



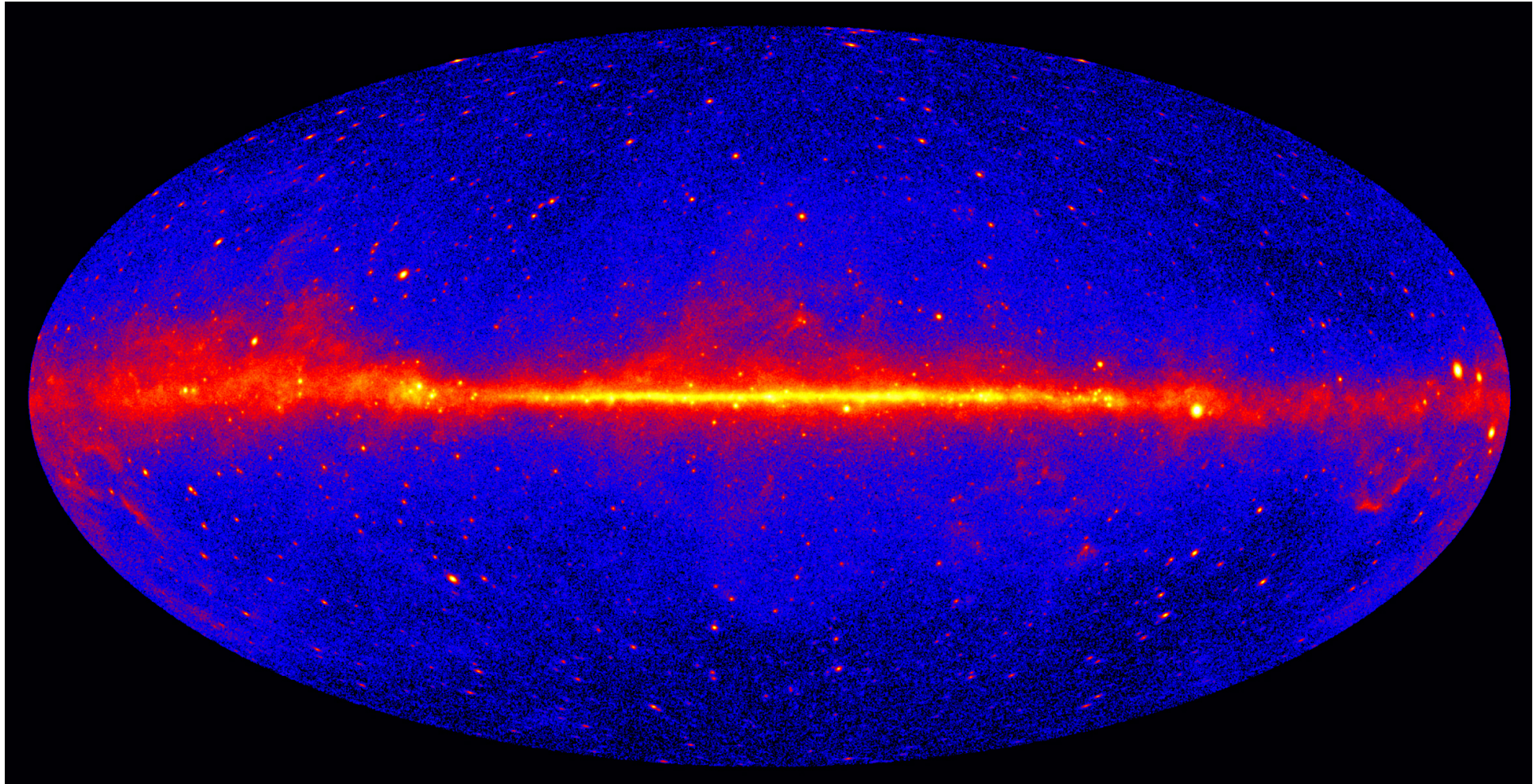
Tutorial on Fermi-LAT data analysis

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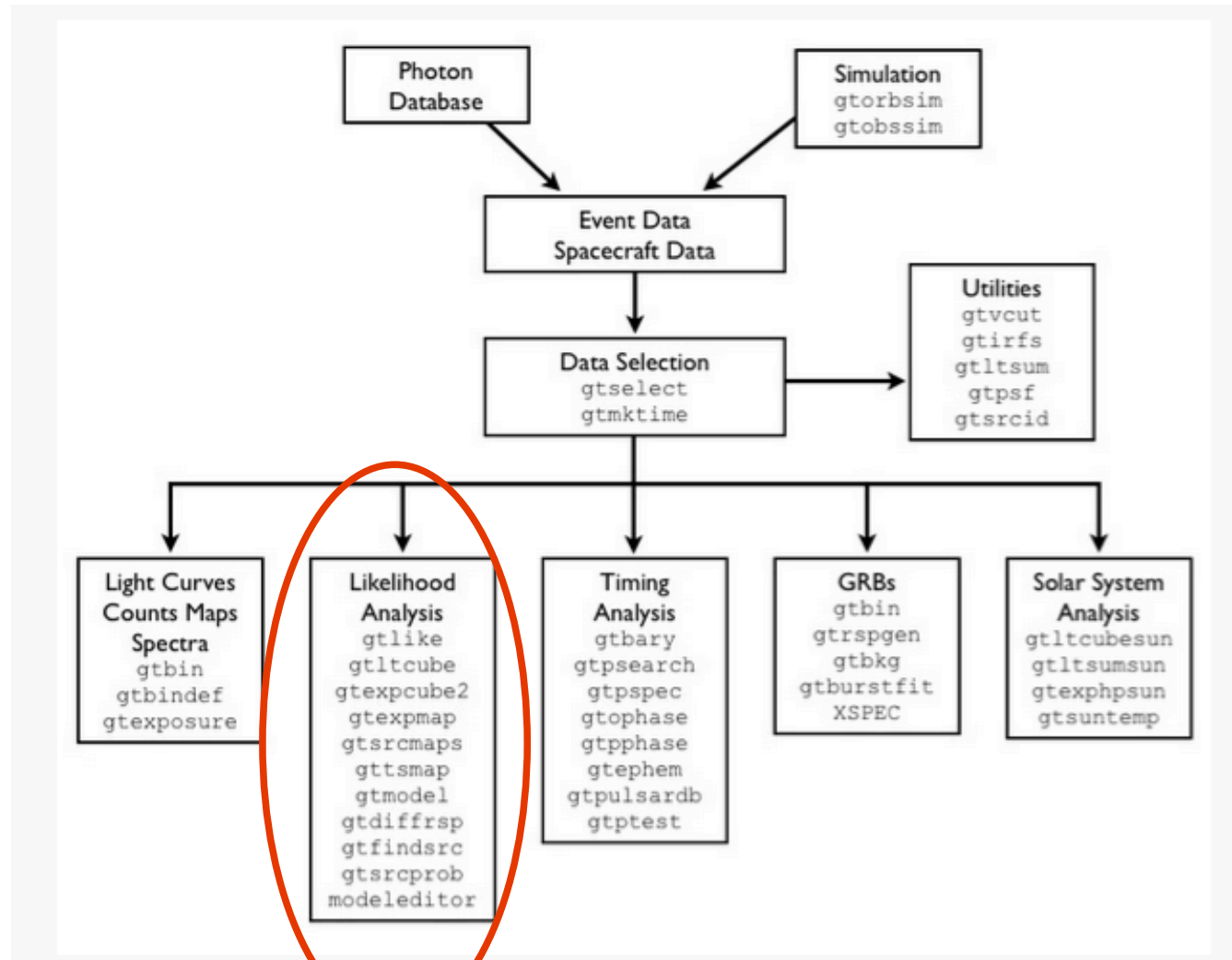
Material from P.Bruehl, M.Razzano,
S.Buson and R.Desiante

- **Overview of the Fermi Large Area Telescope**
 - How it works
 - LAT data
 - LAT performance
- **Fermi Science Tools**
 - General Introduction
- **Maximum Likelihood Overview**
 - Source modeling

