Population Characteristics of Unassociated *Fermi* LAT Sources

- *Preliminary Results* -

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Unassociated *Fermi* LAT sources provide a population with discovery potential. We discuss using the spectral, spatial, and temporal properties of these sources to provide insight into the underlying populations which these detections may represent.

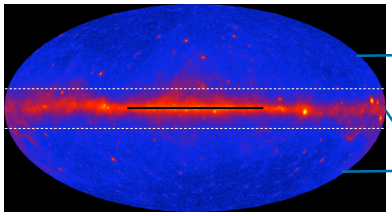
Abstract

In its first year, the *Fermi* Gamma-ray Space Telescope's Large Area Telescope (LAT) has dramatically improved our knowledge of the gamma-ray sky. As a result of the LAT's increased sensitivity and angular resolution over earlier-generation detectors, many previously detected gamma-ray sources have now been identified with objects that belong to known classes of gamma-ray emitters. Such improvements have also significantly expanded the number of detected sources that do not appear to have an association with any known gamma-ray-emitting object type. We use the spectral, spatial, and temporal properties of these unassociated sources, in comparison with LAT sources that have likely associations or are firmly identified, to provide insight into the underlying population(s) that these detections may represent.

Data Sample

We consider intrinsic source parameters for point sources[1] from the 1-year catalog currently under development by the LAT team. Sources along the Galactic ridge ($|l| < 60°$, $|b| < 1°$) have been excluded from both the associated and unassociated portions of the sample, due to uncertainties in diffuse modeling and source localization in that region.

The resulting source list was run through several source association processes. These two lists (associated and unassociated) were then divided into low and high Galactic latitude samples, divided at $|b| = 10°$. More details on the Fermi LAT 1-year catalog were presented by Jean Ballet at this conference.



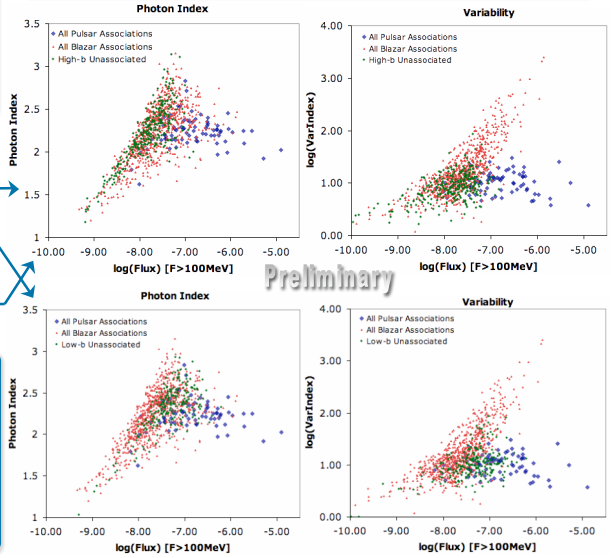
References

1 - Abdo et al. 2009, ApJS, 183, 46
2 - Abdo et al. 2009, ApJ, 699, 976
3 - Cheung, C.C., Fermi LAT Discovery of Gamma-rays from the Giant Radio Lobes of Centaurus A
4 - Abdo et al. 2009, ApJL, 701, 123
5 - Abdo et al. 2009, arxiv:0910.1608
6 - Abdo et al. 2009, Science, 325, 840
7 - Saz Parkinson, P., Fermi LAT Discovery of Gamma-ray Pulsars in Blind Searches
8 - Abdo et al. 2009, ApJ, 700, 597

Potential Trends via Intrinsic Source Parameters

Intrinsic source parameters for unassociated sources can be compared against patterns of known classes. Correlations with such parent populations are easier to identify when the sample is divided into sources inside and outside the Galactic plane.

Low Galactic latitude unassociated sources tend to clump more towards pulsars in parameter space, while high-b sources (unsurprisingly) follow similar trends to blazars. We find a large overlap between the different groups, and the observed trends in the unassociated sample may be driven largely by the detection performance.



