

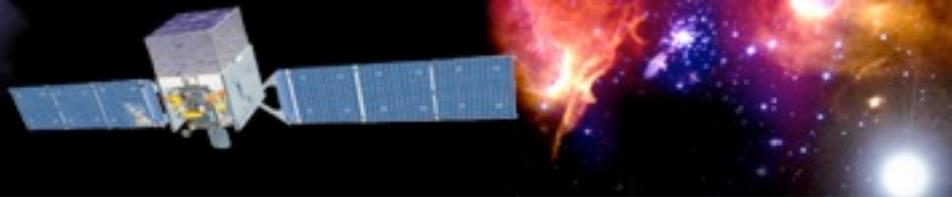


FSSC Science Tools

Generating Source Models: Using the LAT Catalog for Analysis

First LAT Catalog (1FGL)

- ▶ *Released 2010-01-14, with small updates on 2010-02-04.*
 - *Second catalog scheduled for release in Spring 2011*
- ▶ *Available from FSSC at:*
 - http://fermi.gsfc.nasa.gov/ssc/data/access/lat/1yr_catalog/*
 - *Full Catalog in FITS format*
 - *Catalog column descriptions*
 - *XML file containing output models for each source*
 - *DS9 region files (point or ellipse)*
 - *Change log for content updates*
- ▶ *Also available as a BROWSE table:*
 - *Allows for queries/searches based on Catalog content*



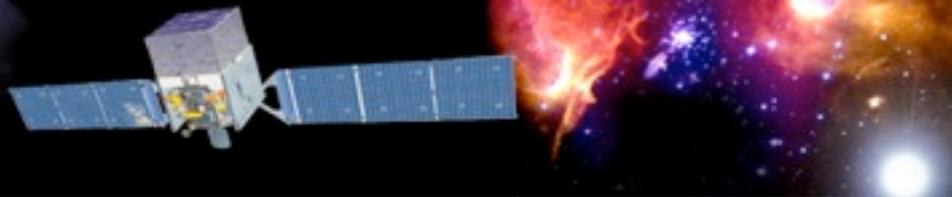
1FGL Catalog

▶ *Cuts used for analysis*

- *100 MeV - 100 GeV*
- *Integrated data for 4 August 2008 - 4 July 2009 (11 months)*
- *Rocking angle < 43° (more recent data requires a looser cut)*
- *Excluded 20 min around GRB 080916C and 300 sec around GRB 090510*

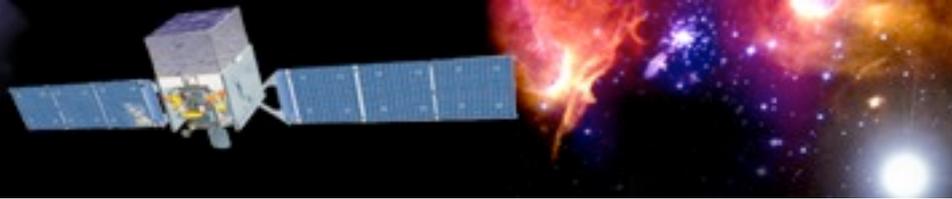
▶ *Catalog includes*

- *1451 sources with Test Statistic ≥ 25*
- *Positions in celestial and galactic, 68% and 95% confidence error ellipses*
- *Total flux (>1 GeV), source significance*
- *Average flux in 5 energy bands (.1-3-1-3-10-100 GeV) with significance per band*
- *Overall spectral index, pivot energy, curvature index*
- *Flux per month, variability index*
- ▶ *Associations with known sources and other gamma-ray catalogs*
- ▶ *Error flags to indicate possible concerns with selected sources*