The Fermi Sky



Overview of Fermi Science Tools



Perform the fit: the likelihood approach

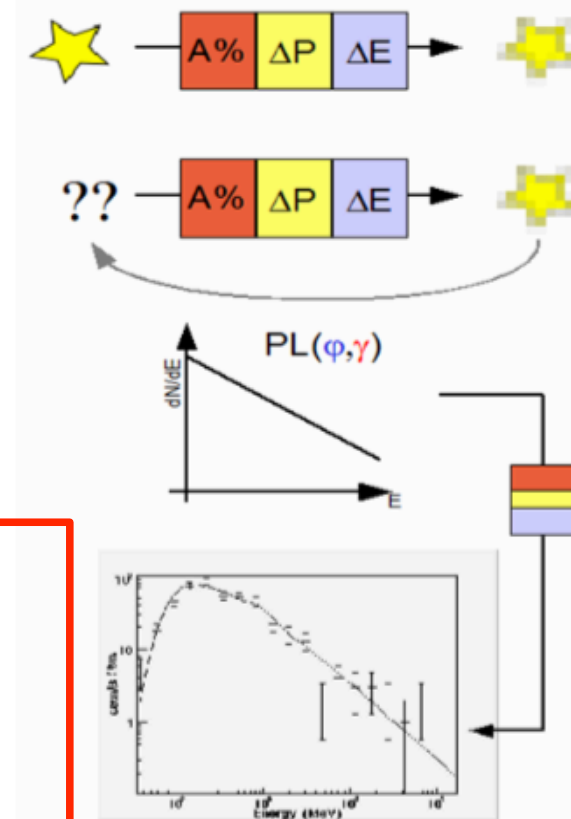
In high energy gamma rays it is never possible to really isolate a source because of limited statistics and strong and structured background.

Therefore statistical techniques have to be applied.

The most used method is the likelihood analysis based on the Poisson statistics.

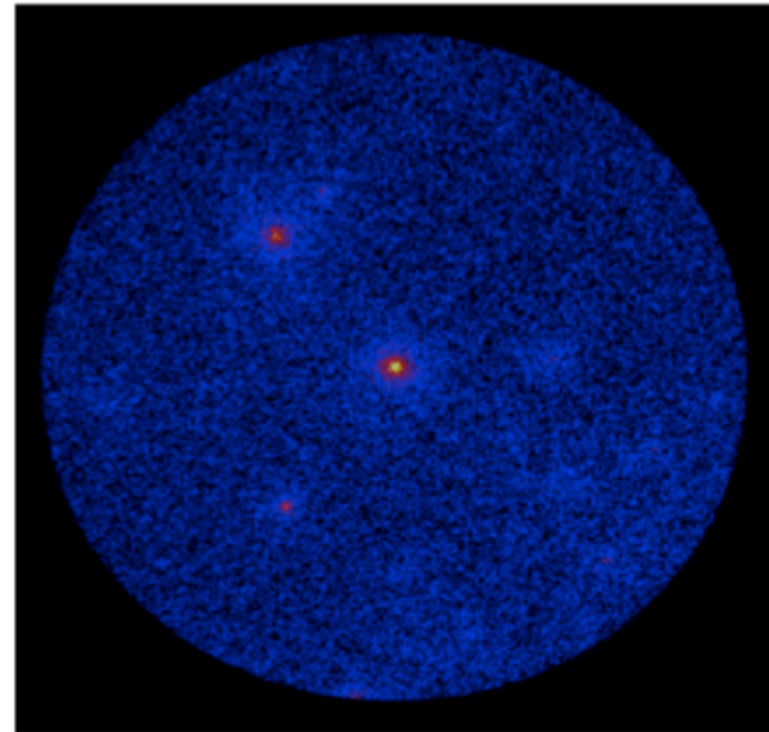
The method requires to assume a model for the signal detected by the telescope.

