Characteristics of Fermi-LAT Unassociated Sources in the 2FGL Catalog

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Unassociated Fermi LAT sources provide a population with discovery potential. Using classification techniques exploiting only the gamma-ray properties, we separate the 2FGL sources into pulsar and AGN candidates, and compare them to the associated source populations.

Abstract
A significant fraction of gamma-ray sources detected by the Fermi Large Area Telescope are not associated with any known gamma-ray emitting object. These sources represent discovery space for new source classes, or new members of existing source classes. We discuss the spatial, spectral and temporal characteristics of the unassociated sources in the second Fermi-LAT source catalog (2FGL). We compare these distributions with the characteristics of the primary source classes (extragalactic vs. Galactic sources) to provide likely source classifications, and compare our results against the total predicted numbers of each source population. We also review the 1FGL unassociated source population, and discuss how changes in the catalog analysis have affected the resulting unassociated source sample.

LAT Catalog Improvements
The first LAT catalog (1FGL) had a number of known issues that were addressed to some extent in 2FGL. These include:
- Smaller pixel size and shift in registration for the Galactic diffuse model
- Curved spectra where tests show improvement in detection significance
- Exponentially cut-off power-law spectrum for known gamma-ray pulsars

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.) ~58%
- Other AGN (Seyferts, Radio Galaxies, etc.) ~2%
- Pulsars and binaries (HMXBs, LMXBs, etc.) ~6%
- Other Galactic Sources (SNRs, PWNe, Globular Clusters, etc.) ~4%

Even after such searches, ~30% 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 clear indication of a significantly numerous new class of gamma-ray emitters in the Fermi LAT dataset.

Finding Pulsars
Currently detected LAT pulsars are typically:
- Non-variable (V < 41.6 in 2FGL)
- Average cutoff at 2.3 GeV
- Hard F_{0.3-1}/F_{3-10} flux ratio (~1.4) below the cut-off

Blind searches\(^1\) of previously unassociated LAT sources that appear pulsar-like have proved extremely successful at identifying new pulsars. To date, 25 new radio-faint/quiet gamma-ray pulsars 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. By following up on strong LAT detections, this group has discovered 31 new millisecond and 2 new young pulsars\(^2\).

Finding Blazars
Typical blazar characteristics in the LAT are:
- Time-variable (TSvar > 41.6)
- High probability of association with a known blazar\(^3\)

Since gamma-ray background is significantly higher near the plane, a blazar at low-Galactic latitude must be significantly more luminous to be well-localized. 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 is working to fill in the low-Galactic latitude region of AGN surveys. This has significantly improved the AGN association rate at low latitudes.

References
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2. Ackermann, M. et al., 2011, apj, 730, 95
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