Source Identification

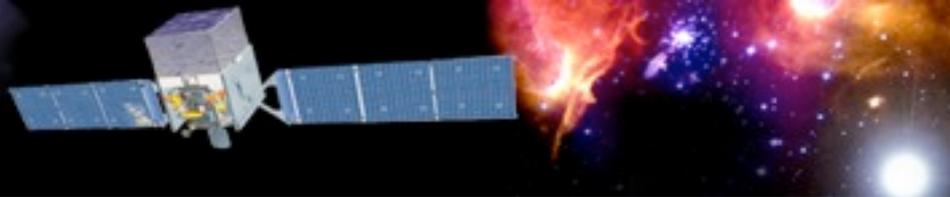
- ▶ *Three types of sources in the catalog*
 - *Identified - indicated by an uppercase class type (e.g. PSR)*
 - *Require periodic signature, correlated variability, or correlated spatial morphology*
 - *Associated - indicated by a lowercase class type (e.g. bzq)*
 - *>80% probability of being associated with the indicated source*
 - *Associated sources are considered “unidentified,” as they do not meet the requirements above*
 - *Unassociated - class type left empty*



Cautioned sources

- ▶ *Certain source names end with a “c”*
 - *“c” indicates you should treat these sources carefully*
 - *“c” sources are **unidentified** sources flagged for one of three reasons*
 - *They are located within the Galactic ridge ($|l| < 60^\circ$, $|b| < 1^\circ$)*
 - *They are coincident with peaks in Galactic gas maps*
 - *They are located in a region with many LAT sources (overlapping PSFs)*

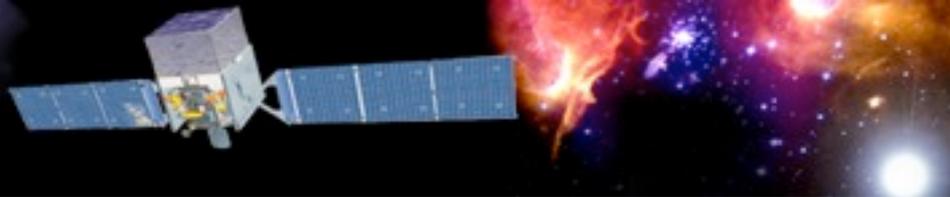
- ▶ *Galactic ridge is a difficult region*
 - *Many sources, overlapping PSFs*
 - *Low source to background ratio (<50% below 3 GeV)*
 - *Large uncertainties in Galactic diffuse model in this region*



Using the Catalog for Data Analysis

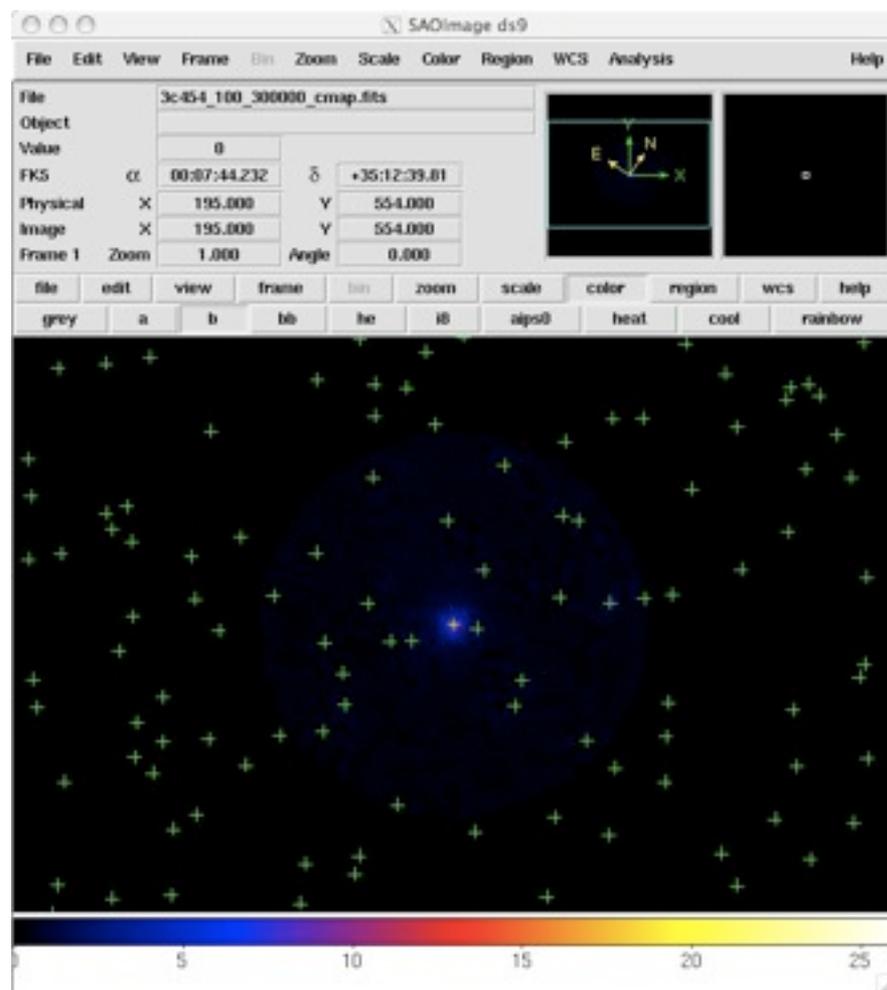
- ▶ *Useful to select specific sources for further study*
 - *Using more (or less) data than in the catalog*
 - *Compare output with different spectral models*
 - *Add fainter sources to reduce residuals*