- Assume a **model**
- Model **convolved** with Instrument response Function (IRF)
- Maximizing likelihood find the best set of parameters that reproduce the observed spectrum



The Challenge

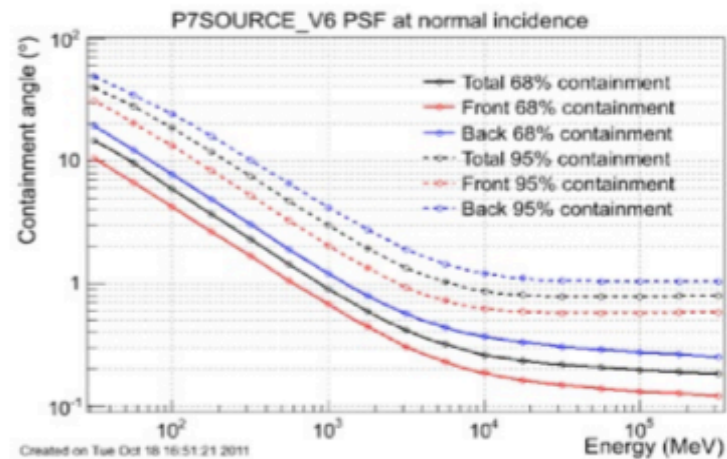
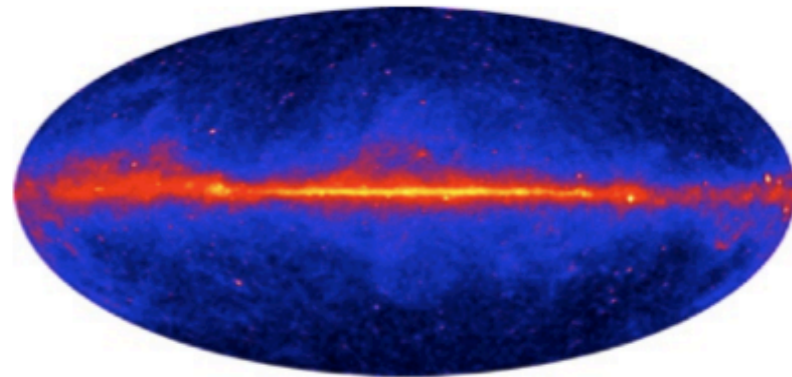
- Gamma-ray data is a list of counts (photons) reconstructed in the detector.
- Qualitative exploration of the data suggests the presence of sources (spatial clustering).
- Quantitative analysis requires evaluating the significance of a 'model' of our region.



