Fermi Gamma-ray Space Telescope

The Second Fermi LAT Catalog (2FGL): Why Has It Taken So Long?

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The Second Fermi LAT Catalog (2FGL)

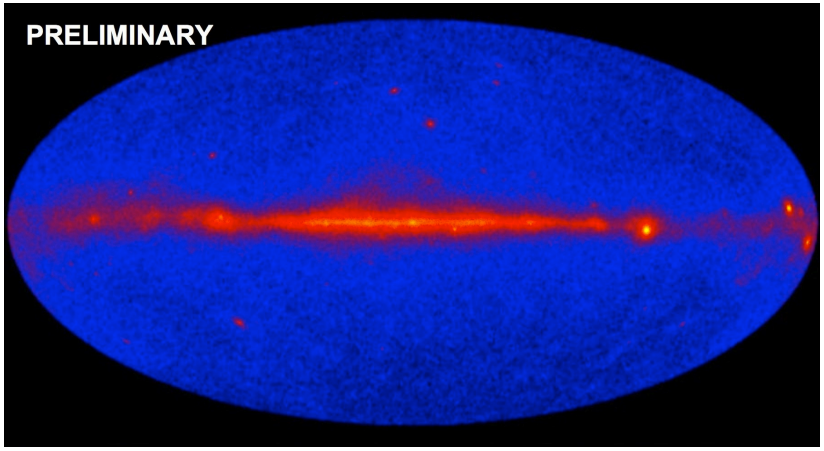
A decision made last Fall: 2FGL would not be "more of the same," just repeating the 1FGL analysis with 24 months of data.

Instead, 2FGL would be an improved analysis.

Some of these improvements were already mentioned by Peter.

Catalog – Input Improvements

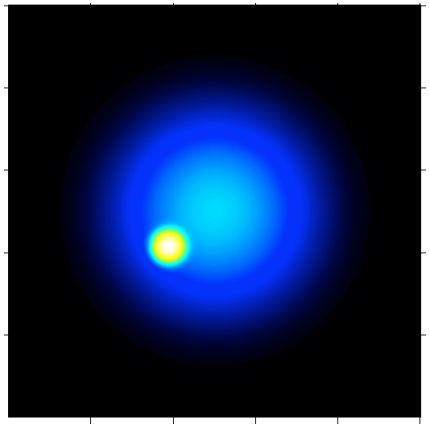
- **The 2FGL catalog is based reprocessed LAT event data, going from Pass 6 to Pass 7. Pass 7 has lower background and more sensitivity at low energies, and therefore new Instrument Response Functions (IRFs).**
  This skymap was generated from Pass 7 events in the 1FGL time frame that were NOT in the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



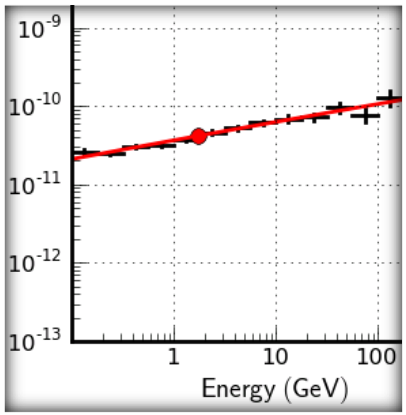
- **The diffuse model includes new information about large-scale structures like Loop I and the giant lobes. It also uses 1/8° binning instead of 1/2°, and the bins are centered on b=0 instead of having b=0 at an edge.**

