

# The Second Fermi LAT Catalog (2FGL): Caveats and Classifications

Dave Thompson  
NASA Goddard Space Flight Center  
on behalf of the  
Fermi Large Area Telescope  
Collaboration

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## **The Second Fermi LAT Catalog (2FGL)**

**Work on the LAT catalog involves the entire LAT collaboration, all the way back to the beginning of the project.**

**Nevertheless, there is a core group who have led the actual production of the 2FGL catalog.**



## Catalog – Core Team

- **Jean Ballet**
- **Toby Burnett**
- **Jean-Marc Casandjian**
- **Seth Digel**
- **Steve Fegan**
- **Elizabeth Ferrara**
- **Isabelle Grenier**
- **Jürgen Knödlseeder**
- **Gino Tosti**



# Caveats

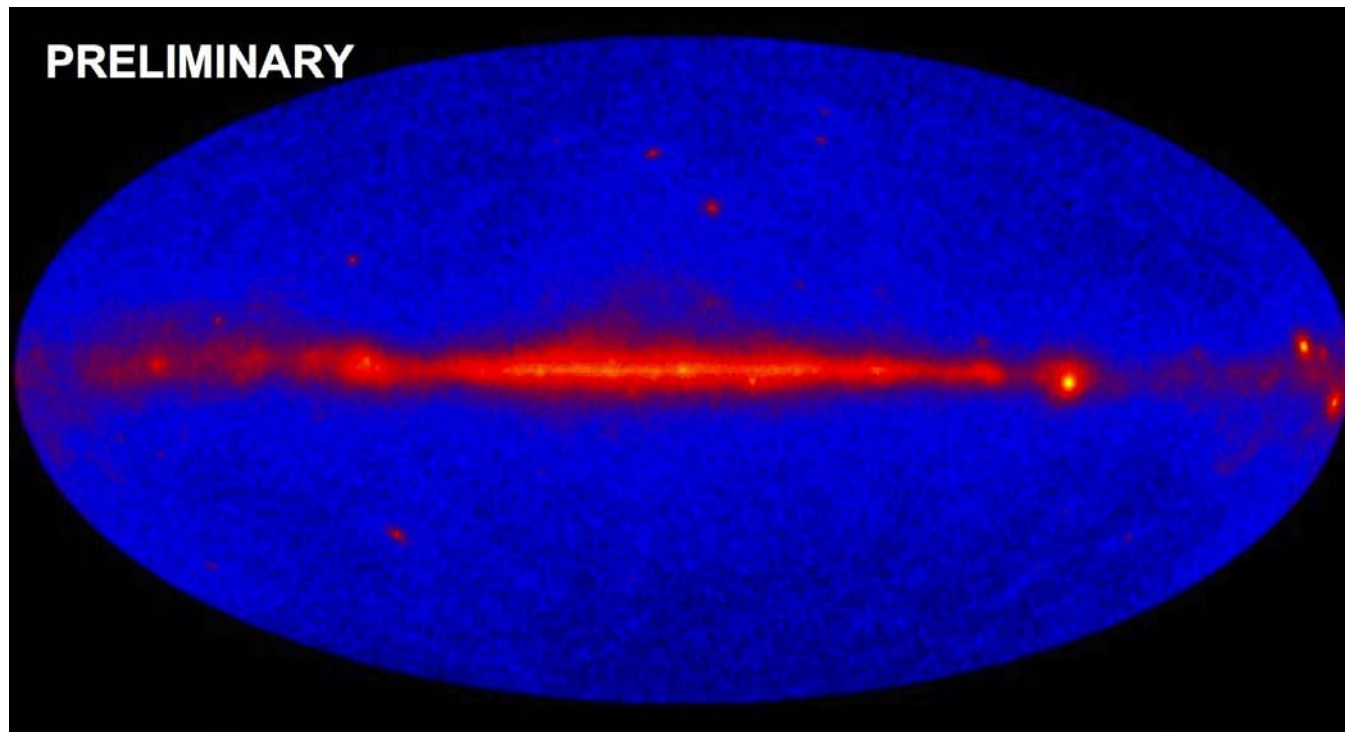
**Why?**

**In the course of producing the 2FGL catalog, we have learned a number of ways NOT to do the analysis if we want the best scientific results.**

# 1. A New Data Set → New Results

- The 2FGL catalog is based on reprocessing of the LAT event data, going from Pass 6 to Pass 7. Pass 7 has lower background and more sensitivity at low energies, and therefore new Instrument Response Functions (IRFs). Talk by Eric Charles tomorrow.
- The skymap below was generated from Pass 7 events in the 1FGL time frame that were NOT in the Pass 6 1FGL data set.