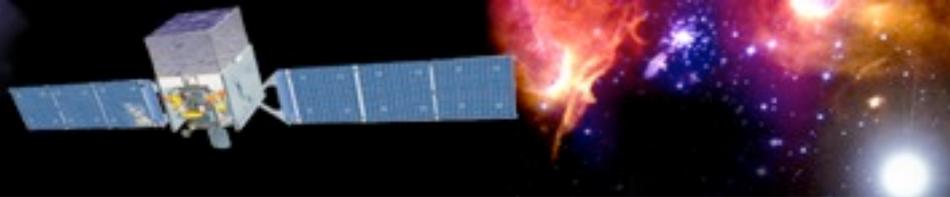
- ▶ ***Very useful to define an initial point-source model***
 - *Fitted parameters from the catalog can be an initial guess for future fitting, or held fixed for investigation of other sources*
 - *XML model results from catalog analysis are good model inputs*
 - *Use a text editor to create the XML, or*
 - *Use modeeditor gui to generate the XML*
 - *Python script available to generate initial model file from “User Contributed Tools” page at: <http://fermi.gsfc.nasa.gov/ssc/data/analysis/user/>*



Find sources in your region

- ▶ *Plot counts map from gtbin*
- ▶ *Overlay catalog region file*
- ▶ *Find significant sources in your ROI*
 - ▶ *These should be input into your source model*
 - ▶ *For long integrations you need to include fainter sources*





Source Model Structure

```

<?xml version="1.0" ?>
<source_library title="source library">

  <!-- Diffuse Sources -->

  <source name="GAL_v02" type="DiffuseSource">
    <spectrum type="PowerLaw">
      <parameter free="1" max="10" min="0" name="Prefactor"
        scale="1" value="1.22" />
      <parameter free="0" max="1" min="-1" name="Index" scale="1.0" value="0" />
      <parameter free="0" max="2e2" min="5e1" name="Scale" scale="1.0" value="1e2" />
    </spectrum>
    <spatialModel file="/net/users/ddavis/lat/bkg/gll_iem_v02.fit" type="MapCubeFunction">
      <parameter free="0" max="1e3" min="1e-3" name="Normalization" scale="1.0" value="1.0" />
    </spatialModel>
  </source>
  <source name="EG_v02" type="DiffuseSource">
    <spectrum type="FileFunction" file="/net/users/ddavis/lat/bkg/isotropic_iem_v02.txt">
      <parameter free="1" max="10" min="1e-2" name="Normalization" scale="1" value="1" />
    </spectrum>
    <spatialModel type="ConstantValue">
      <parameter free="0" max="10.0" min="0.0" name="Value" scale="1.0" value="1.0" />
    </spatialModel>
  </source>
  <!-- Target Sources -->
  <source name="_3c454" type="PointSource">
    <spectrum type="PowerLaw2">
      <parameter free="1" max="10000" min="0.0001" name="Integral" scale="1e-07" value="15.6325" />
      <parameter free="1" max="5" min="1" name="Index" scale="-1" value="2.507" />
      <parameter free="0" max="500000" min="30" name="LowerLimit" scale="1" value="100" />
      <parameter free="0" max="500000" min="30" name="UpperLimit" scale="1" value="300000" />
    </spectrum>
    <spatialModel type="SkyDirFunction">
      <parameter free="0" max="360" min="-360" name="RA" scale="1" value="343.490616" />
      <parameter free="0" max="90" min="-90" name="DEC" scale="1" value="16.148211" />
    </spatialModel>
  </source>

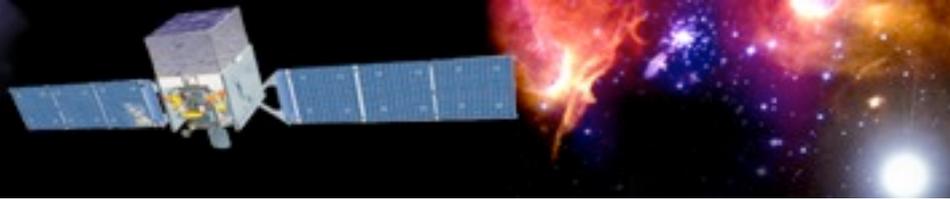
```