Source Association in the LAT Catalog

Associating *Fermi* LAT sources with counterparts of interest is performed using a Bayesian probability based on the position match and the chance coincidence in a given direction. The most likely source classes have been considered:

- Blazars (BL Lacs, FSRQs, etc.) ~55%
- Other AGN (Seyferts[2], Radio Galaxies[3], etc.) ~2%
- Pulsars and binaries (HMXBs[4], LMXBs, etc.) ~4%
- Galactic Sources (SNRs, PWNe, Globular Clusters, etc.) ~1%

Even after such searches, ~38% of *Fermi* LAT source detections remain unassociated with one of these potential counterparts. These sources represent areas of new discovery.

At this time, there is no indication of a significantly numerous new class of gamma-ray emitters in the Fermi LAT dataset, though there have been several surprising detections[2,3,4].

Variability Index

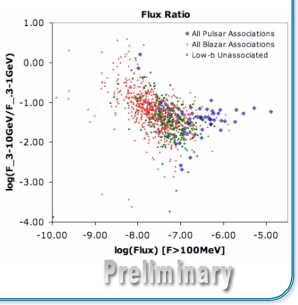
Only ~5% of unassociated sources are found to be variable. Variability is much easier to detect outside the bright Galactic plane, with only 11% of low-b LAT sources exhibiting variability. Here, the variability index represents the value of χ^2 calculated against a constant hypothesis.

Photon Index

Spectral index returned from the log(Likelihood) analysis using a power-law model across the entire 100 MeV to 100 GeV range. While this parameter is useful in determining the overall spectral hardness, it is insensitive to curved spectral shapes and cut-offs.

Flux Ratio(s)

Flux was calculated for each source in five separate energy bands, and then summed to find the total flux. Comparisons of flux in several different bands can prove a useful probe of source properties. Care was taken to exclude sources from this analysis where statistics were not significant in any one of the pertinent bands.



Finding Pulsars

Currently detected LAT pulsars are typically:

- Non-variable (V < 25)
- Average spectral break at 2.2 GeV[5]
- Hard $F_{0.1\text{-}0.3}/F_{0.3\text{-}1}$ flux ratio (~1.4) below the cut-off

Less than 1% of this sample of LAT unassociated sources match these characteristics.

Blind searches[6] of previously unassociated LAT sources that appear pulsar-like has proved extremely successful at identifying new pulsars. To date, 22 new radio-faint/quiet gamma-ray pulsars[5,7] have been identified from such sources. In addition, a consortium of radio astronomers is working closely with the LAT team to provide accurate timing models for radio pulsars, as well as following up on strong LAT detections as a method of identifying new pulsars.

It is expected that many LAT sources within the excluded Galactic ridge region are likely to be pulsars. However, a point source of any kind has a better chance of being detected over the intense Galactic diffuse emission if it has a high Test Statistic, which is inherently better in harder sources. Also, it is difficult to detect a significant variability index above the large background counts under the PSF in this region. The result of these detection biases is that at low latitude ALL detected sources tend to look harder and less variable, i.e. more like pulsars.

Finding Blazars

Typical blazar characteristics in the LAT are:

- Time-variable
- High probability of association[8] with a known blazar

By definition, LAT unassociated sources do not have a high association probability. While high-latitude unassociated sources are clearly more blazar-like than pulsar-like, this is not the case for low-b unassociated sources. As most blazar surveys avoid the region near the Galactic plane, one might expect a number of unassociated sources in the low-b sample to be blazars.

Since gamma-ray background is significantly higher near the plane, a blazar at low-b must be significantly more luminous to be well-localized. For this reason, less than 2% of the associated blazars are at $|b| < 10°$. Identifying new blazars from LAT unassociated sources is typically the result of significant variability in the source. Such transient activity must be followed up by multi-wavelength observations in order to secure a blazar classification.

An ongoing program of radio observations of LAT unassociated source fields is being conducted with the goal of filling in the low-Galactic latitude region of the AGN surveys. Additionally, rapid notification of transient activity (via ATELs) and immediate X-ray/optical follow-up provides for the best chance of firm blazar identification following a detected gamma-ray flare.