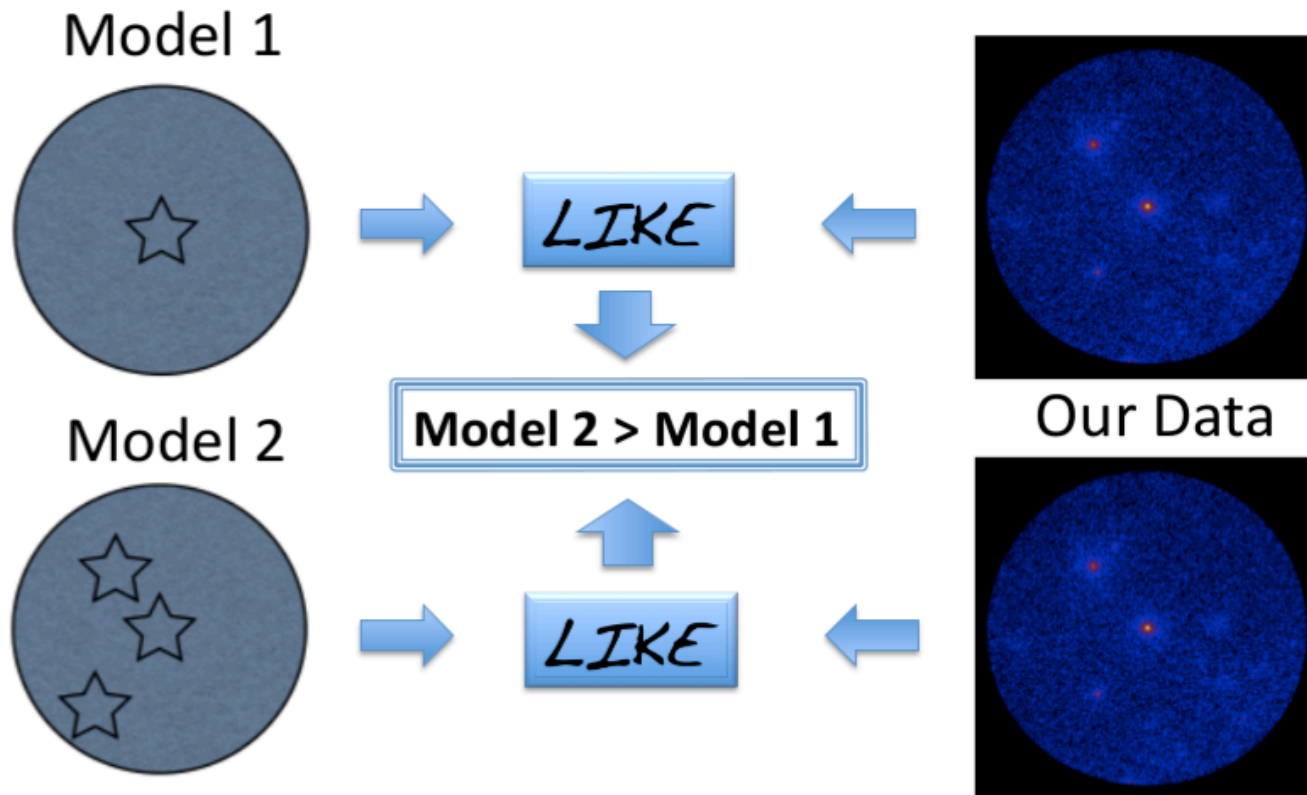
Count Map

Why Model Fitting?

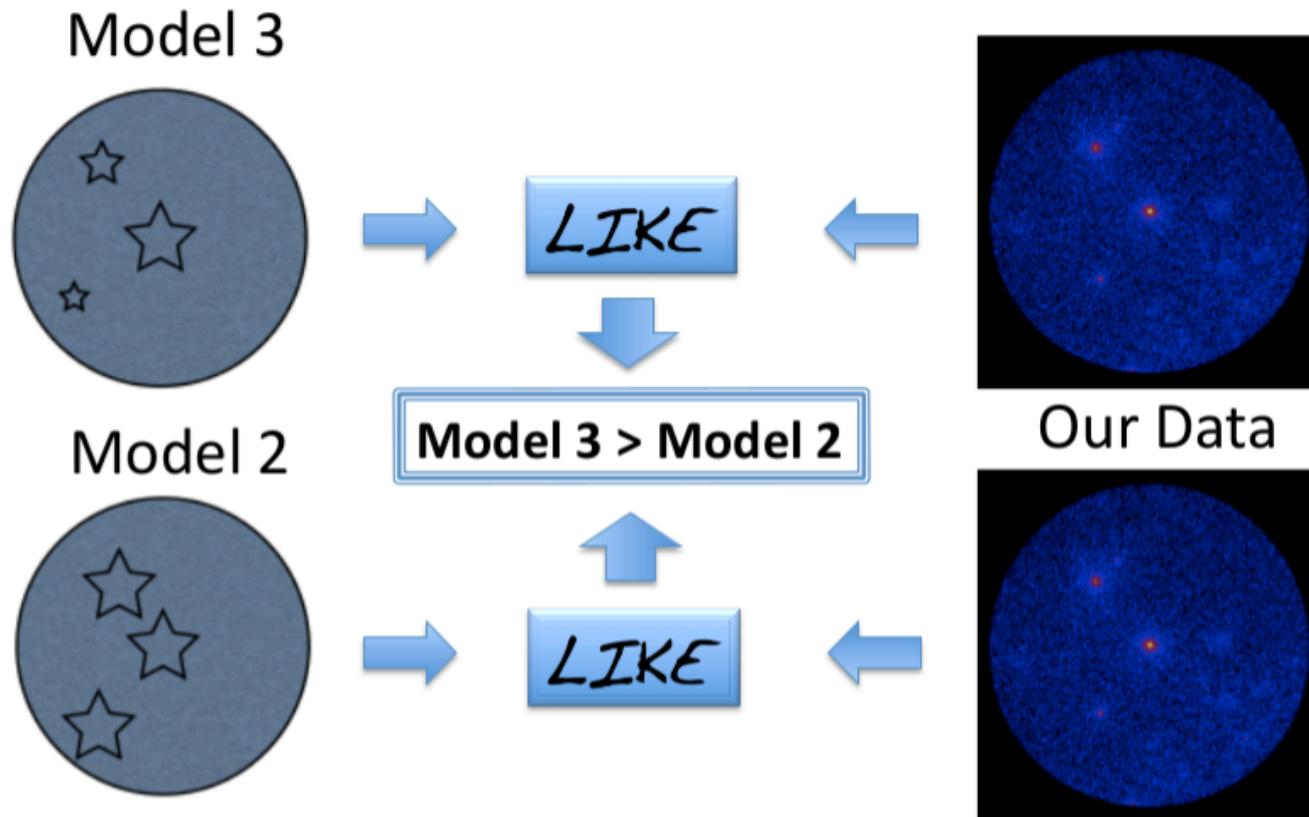
- We use the Likelihood method because the LAT data are limited by statistics, a bright diffuse background and a broad PSF.
- The model construction defines the questions we want to ask which means:
 - It will not answer a question you are not asking (ie. unknown parameters).
- The Likelihood will not tell you if a fit is 'good'. If the model does not represent your data well, the results will also not represent reality well.



