which analyzed sources with photon energies above 0.1 GeV, we have used three years of Fermi LAT data to search for gamma-ray sources with significant emission above 10 GeV. Such sources, which typically have very hard energy spectra, represent some of the most extreme astrophysical objects.

Analysis Methodology

The present analysis uses LAT data from August 2008 through July 2011, nearly three years. The data set is based on the P7_V6_Clean event selections and associated Instrument Response Functions, together with Galactic and isotropic diffuse background models similar to those used for the 2FGL catalog (available through the Fermi Science Support Center).

Fermi-LAT photons with energies above 10 GeV have significantly better angular resolution than lower-energy photons. The trade-off is limited counting statistics, which are now large enough to map the > 10 GeV sky to a reasonable depth, as can be seen in Fig. 1.

The analysis pipeline used is the same as that for the 2FGL catalog: candidate sources ("seeds") are identified and localized, and then a maximum likelihood analysis extracts results on statistical significance, flux, and energy spectrum. Only sources with statistical significance greater than 4 σ (Test Statistic TS = 2 Δ (Log L0 – Log L1) > 25, comparing likelihood with and without a source present) are retained.

Preliminary Results

496 sources pass all the acceptance tests.

Associations of these sources with known types of gamma-ray-producing astrophysical objects is carried out in the same manner as for the 2FGL catalog, comparing source locations with catalog objects, taking into account the local density for the catalog objects to require at least an 80% probability of association.

Results of the association analysis are shown in Fig. 3 and Table 1. The 10 GeV sky is strongly dominated by Active Galactic Nuclei, primarily blazars. 20% of the sources have no clear association at other wavelengths.

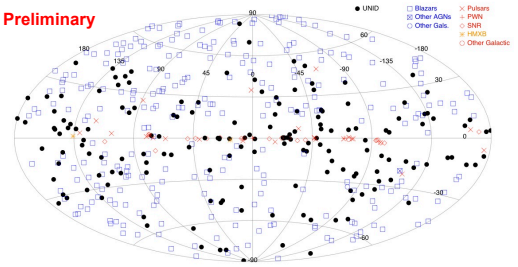

Fig. 3 Automated association analysis for the 496 sources.

Association Class	No. of Sources
Active Galactic Nuclei	274
Other galaxies	1
Pulsars	25
Supernova Remnants and Pulsar Wind Nebulae	25
High-mass binaries and other Galactic sources	3
Unassociated	168
TOTAL	496

Table 1. Summary of automated associations by object class.

Variability

Even with the three-year data set, counting statistics for Fermi-LAT sources are limited. A variability analysis used Bayesian Blocks, an unbinned method for identifying statistically significant variability. 27 of these sources show evidence of variability, at a confidence level of 10^{-3}. All of these are associated with AGNs.

The Sky Above 10 GeV

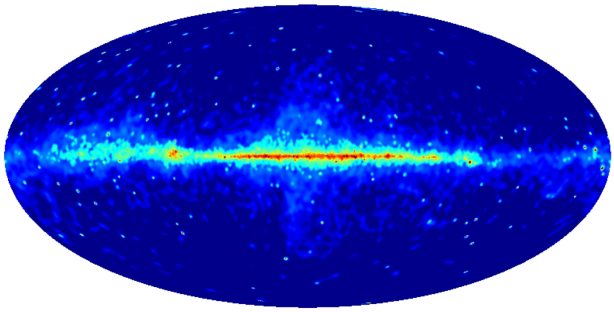

Fig. 1. Adaptively smoothed 36-month counts map of Fermi-LAT data above 10 GeV, in Galactic coordinates.

Energy Spectra

In the energy range above 10 GeV, the source spectra were all consistent with power-law fits. Trial fits with a log parabola form did not improve the fit for any of the sources. Comparison with results at lower energies, however, often shows spectral features appearing at or above 10 GeV, as illustrated in Fig. 2.

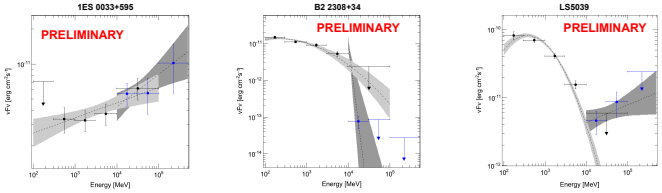

**Fig. 2 Sample Spectral Energy Distributions of sources seen above 10 GeV. In each case, the black points and light gray band are the results from the 2FGL Catalog, while the blue points and dark gray band show the power-law fit using only photons above 10 GeV.
Left: a BL Lac object; Center: a Flat Spectrum Radio Quasar; Right: a High-Mass Binary.**

Candidate TeV Sources

Using the flux and energy spectra of the sources, we have estimated their detectability by current ground-based Atmospheric Cherenkov Telescopes that operate at energies above 100 GeV, such as VERITAS, MAGIC, and H.E.S.S. The spectrum shown in the left panel of Fig 2 is an example of such a candidate, since it is detected by the LAT even at energies above 100 GeV. Many of the good source candidates from this analysis have already been detected by Cherenkov Telescopes, but there are many more that have not yet been detected at Very High Energies (VHE). We foresee that future Cherenkov Telescope observations of these objects will result in further VHE detections and hence a substantial increase in the VHE sky.

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