Some events were also removed from the previous data set.



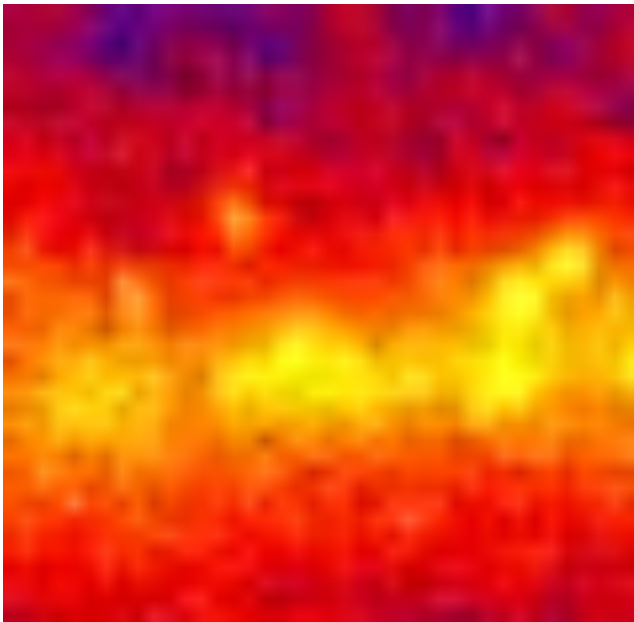


## 2. The New Diffuse Model is Not a Physical Model of the Galactic Emission

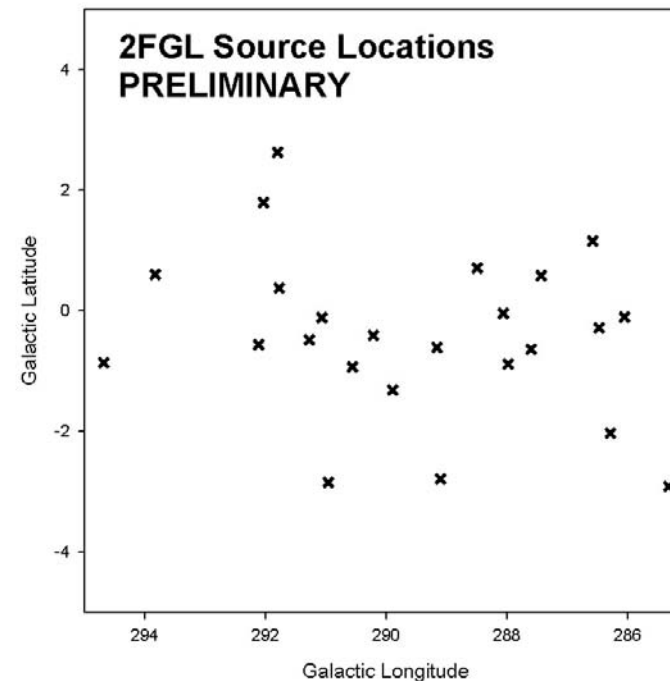
- As was the case for the 1FGL catalog, the improved diffuse model used to construct the 2FGL catalog was developed empirically for the purpose of point source analysis, not for studying the diffuse emission itself. Talk by Jean-Marc Casandjian later today.
- As with any empirical model, it involves assumptions about which structures are truly diffuse and which are related to sources. This issue is particularly important in regions near spatially extended sources, which are now included in the 2FGL catalog, or near regions of interstellar gas clouds. See Seth Digel's poster about sources possibly associated with gas clouds.

### 3. Source Confusion is an Issue in the Galactic Ridge

- The concentration of sources at low Galactic latitudes toward the inner Galaxy results in sources close enough to each other that their Point Spread Functions overlap, particularly at the lower energies. The strong diffuse emission complicates the analysis. As in 1FGL, we mark these sources as “c” as a warning about confusion.
- Parts of the sky away from the Galactic Plane show little impact of source confusion.