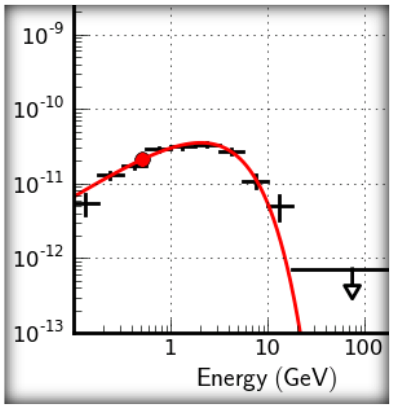
Catalog – Source Modeling Improvements

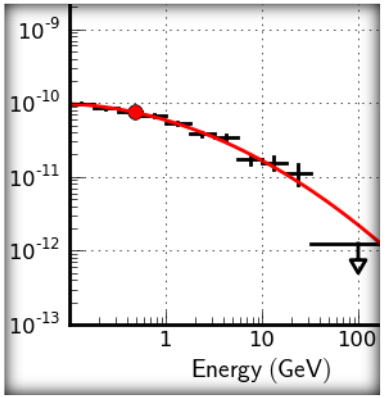
- **Spatially extended sources were included in the modeling of the sky.** **The LMC, for example, was modeled with two gaussians, as shown here.**



- **Instead of only power-law spectral modeling, we also allowed exponential cutoffs (pulsars) and log parabola (some AGN) spectra.**

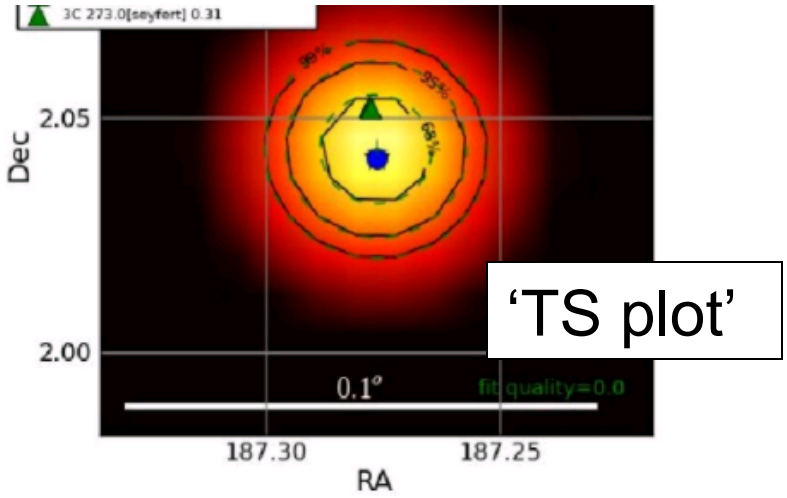




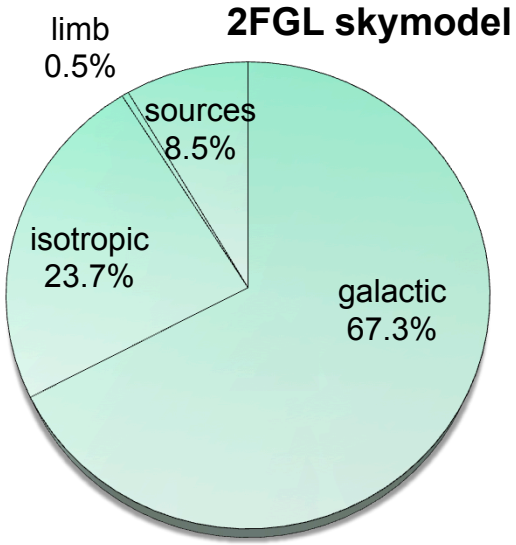


Catalog – Process Improvements

- **The key is that we have to account for all the photons – diffuse Galactic, isotropic, point and extended sources, Earth limb (events that escape the zenith angle cut). Energy range 100 MeV – 100 GeV.**
- **Stage 1 – use a variety of finding algorithms to look for candidate sources, then optimize the locations for all "seeds" that seem significant.**
- **For all analysis, use maximum likelihood as the basic tool.** Test Statistic: $TS=-2\log(L_{fit}/L_{null})$
- **Retain all seeds with TS > 10.**



'TS plot'