Diffuse components may be scaled by a constant or power law

Leave parameters free (1) to have them fit by likelihood

Change spectral models for different source types

Scale is used to interpret results



Available Models

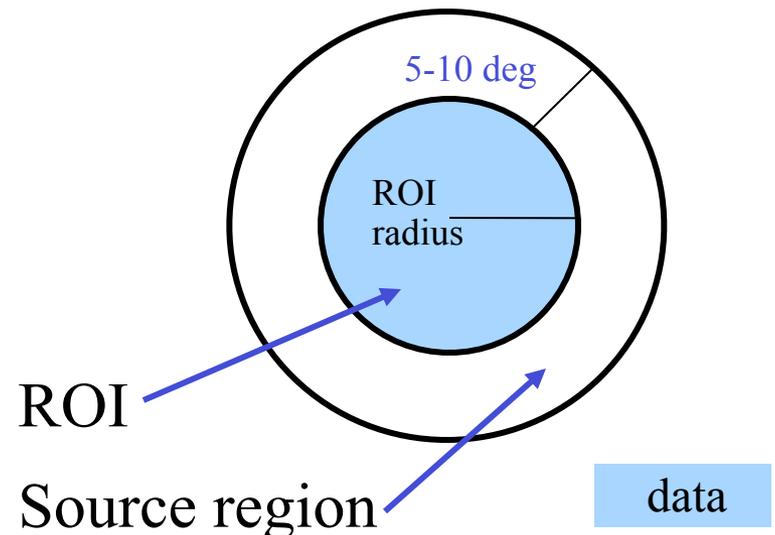
- ▶ *A listing of all available models and their functional forms can be found at:*
 - http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/source_models.html
 - *Available models include:*

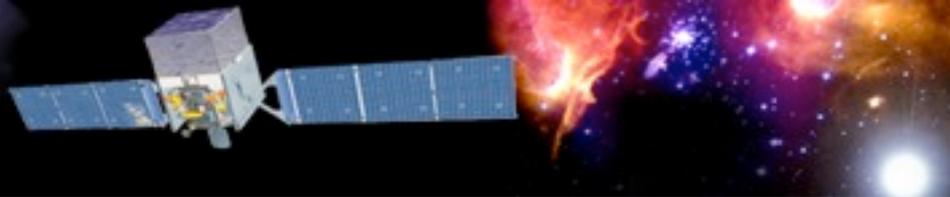
<i>Constant</i>	<i>Gaussian</i>
<i>Power Law</i>	<i>Log Parabola</i>
<i>Broken Power Law</i>	<i>Exponential Cutoff</i>
<i>BPL with Exp Cutoff</i>	<i>PL with Superexponential Cutoff</i>
<i>Band Function</i>	<i>User-defined Function</i>
 - *Also several spatial models are available:*

<i>Constant Value</i>	<i>Sky Direction Function (point only)</i>
<i>Spatial Map (extended sources) diffuse)</i>	<i>Map Cube Function (usually</i>

