The Second Catalog of AGNs Detected by the Fermi LAT (2LAC)

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*The Second Catalog of Active Galactic Nuclei Detected by the Fermi LAT*

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Charles Dermer
GLAST: The Gamma Ray Large-Area Space Telescope (launched June 11, 2008)

Large Area Telescope (LAT) images the sky one photon at a time: $\gamma$-ray converts in LAT to an electron and a positron; direction and energy of these particles tell us the direction and energy of the photon.
• unprecedented sensitivity

• sky scanned every 3 hours in survey mode

• fairly uniform at high galactic latitude

• alerts issued shortly after transient or new flaring sources are detected

• continuous survey allows for source monitoring and variability studies on time scales ranging from months down to a few hours

• covers the little-explored 10-100 GeV domain
  • new spectral features at high energy discovered
  • identification of potential candidates of TeV sources (several discoveries)
Fermi Large Area Telescope 2FGL catalog

Credit: Fermi Large Area Telescope Collaboration
Fermi Large Area Telescope 2FGL catalog

- AGN
- AGN-Blazar
- AGN-Non Blazar
- Galaxy
- Starburst Galaxy
- Radio Galaxy
- Seyfert Galaxy
- Nova
- PSR
- PWN
- PSR w/PWN
- SNR
- Globular Cluster
- HMB

1873 sources with TS>25
The Second LAT AGN catalog (2LAC)

- 24 month data set
- 1319 TS>25, |b|>10° sources
- 2LAC: 1017 counterparts
  991 sources
- 886 high-confidence
  \(P_{\text{assoc}}>80\%\) AGNs
  in clean sample

Differences between Northern and Southern Hemisphere
(only 38% BL Lacs in South)

<table>
<thead>
<tr>
<th></th>
<th>1LAC/1FGL</th>
<th>2LAC/2FGL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period</strong></td>
<td>11 m</td>
<td>24 m</td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>unbinned</td>
<td>binned</td>
</tr>
<tr>
<td><strong>IRFs</strong></td>
<td>P6_V3_DIFFUSE</td>
<td>P7_V6_SOURCE</td>
</tr>
<tr>
<td><strong>Association methods</strong></td>
<td>Bayesian</td>
<td>Bayesian</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Likelihood-Ratio Log N- Log S</td>
</tr>
<tr>
<td><strong>Parent catalogs</strong></td>
<td>CRATES/BZCat</td>
<td>Many*</td>
</tr>
<tr>
<td><strong>Association</strong></td>
<td>663/1079 (61%)</td>
<td>991/1319 (75%)</td>
</tr>
<tr>
<td><strong>Clean Sample</strong></td>
<td>599</td>
<td>886</td>
</tr>
</tbody>
</table>

* CRATES, BZCat, NVSS, SUMSS, PMN, ATCA 20 GHz, FRBA, GAPS, CLASS, VCS, RASS
** γ-ray AGN source associations/total γ-ray sources at |b|>10°
SED-based classification


- relation with $\nu_{\text{syn}}$ estimated from $\alpha_{\text{ox}}$, $\alpha_{\text{ro}}$
- subclasses assigned from $\nu_{\text{syn}}$
  - LSP, ISP, HSP: Low-, Intermediate-, High-Synchrotron Peaked blazars
    - LSP: $\log[\nu_{\text{syn}} \text{ (Hz)}] < 14$
    - ISP: $14 < \log[\nu_{\text{syn}} \text{ (Hz)}] < 15$
    - HSP: $\log[\nu_{\text{syn}} \text{ (Hz)}] > 15$
## Census

<table>
<thead>
<tr>
<th>AGN type</th>
<th>Entire 2LAC</th>
<th>2LAC Clean Sample*</th>
<th>Low-lat sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>1017</td>
<td>886</td>
<td>104</td>
</tr>
<tr>
<td>FSRQ</td>
<td>360</td>
<td>310</td>
<td>19</td>
</tr>
<tr>
<td>...LSP</td>
<td>246</td>
<td>221</td>
<td>7</td>
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<tr>
<td>...ISP</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>...HSP</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>...no classification</td>
<td>108</td>
<td>86</td>
<td>10</td>
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<tr>
<td>BL Lac</td>
<td>423</td>
<td>395</td>
<td>16</td>
</tr>
<tr>
<td>...LSP</td>
<td>65</td>
<td>61</td>
<td>3</td>
</tr>
<tr>
<td>...ISP</td>
<td>82</td>
<td>81</td>
<td>3</td>
</tr>
<tr>
<td>...HSP</td>
<td>174</td>
<td>160</td>
<td>5</td>
</tr>
<tr>
<td>...no classification</td>
<td>102</td>
<td>93</td>
<td>5</td>
</tr>
<tr>
<td>Blazar of Unknown type</td>
<td>204</td>
<td>157</td>
<td>67</td>
</tr>
<tr>
<td>...LSP</td>
<td>24</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td>...ISP</td>
<td>13</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>...HSP</td>
<td>65</td>
<td>53</td>
<td>13</td>
</tr>
<tr>
<td>...no classification</td>
<td>102</td>
<td>74</td>
<td>41</td>
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<tr>
<td>Other AGN</td>
<td>30</td>
<td>24</td>
<td>2</td>
</tr>
</tbody>
</table>

* 8 misaligned AGNs, 4 NLS1s, 10 AGNs of other types, 2 starburst galaxies
45 (out of 599) 1 LAC clean sample sources are missing in 2LAC
3C 78, 3C 111, 3C 120 out; Fornax A, Cen B in
Redshift distributions

Distributions similar to 1LAC
$z_{\text{max}}$ for FSRQs: 3.1
BAT: 40% of FSRQs with $z>2$
50 BZCat FSRQs with $z>2$

~50% of BL Lacs without redshift for all subclasses
Photon index – Flux distributions

- FSRQs
- BL Lacs
- Other AGNs

- No z
- z<0.5
- z>0.5

Flux [E>100 MeV] (ph cm⁻² s⁻¹)

Photon spectral index

Number of sources vs. Photon spectral index for different categories of AGNs.
Photon index vs. $\nu_{\text{peak}}$
No evolution of photon index vs z for FSRQs

Strong evolution for BLLacs but just due to different subclasses (LSP, ISP, HSP) having different redshift distributions
Luminosity vs. redshift

\[ L_\gamma = 4\pi d_L^2 \frac{S(E_1, E_2)}{(1 + z)^2 - \Gamma} \]

- \( d_L \): luminosity distance
- \( S(E_1, E_2) \): energy flux between \( E_1 (100 \text{ MeV}) \) and \( E_2 (100 \text{ GeV}) \)

index = 2.2
index = 1.8
Photon index vs. luminosity

- FSRQs
- LSP-BL Lacs
- ISP-BL Lacs
- HSP-BL Lacs
- Non AGNs
2LAC summary

- Number of associated sources has increased by 52% over 1LAC
- 75% of 2FGL sources at $|b|>10^\circ$ are in the 2LAC; more than 97% are blazars.
- 24 non-blazar sources in Clean Sample
  - 8 misaligned AGNs
  - 4 NLS1s
  - 10 AGNs of other types
  - 2 starburst galaxies
- BL Lacs outnumber FSRQs (395/310); 55% BL Lacs lack measured redshifts
- Among BL Lacs, HSPs dominate over ISPs and LSPs (53%, 27%, 20%)
- 39/45 TeV AGNs have now been detected
- Radio/$\gamma$-ray connection and Implications for blazar evolution and jet physics

Next catalog should be based on 5 years worth of data.