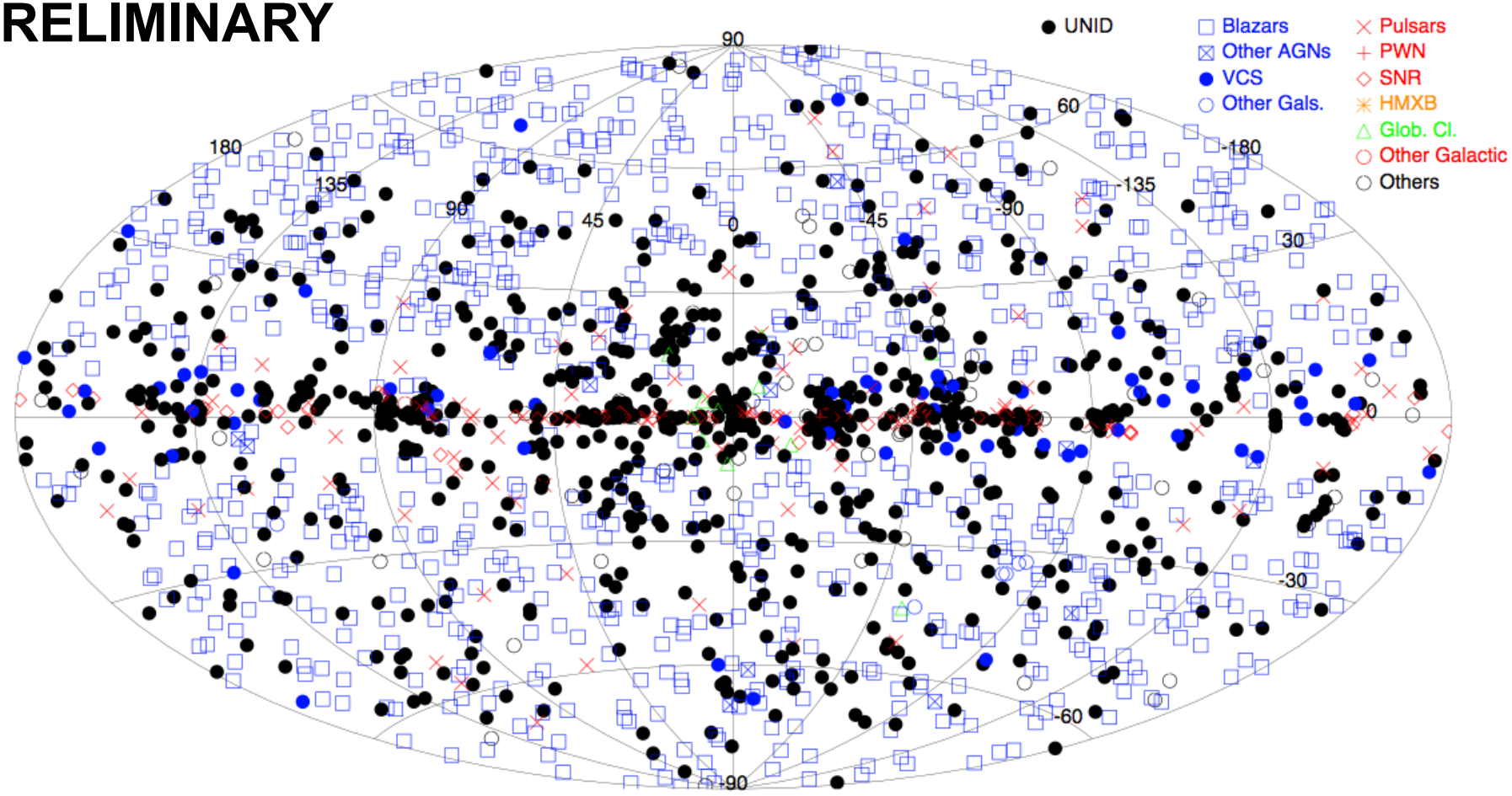


Catalog – Process Improvements

- The key is that we have to account for all the photons – diffuse Galactic, isotropic, point and extended sources, Earth limb.
- Stage 2 – use binned likelihood to optimize the whole sky in overlapping regions. We discovered that the unbinned likelihood used for 1FGL generated biased local fits to the diffuse components. Unbinned is also prohibitively computer-intensive for large data sets. Binned analysis is more conservative.
- Retain all sources with TS > 25 (about 4σ).
- Generate tables, light curves, spectra, and associations.