Building the Source Model

- ▶ *Model should cover both the ROI and the source region*
 - *ROI includes the data you have selected*
 - *Primary source, and nearby sources should have appropriate parameters left free for the fit*
 - *Source region is the modeled area, and includes sources outside the data region*
 - *It is recommended that you set parameters for sources outside your ROI to the values in the catalog since no data is available for a proper fit*





Using Modeleditor

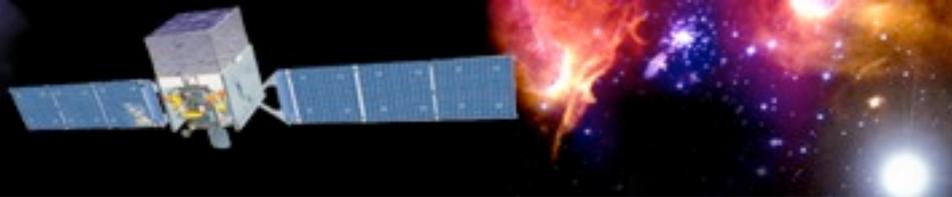
- ▶ *Enter each source separately and provide initial guesses*

Save when all needed sources have been input.

Can be time consuming

name	value	scale	min	max	free
Integral	1.0	0.0001	0.001	1000.0	<input checked="" type="checkbox"/>
Index1	-1.8	1.0	-5.0	-1.0	<input checked="" type="checkbox"/>
Index2	-2.3	1.0	-5.0	-1.0	<input checked="" type="checkbox"/>
BreakValue	1000.0	1.0	30.0	10000.0	<input checked="" type="checkbox"/>
LowerLimit	20.0	1.0	20.0	200000.0	<input type="checkbox"/>
UpperLimit	200000.0	1.0	20.0	200000.0	<input type="checkbox"/>
					<input type="checkbox"/>

name	value	scale	min	max	free
RA	343.49	1.0	0.0	360.0	<input type="checkbox"/>
DEC	16.148	1.0	-90.0	90.0	<input type="checkbox"/>
					<input type="checkbox"/>
					<input type="checkbox"/>
					<input type="checkbox"/>
					<input type="checkbox"/>
					<input type="checkbox"/>

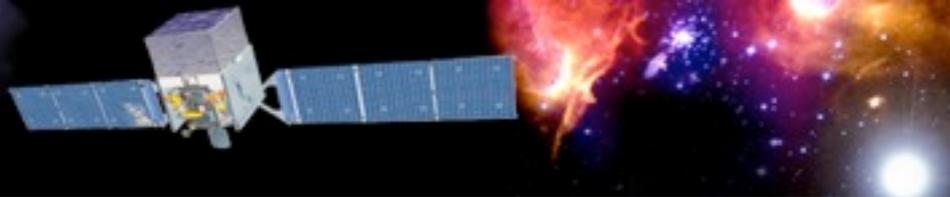


Using Python

- ▶ *User-contributed tool “make1FGLxml”*
 - ▶ *Extracts data from 1FGL catalog file and auto-generates XML*
 - ▶ *Automatically leaves parameters for sources near the center of the field free, and fixes those for sources farther away*
 - ▶ *ALL 1FGL sources in the ROI, plus those up to 5 deg outside the ROI*
 - ▶ *Best to hand-tune model after generation, to ensure content is as desired*
- ▶ *Validate source model by loading it into modeleditor*
 - ▶ *Works for any method of generating a source model*
 - ▶ *Will generate errors if the format is incorrect for use with the Science Tools*

