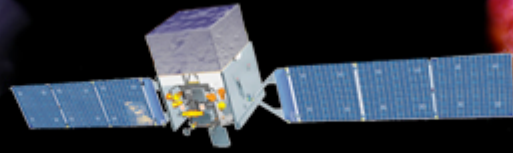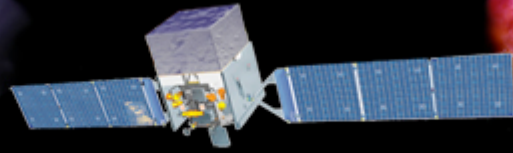# FSSC Science Tools

Using the LAT Catalog for Analysis

First LAT Catalog (1FGL)

▶ *Last updated 4 February 2010*

  – *Next catalog scheduled for Spring 2011*

▶ *Available from FSSC at:*

  http://fermi.gsfc.nasa.gov/ssc/data/access/lat/1yr_catalog/

  - *Full Catalog in FITS format*
  - *Preprint of LAT Catalog papaer and 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*
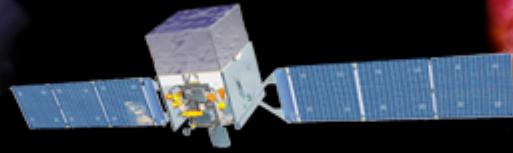
1FGL Catalog

▶ *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*
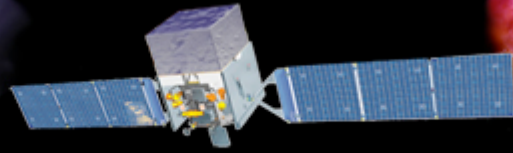
Source Identification

► *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*
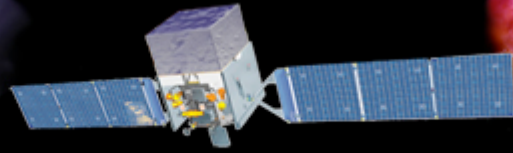
Cautioned sources

▶ *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 ($|l|<60°$, $|b|<1°$)*
- *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*
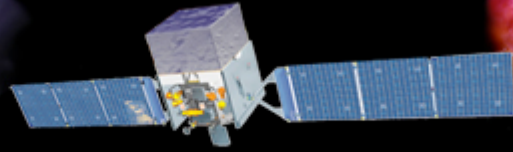
Using the Catalog for Data Analysis

▶ *Useful to select specific sources for further study*

- *More or less data than in the catalog*
- *Compare output with different spectral models*
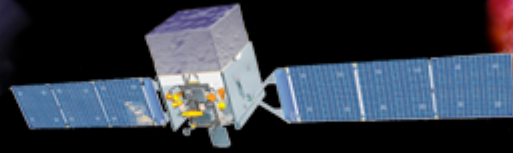- *Add fainter sources to reduce residuals*

▶ **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 modeleditor 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/*
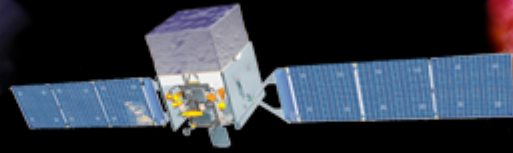
Find sources in your region