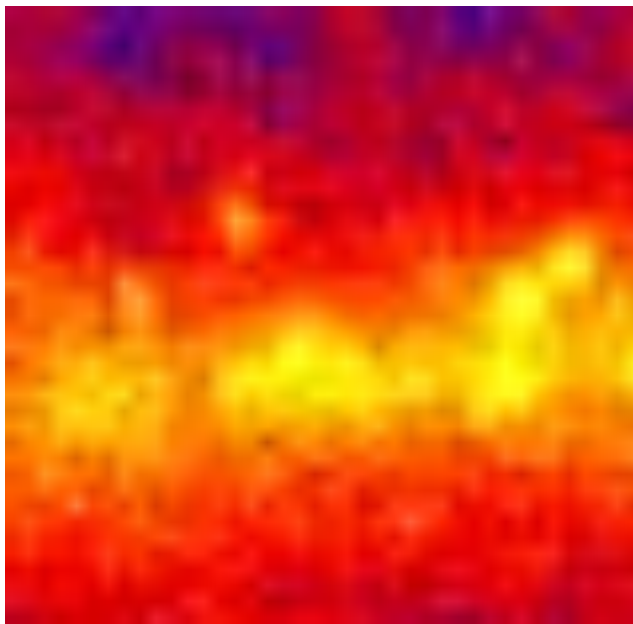


Counts map  $E > 1$  GeV

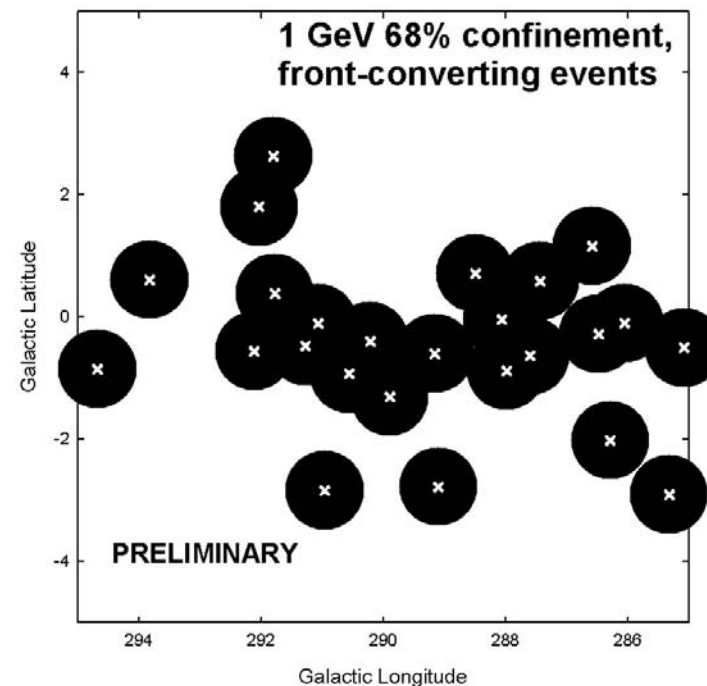


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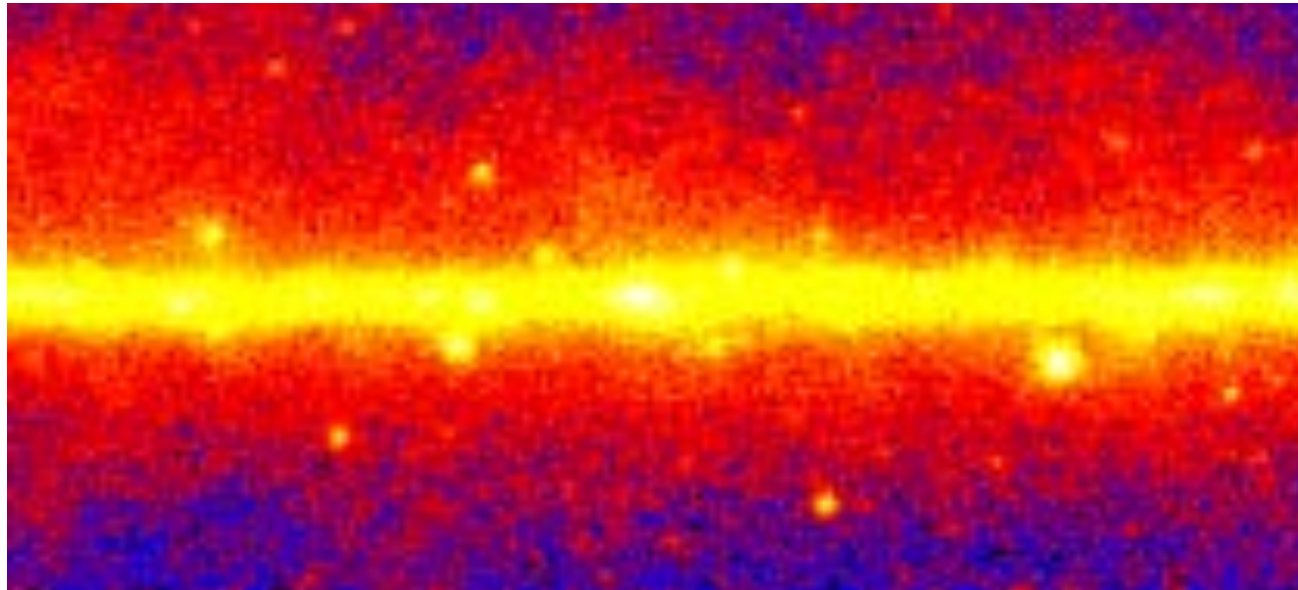


## 4. The Region Around the Galactic Center is Particularly Complex

- There are many sources in the Galactic Center region, and the diffuse model used for the 2FGL catalog work shows some residuals compared to the large-scale diffuse emission observed in this region. Talk by Troy Porter later today.
- The 2FGL catalog results for the region around the Galactic Center should be considered a good first approximation rather than a comprehensive analysis.