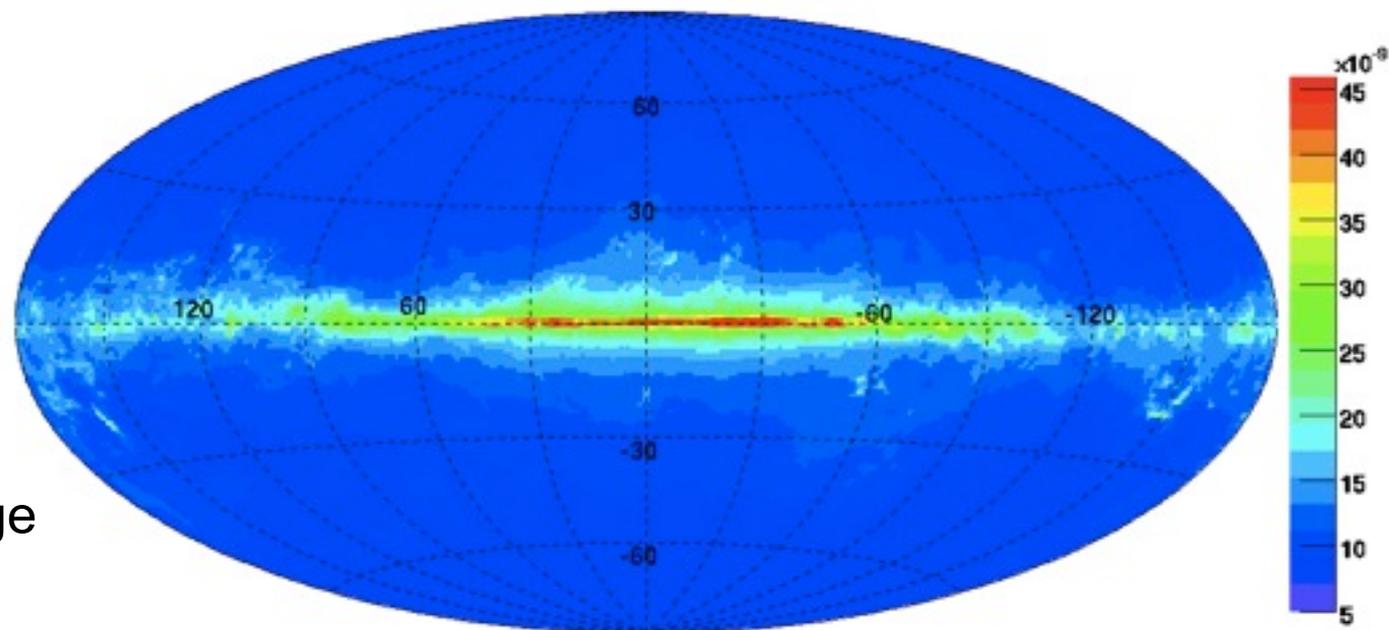


Backup Slides

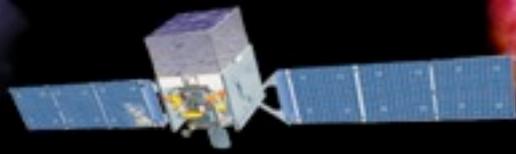


Sensitivity

- ▶ *Factor of 10 difference depending on location*
 - *Structure is mostly due to Galactic diffuse background*
 - *At high latitudes ($|b| > 30$), sensitivity is below 10^{-8} ph/cm²/s*
 - *Strongly dependent on source spectral index*