The 2FGL Catalog – 1873 Sources

PRELIMINARY



Classifications

Type	Number	Percentage of total
Active Galactic Nuclei	1077	57%
Unassociated	591	32%
Pulsars (pulsed emission)	81	4%
Pulsars (no pulsations yet)	26	1%
Supernova Remnants/ Pulsar Wind Nebulae	70	4%
Globular Clusters	11	< 1%
Other Galaxies	12	< 1%
Binary systems & Misc.	5	< 1%
TOTAL	1873	100%

The Delay

- We had the catalog essentially finished six weeks ago.
- Then we presented the preliminary results at the Fermi Symposium in Rome.
- Essentially everyone had the same question: Why are there so many 1FGL sources that are not found in the 2FGL catalog?
- We realized that we had not done a careful enough analysis of that question.

The 'Missing' Sources

- 350 1FGL sources (out of 1451) are not formally associated with 2FGL sources.
- The number of changes since 1FGL is large enough that a unique reason is not always possible for why a source is not associated.
- 50 of the sources moved beyond the association radius – changes in the diffuse model or splitting a single source into two can account for these.
- 200 of the sources are seen, but at TS<25 – variability, change from unbinned likelihood to binned, or changes in the diffuse model.
- 100 of the sources are not confirmed – some are Sun detections, some were statistical fluctuations, and some were due to diffuse model changes.

Status

- The 2FGL catalog analysis complete.
- The source list, locations, location uncertainties, fluxes in 5 energy bands, light curves, and spectra have all been produced.
- We are finishing putting some flags on sources, including 162 that will have a “c” flag warning of confusion with diffuse emission.
- The text of the paper is essentially complete.
- Internal review of the work is in progress.
- We expect to have the catalog release within the next two weeks, and we are trying for next week.

Summary

- The 1873 sources in the 2FGL catalog represent a significant advance in tracking the overall content of the gamma-ray sky.
- As with any catalog, research is enabled by having these results available.
- Multiwavelength opportunities include long time series studies, searches for counterparts for unassociated sources, and detailed modeling of known sources.
- The catalog and its related products - data, diffuse model, IRFs - are imminent.

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LAT 2-year Point Source Catalog

The Fermi Gamma-ray Space Telescope (Fermi) Large Area Telescope (LAT) is a successor to EGRET, with greatly improved sensitivity, resolution, and energy range. This web page presents the second full catalog of LAT sources, based on the first 24 months of survey data. For a full explanation about the catalog and its construction see the LAT 2-year Catalog Paper preprint.

The source designation is 2FGL JHHMM.m+DDMM(c,e) where the 2 refers to the second catalog (one was released at 1 year, and another is planned for after 5 years) and FGL represents Fermi Gamma-ray LAT. The optional "c" and "e" designators are explained in the caveats below.

LAT Catalog Data Products

The LAT 2-year Point Source Catalog is currently available as a FITS file and as an XML model file to be used for data analysis within the Fermi Science Tools. It will also be made available as a BROWSE table. Supporting tools and information have been provided and are linked below.

It is important that all users of this catalog review the caveats listed below the catalog links. These describe the content of the catalog at a high level, as well as some cautions for the user.