▶ *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*
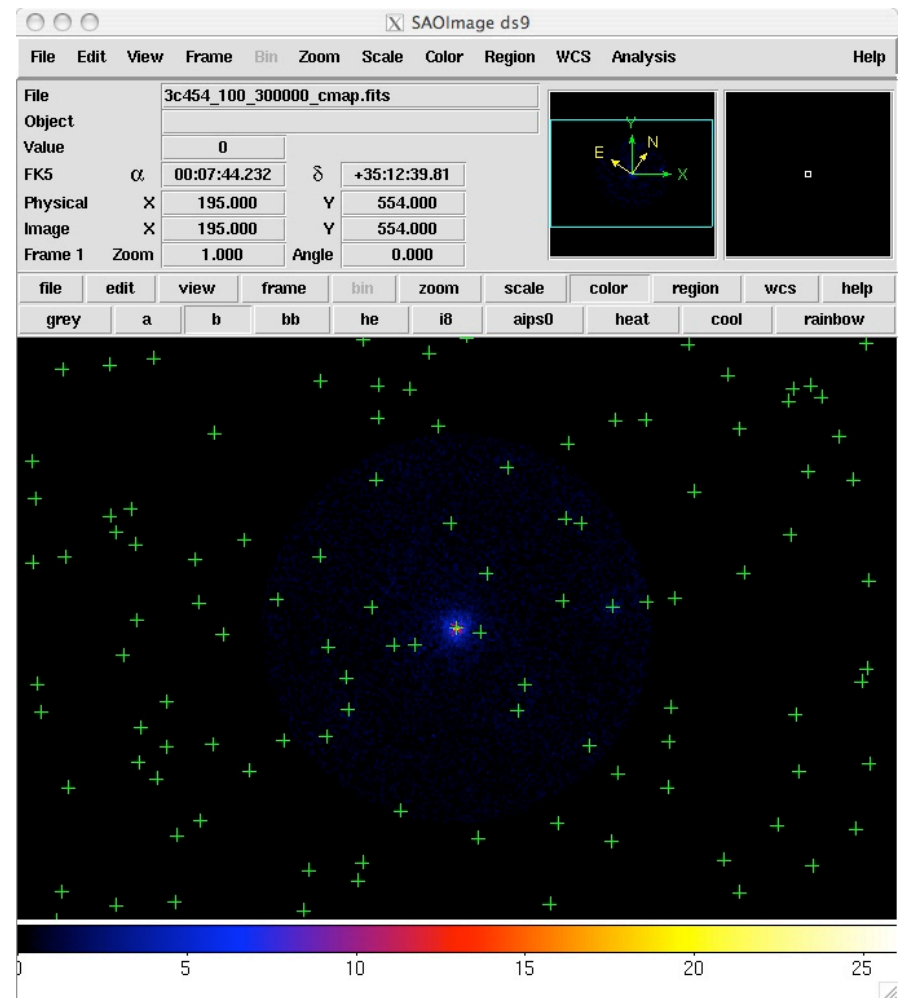
Source Model Structure

```xml
<?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>
```
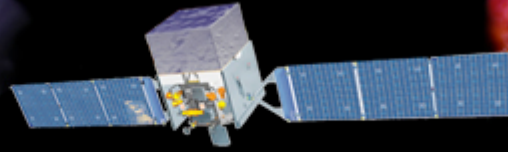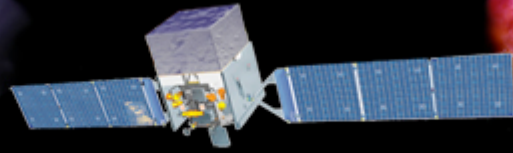
Diffuse components may be scaled by a constant or power law

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

Scale is used to interpret results

Change spectral models for different source types

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:*

Constant	*Gaussian*
Power Law	*Log Parabola*
Broken Power Law	*Exponential Cutoff*
BPL with Exp Cutoff	*PL with Superexponential Cutoff*
Band Function	*User-defined Function*

– *Also several spatial models are available:*

Constant Value	*Sky Direction Function (point only)*
Spatial Map (extended sources)	*Map Cube Function (usually diffuse)*

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*

5 deg

ROI radius

ROI

Source region

data
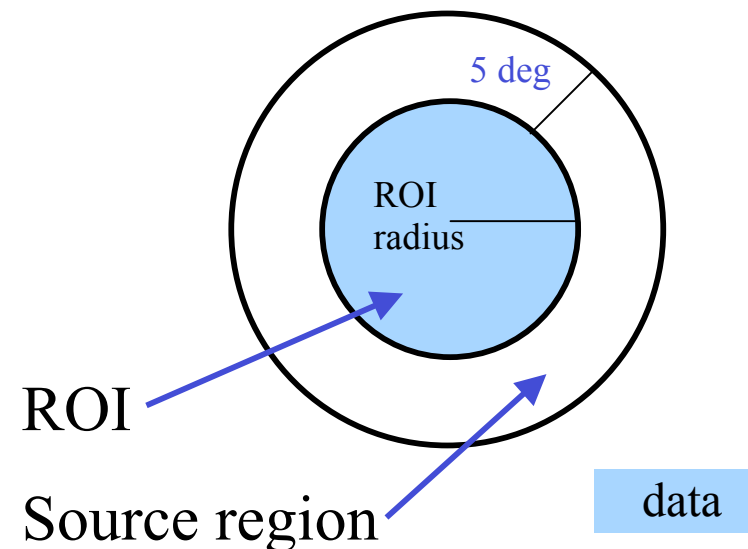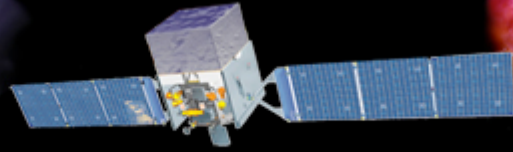
Using Modeleditor