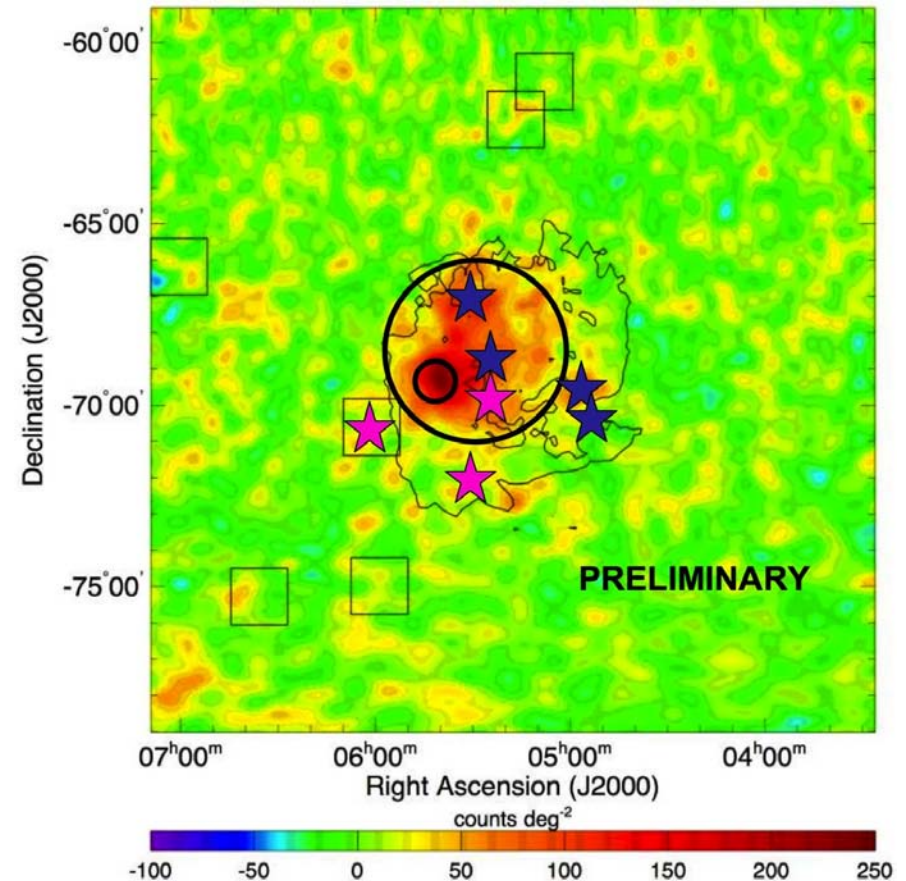
$50^\circ \times 25^\circ$

$E > 1 \text{ GeV}$



## 5. Modeling of Spatially Extended Sources Introduces Its Own Uncertainties

- The templates for the 12 sources in 2FGL that are spatially extended are approximations based on our best current knowledge.
- Analysis of regions around such sources can leave residuals that look like point sources (and in some cases may be). For example, there are 7 point sources in the vicinity of the Large Magellanic Cloud. 3 of these have blazar/radio source associations, but 4 do not and could be artifacts.



LAT LMC map with overlay showing 2 component template and nearby 2FGL sources.



## 6. Positional Association is Not Adequate for Source Identification

- As with the 1FGL catalog, the 2FGL results will show associations with plausible gamma-ray-producing objects. The average 95% uncertainty radius is about 7 arcmin, too large in most cases to claim identification based on position.
- The association technique developed by Jürgen Knödseder is a Bayesian probability analysis based on the local density of sources from catalogs of likely objects. Additional association tests are being done by the LAT AGN group (talk by Cavazzuti).
- Some 2FGL sources are firmly identified, based on periodic signals, spatial morphology, or correlated variability with objects known at other wavelengths.



## 7. The 2FGL Catalog is Not Perfect

- **We have taken far longer than we expected to build the second LAT catalog, trying to make it as good as possible for the scientific community.**
- **Some of what we have learned in the process is included in these caveats.**
- **Nevertheless, the time spent has been useful. The 2FGL catalog is a major improvement over the 1FGL catalog and will be a valuable resource for future LAT analysis.**
- **SCHEDULE: the catalog itself will be out this month, and the new Pass 7 data, IRFs, and diffuse model will be released through the Fermi Science Support Center within 2 months.**

