A Search for Candidate TeV Emitters in the High-latitude Fermi Unassociated Sources

P. Fortin and D. Horan
Laboratoire Leprince Ringuet / École Polytechnique / CNRS / IN2P3, Palaiseau, France

E. Ferrara
NASA Goddard Space Flight Center, Greenbelt, MD, USA
on behalf of the Fermi-LAT Collaboration

We report the results of an analysis to identify candidates for very-high-energy (VHE; \( E > 100 \) GeV) emission from the high-latitude (|\( \theta | > 10 \)) unassociated sources in the year-1 catalog under development by the Fermi Large Area Telescope (LAT) team. These are sources with no known counterparts at other wavelengths. Since VHE instruments are pointed instruments with small fields of view and low duty cycles, their observing programs need to be planned carefully to identify the most promising targets for observation. The scientific potential of combined Fermi and VHE observations has already been demonstrated with a number of joint VHE-Fermi papers. The goal of this work is to select the most promising unassociated Fermi sources for joint observations with Fermi and the VHE instruments.

I. INTRODUCTION

The goal of this work is to find candidate very-high-energy (VHE) emitters from the sources in the Fermi year-1 catalogue. Many of the sources that have already been detected at VHE are in the catalog so it is already clear that Fermi can provide further targets of interest for VHE observatories.

II. METHOLDOLOGY

A. Preliminary Scan

To begin, a preliminary scan of the catalog was performed to select unassociated sources above galactic latitudes of 10° that had potential to be VHE emitters based on their flux, spectra and redshift. Unassociated sources that met the following criteria were selected:

- | Galactic Latitude | > 10°
- Flux \( E > 100 \) MeV \( > 2 \times 10^{-9} \) cm\(^{-2}\) s\(^{-1}\)
- Photon Index < 2.0
- Number of predicted photons > 20

This resulted in a list of 80 candidates corresponding to \( \sim 11\% \) of the total number of unassociated sources in the year-1 catalog. A skymap of these sources in galactic coordinates is shown in Figure 1.

B. Detailed Analysis

These 80 sources were then re-analyzed to search for curvature in their spectra; the sources in the catalog were all fit with power-law spectra, which gives, to first order, a good indication of their properties across the Fermi energy band but does not always describe accurately their spectra above 1 GeV. We included only those data at energies above 1 GeV from these sources to see if the resulting flux agrees with the power-law fit in the catalog. For each source, events were selected from a region of 10° radius centered on the catalog coordinates for that source. These data were analyzed using the standard Fermi analysis software (ScienceTools v9r15p3; IRF P6_V3_DIFFUSE) available from the HEASARC. All of the Fermi sources in the field of view were modeled and the background emission was modeled using a galactic diffuse emission model and an isotropic component. Events were analyzed using an unbinned maximum likelihood method.

The sources were modeled using a power law covering two overlapping energy ranges: 100 MeV - 300 GeV and 1 GeV - 300 GeV. In addition, a log parabola covering the full energy range (100 MeV - 300 GeV) was used to search for curvature. The differential flux,
C. Predicting the TeV Flux

For sources where there was no evidence for curvature, the flux above 100 MeV and the spectral index obtained from the power-law fit were used to estimate the flux in the VHE band (200 GeV - 1 TeV). The Fermi spectrum was extrapolated to higher energies assuming no break in the spectrum and the flux was absorbed for the extragalactic background light (EBL) with the model of Franceschini et al. [4]. A redshift value of $z = 0.2$ was assumed for all sources.

For those sources where a log-parabola was a better fit, the flux and spectral index obtained using the power-law fit above 1 GeV were used for the extrapolation to the VHE band. Given that curvature was detected in the Fermi energy band, it is likely that the predicted TeV flux is overly optimistic. But, given the lack of knowledge about the redshift of these sources, we consider the brightest ones as good “filler” targets in under-populated RA bands. Table I lists the 10 most promising unassociated Fermi sources for the VHE band using our methodology.

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TABLE I: Predicted fluxes in the VHE energy band (200 GeV - 1 TeV) for the top 10 candidates for VHE emission from the Fermi unassociated sources in the year-1 catalog.

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[1] http://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html
[2] Cash, W. 1979, ApJ, 228, 939
[3] Mattox, J.R., et al. 1996, ApJ, 461, 396
[4] Franceschini, A., Rodighiero, G., & Vaccari, M. 2008, A&A, 487, 837