▶ *Enter each source separately and provide initial guesses*

Save when all needed sources have been input.

Can be time consuming

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*
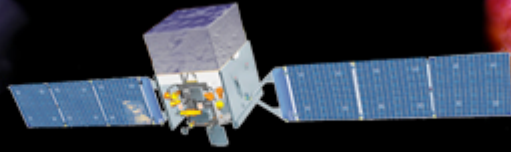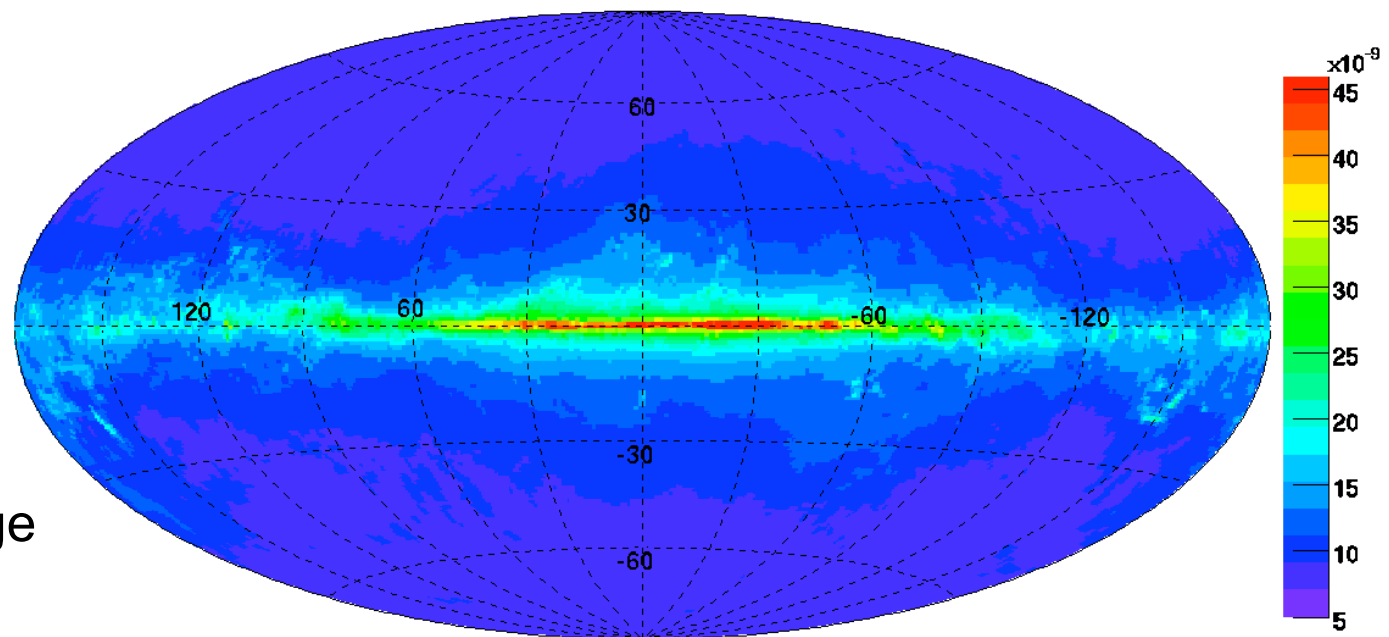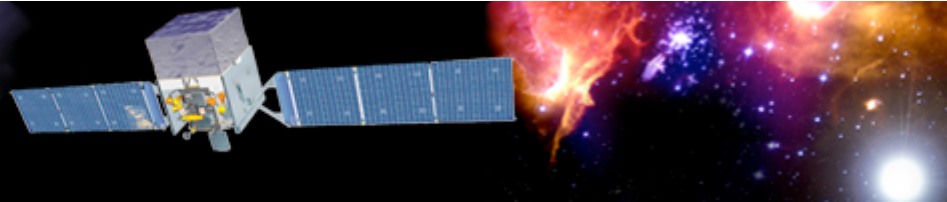
Backup Slides
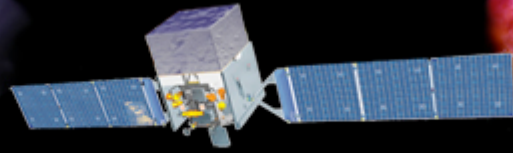
Sensitivity