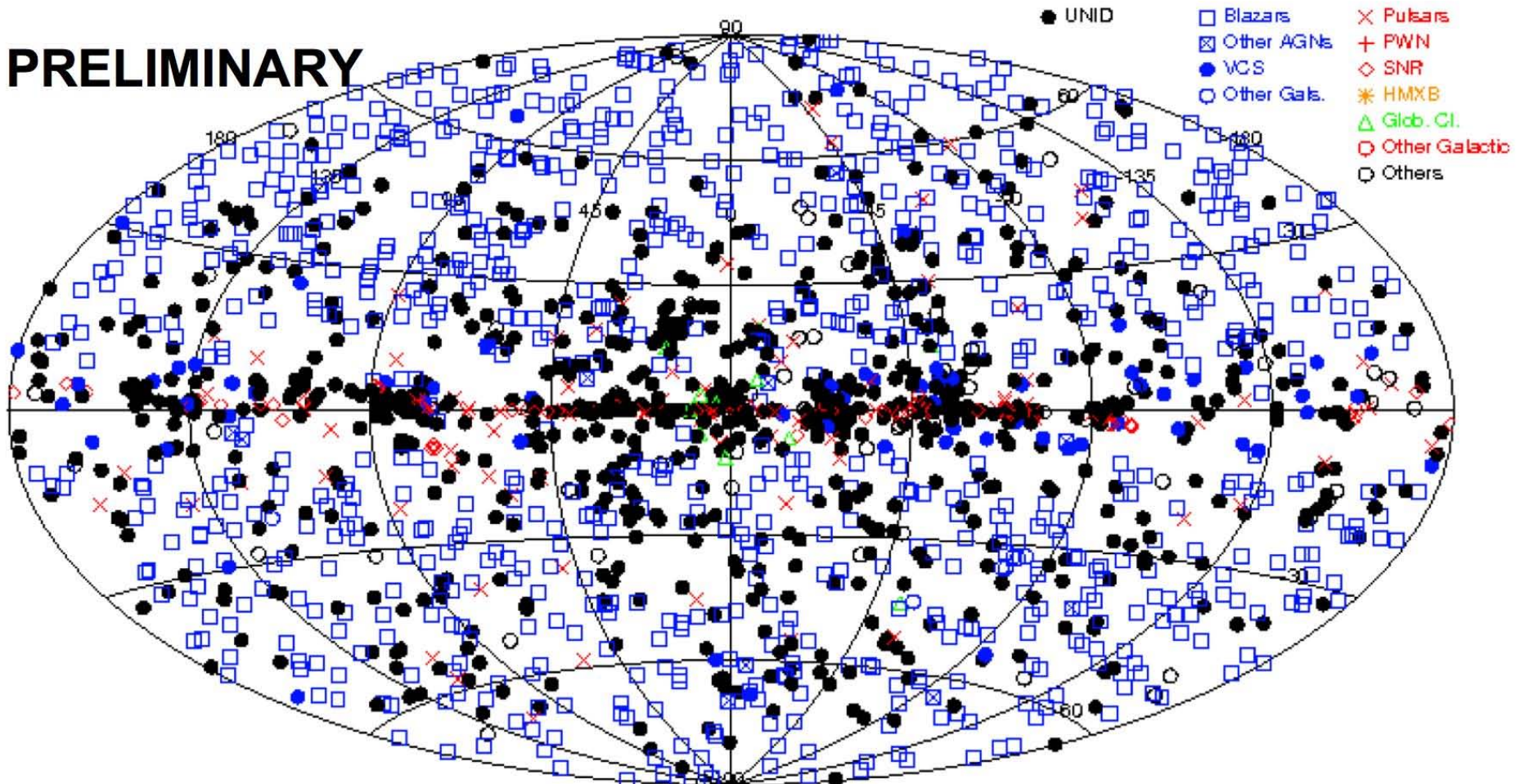


# Classifications

**What is (and is not) in the 2FGL catalog?**

# Classifications

PRELIMINARY





# Classifications

Type	Number	Percentage of total
Active Galactic Nuclei	832	44%
Candidate Active Galactic Nuclei	268	14%
Unassociated	594	32%
Pulsars (pulsed emission)	86	5%
Pulsars (no pulsations yet)	26	1%
Supernova Remnants/Pulsar Wind Nebulae	60	3%
Globular Clusters	11	< 1%
Other Galaxies	7	< 1%
Binary systems	4	< 1%
<b>TOTAL</b>	<b>1888</b>	<b>100%</b>

**Very Preliminary - Work Still In Progress**



# Some Highlights

- **The number of known gamma-ray blazars and pulsars continues to grow.**
- **A new gamma-ray binary. Talk by Robin Corbet on Thursday.**
- **Despite expanded searches for counterparts, the number of unassociated sources remains a significant part of the 2FGL catalog.**
- **The spatially extended sources add confidence to our associations of LAT sources with supernova remnants and pulsar wind nebulae.**





# What is Not in the Catalog is Also Important

- **Seyfert Galaxies (except for Narrow Line Seyfert 1s)**  
- poster by Masaaki Hayashida
- **Clusters of Galaxies** - talk by Stephan Zimmer on Wednesday.
- **Dwarf Spheroidal Galaxies** - talk by Maja Llena Garde on Tuesday.

# Summary

- The 1888 sources in the 2FGL catalog represent a significant advance in tracking the overall content of the gamma-ray sky.
- Separating sources from each other and from the diffuse background has presented challenges.
- Source classes are better defined, and the absence of some predicted sources has important implications.
- The catalog and its related products - data, diffuse model, IRFs - are coming soon.



# Backup Slides

# Spatially Extended Sources

Extended Source	Spatial Form	Spectral Form
SMC	2D Gaussian	Exp Cutoff PL
LMC	2D Gaussian <sup>a</sup>	Exp Cutoff PL
IC 443	2D Gaussian	Log Parabola
Vela X	Disk	Power Law
Centaurus A (lobes)	Contour Map	Power Law
MSH 15–52	Disk	Power Law
W28	Disk	Log Parabola
W30	Disk	Log Parabola
HESS J1825–137	2D Gaussian	Power Law
W44	Ring	Log Parabola
W51C	Disk	Log Parabola
Cygnus Loop	Ring	Exp Cutoff PL