A Graphical Example



A Graphical Example



Likelihood 3rd step: the XML model

5. Create a source model XML file

The `gtlike` tool reads the source model from an XML file. The model file contains your best guess at the locations and spectral forms for the sources in your data. A source model can be created using the `model editor` tool, by using the user contributed tool `make3FGLxml.py` (available at the [user-contributed tools](#) page), or by editing the file directly within a text editor.

Here we cannot use the same source model that was used to analyze six months of data in the [Unbinned Likelihood](#) tutorial, as the 2-year data set contains many more significant sources and will not converge. Instead, we will use the 3FGL catalog to define our source model by running `make3FGLxml.py`. To run the script, you will need to download the current [LAT catalog file](#) and place it in your working directory:

```
prompt> make3FGLxml.py gll_psc_v16.fit 3C279_binned_gti.fits -o 3C279_input_model.xml
-G $FERMI_DIR/refdata/fermi/galdiffuse/gll_iem_v06.fits -g gll_iem_v06
-I $FERMI_DIR/refdata/fermi/galdiffuse/iso_P8R2_SOURCE_V6_v06.txt
-i iso_P8R2_SOURCE_V6_v06 -s 120 -p TRUE -v TRUE
This is make3FGLxml version 01r0.
The default diffuse model files and names are for pass 8
and assume you have v10r00p05 of the Fermi Science Tools or higher.
Creating file and adding sources from 3FGL
Added 312 point sources, note that any extended sources in ROI were modeled as point sources
because psForce option was set to True
prompt>
```

Note that we are using a high level of significance so that we only fit the brightest sources and we have forced the extended sources to be modeled as point sources. This only affects the lobes of Centarus A which are just outside the FOV.

It is also necessary to specify the entire path to location of the diffuse model on your system. The resulting XML model contains 312 sources. Clearly, the simple 4-source model we used for the 6-month [Unbinned Likelihood](#) analysis would have been too simplistic.

This XML file uses the spectral model from the 3FGL catalog analysis for each source. (The catalog file is available at the [LAT 4-yr Catalog page](#).) However, that analysis used a subset of the available spectral models. A dedicated analysis of the region may indicate a different spectral model is preferred. For more details on the options available for your XML models, see:

- Descriptions of available [Spectral and Spatial Models](#)
- Examples of [XML Model Definitions for Likelihood](#)