▶ *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
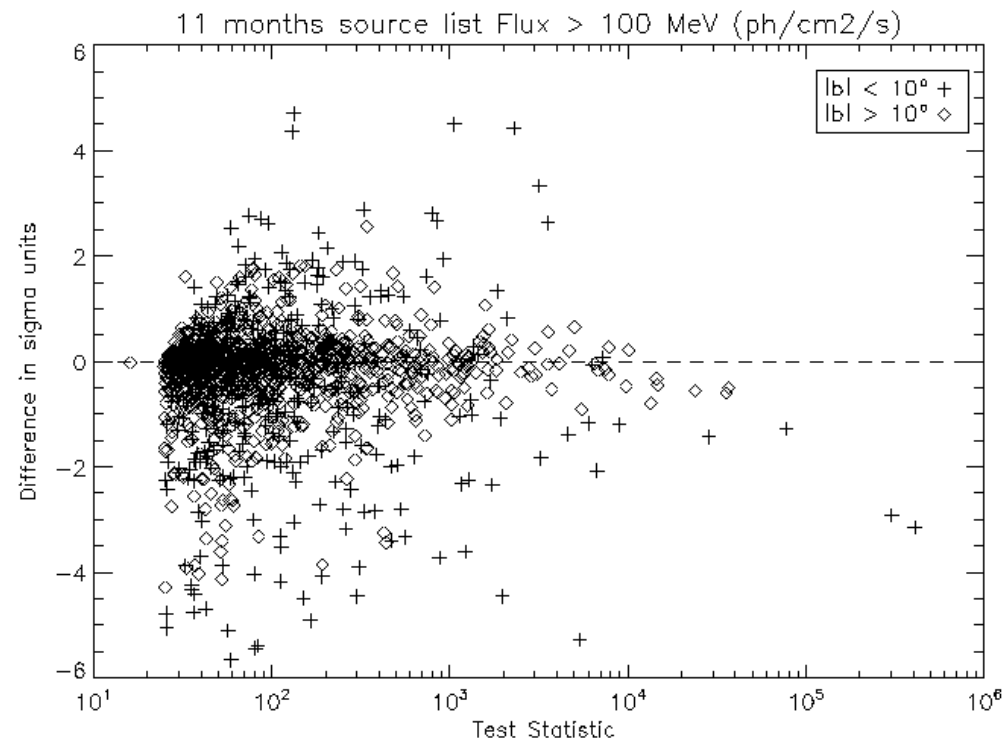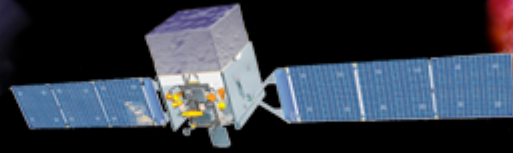TS=25 for average
$E^{-2.2}$ spectrum

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*

11 months source list Flux > 100 MeV (ph/cm2/s)

Source Confusion

► *Overlapping PSFs*

- *Spectrally weighted PSF is much larger for soft sources*

- *Outside the plane, average separation is ~3°*
  - *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°*