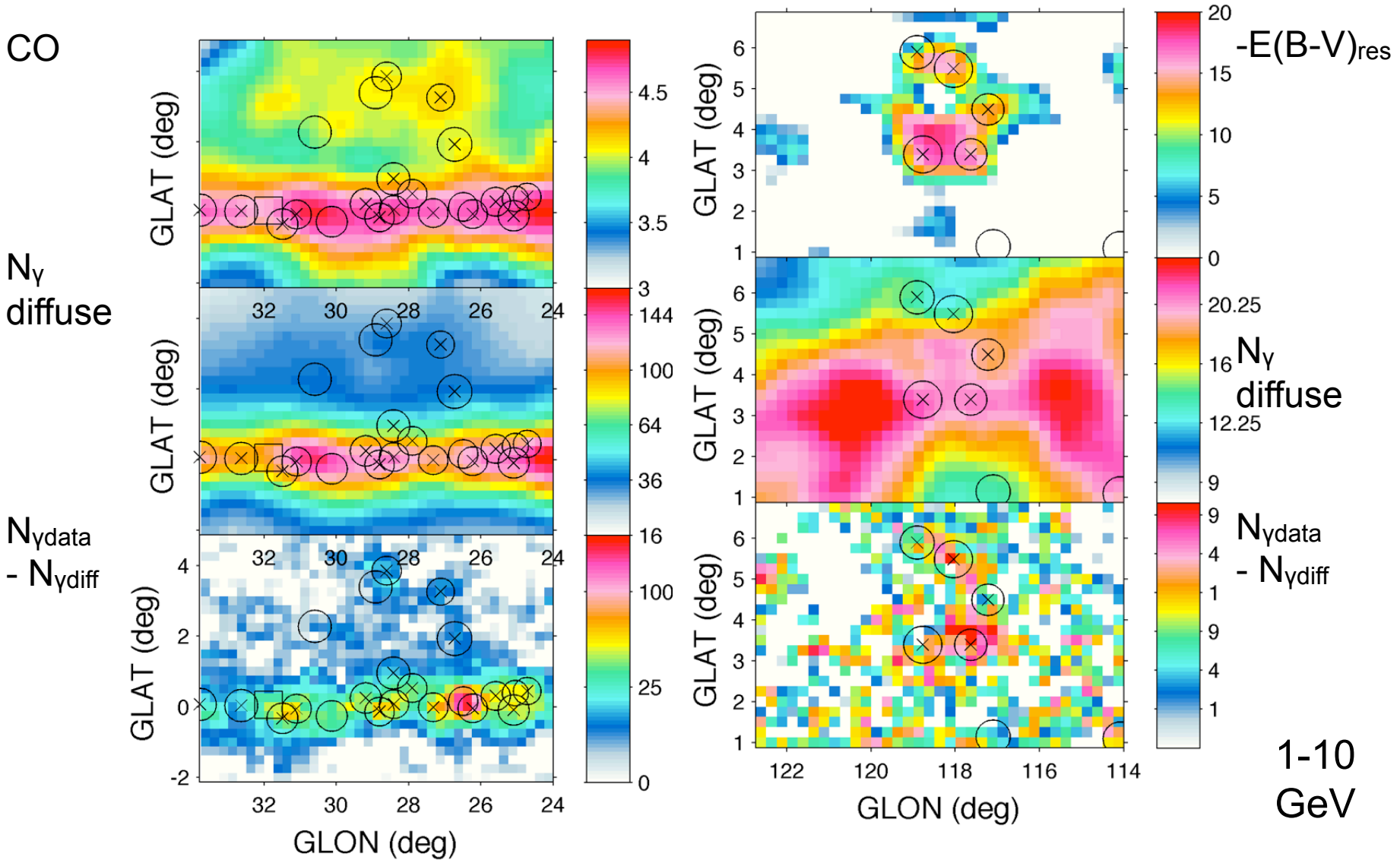
- LAT 2-year Point Source Catalog (FITS format)
- LAT 2-year Point Source Catalog (BROWSE table) <- Coming Soon!
- LAT 2-year Catalog Paper preprint
- LAT 2-year Catalog column descriptions <- Coming Soon!
- XML Model File for LAT 2-year Catalog
- DS9 Region File
  (Crosses indicate sources with fixed positions - pulsars and binaries. Ellipses are provided for all other sources.)
- Python tool to convert FITS information to XML (User contributed) <- Coming Soon!

LAT Catalog Caveats

Backup Slides

"c" sources

- **sources confused with ISM structures or caused by defects in the ISM model with respect to the observed emission**



Spatially Extended Sources

Extended Source	Spatial Form	Spectral Form
SMC	2D Gaussian	Exp Cutoff PL
LMC	2D Gaussian[a]	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