Flux > 100 MeV
required to reach
TS=25 for average
 $E^{-2.2}$ spectrum

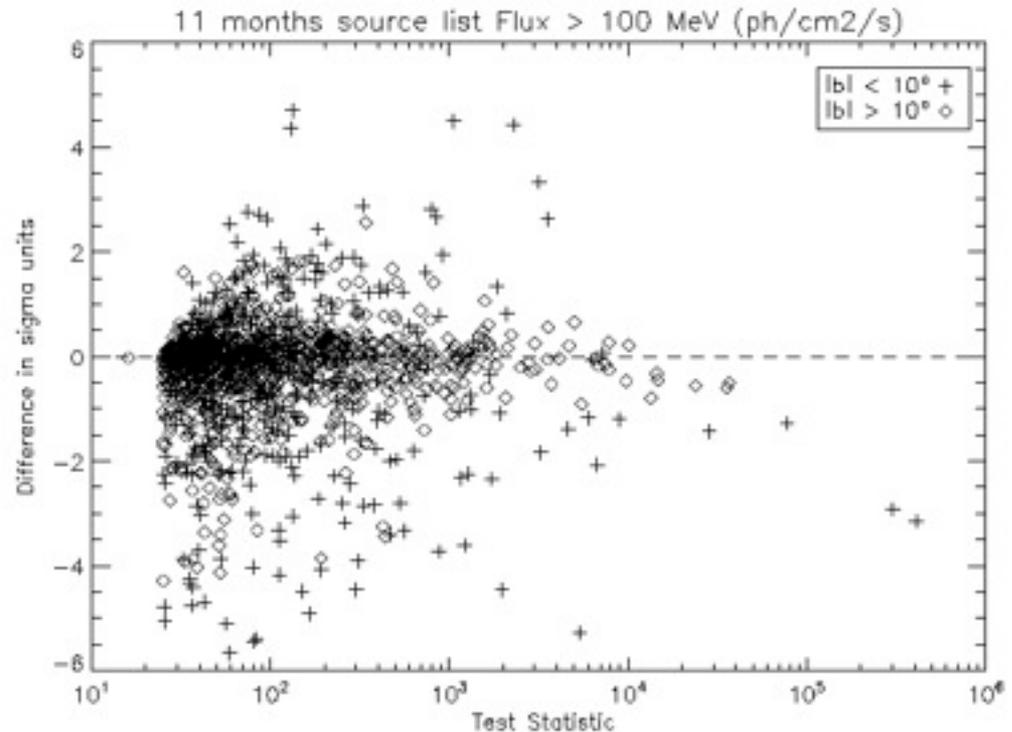


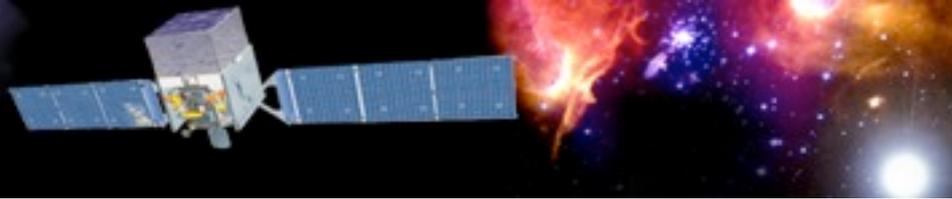
Diffuse Emission Uncertainties

- ▶ *Compared output using two different diffuse models*
 - *With good statistics, 10% of the background can still be significant*