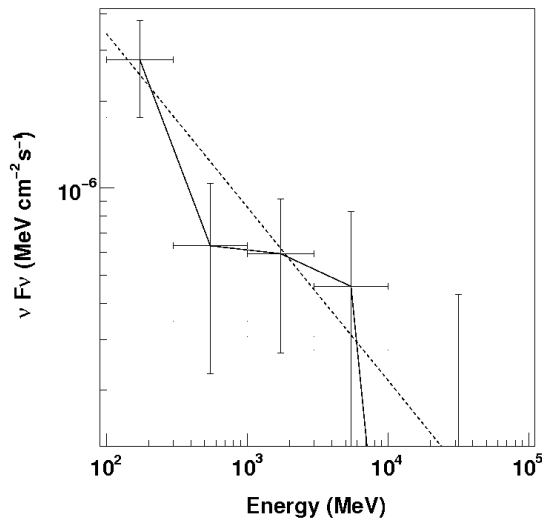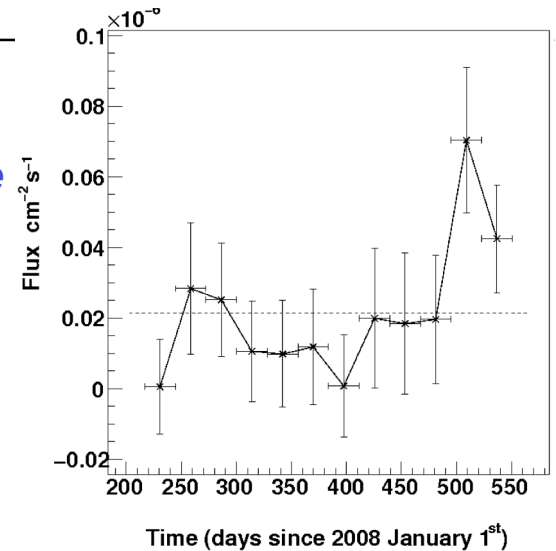- *Strong galactic diffuse component introduces bias against soft sources*
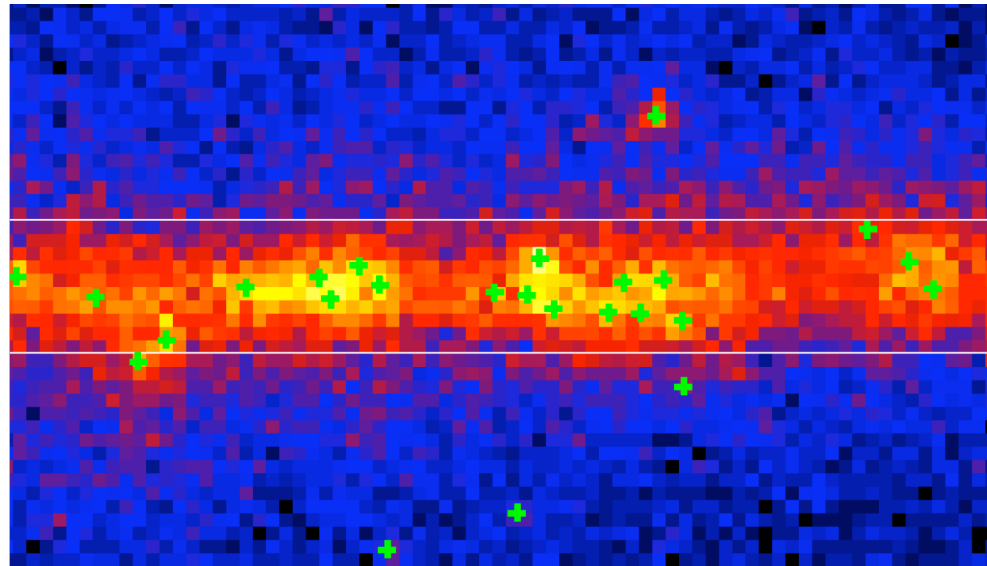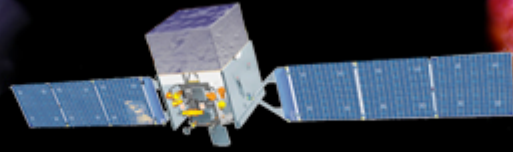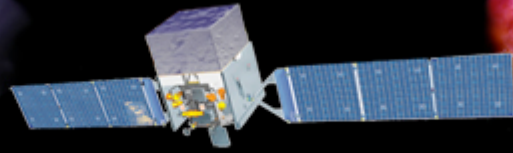
Finding Interesting Sources

▶ *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*