*In the Galactic plane,
dispersion due to
diffuse model is 1.8σ*

*Outside the plane,
dispersion is 0.7σ*

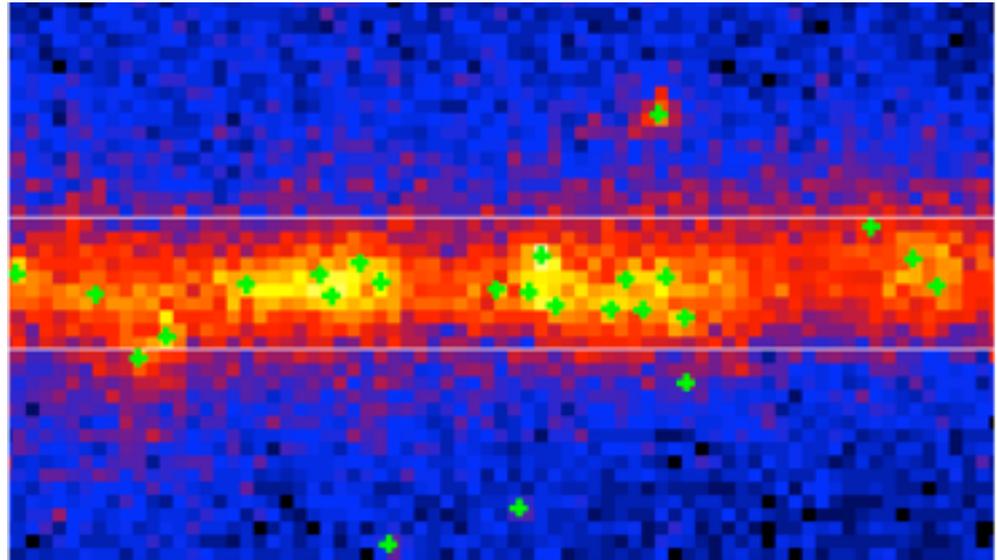


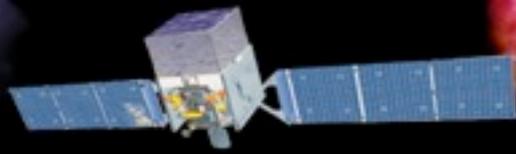


Source Confusion

► *Overlapping PSFs*

- *Spectrally weighted PSF is much larger for soft sources*
- *Outside the plane, average separation is $\sim 3^\circ$*
 - *Much larger than r_{68} (0.8°) at 1 GeV*
- *In the plane, sources clearly not separated (below)*
 - *Possibly unmodeled diffuse emission*
- *15° region of the Galactic Ridge*
- *1 - 100 GeV*
- *Crosses are sources*
- *Pixel size = 0.2°*
- *Strong galactic diffuse component introduces bias against soft sources*

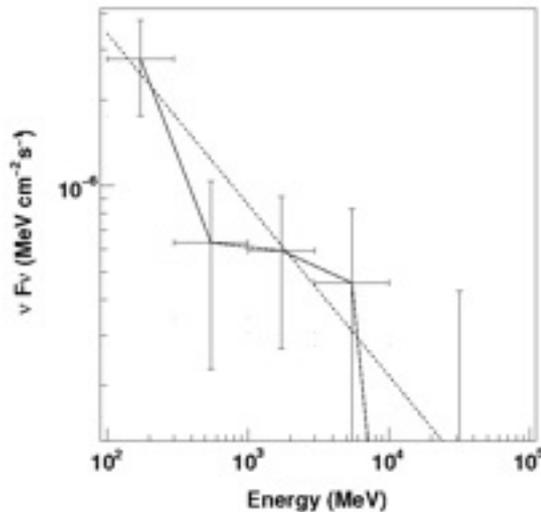
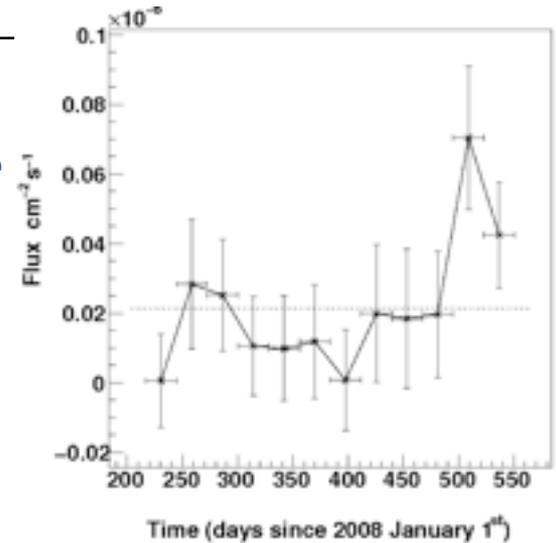




Finding Interesting Sources

► Source variability

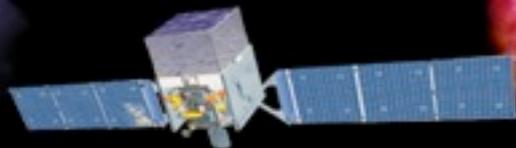
- Light curves and variability index for each source (available in Browse)
 - Variability index is χ^2 against constant hypothesis (~250 sources)
- Pulsars are stable within 3%
- Bright blazars are very clearly variable



► Spectral shape

- 5-band initial spectrum for each source
 - Curvature index is χ^2 against power-law spectral shape
- Typical spectrum is broken, so power-law estimate is high

Upper limits are given for bands or intervals where the source is not significant



Finding More Interesting Sources

► *Source Associations*

- *Positional associations with other gamma-ray catalogs*
 - *3rd EGRET, Revised EGR, and First AGILE catalogs*
- *Probabilistic associations with likely source catalogs*
 - *Pulsars, SNRs, PWNe, blazars, other AGN, etc.*
- *Find your favorite source!*

► *Be aware...*

- *For studies at low Galactic latitudes and toward prominent local clouds, be aware that some 1FGL sources may be unresolved diffuse emission*
- *Whether or not to include such sources in the source model is a case-by-case decision*