

How to produce a SED with the Fermi-LAT DATA

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INTRODUCTION

In this guide I will follow you through the entire Fermi-LAT data analysis. SED analysis requires a huge amount of time proportionally to the selected time slice and events. Let's select from the photon file 1000s seconds from 100 MeV to 300 GeV.

Useful links:

standard analysis https://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/likelihood_tutorial.html

python SED https://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/python_tutorial.html

- ▶ first type `source fermitools_heasoft.sh` from bash
- ▶ go to your `/media/sf_Shared/Crab_Flare_2014`
- ▶ create a folder `mkdir SED`
- ▶ inside the SED folder `cp ../../Crab_2016/*PH00.fits .` and `cp ../../Crab_2016/*SC00.fits .`

DATA SELECTION AND CHECK

▶ gtselect

```
$gtselect infile=L1707191130548796F97338_PH00.fits  
outfile=Crab_selection.fits ra=83.633 dec=22.014  
rad=10 evclass=128 evtype=3 tmin=473300000  
tmax=473400000 emin=100 emax=300000 zmax=90
```

▶ check if there are events, "rows" in your selected file

```
$fv Crab_selection.fits
```

▶ gtmktime

```
$gtmktime scfile=L1707191130548796F97338_SC00.fits  
filter="DATA_QUAL>0 && LAT_CONFIG==1" roicut=no  
evfile=Crab_selection.fits  
outfile=Crab_selection_mkt.fits
```

▶ gtvcut, gtbin (CMAP)

```
$gtbin evfile=Crab_selection_mkt.fits  
scfile=L1707191130548796F97338_SC00.fits  
outfile=Crab_selection_mkt_cmap.fits algorithm=CMAP  
nxpix=120 nypix=120 binsz=0.25 coordsys=CEL  
xref=83.633 yref=22.014 axisrot=0 proj=AIT
```

▶ check if there are events in the counts map file

```
$ds9 Crab_selection_mkt_cmap.fits
```

XML FILE CREATION

If you want to generate a complete source xml file you can use the `make3FGLxml.py` that you already have in your `/media/sf_Shared/Crab_Flare_2014` folder or you can download from the Fermi SSC site. Moreover you need the source catalogue file, the galactic diffuse model FITS file and the isotropic diffuse template file

(https://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr_catalog/)

```
$python make3FGLxml.py
gll_psc_v16.fit Crab_selection_mkt.fits -o Crab_1GeV.xml
-G gll_iem_v06.fits -g gll_iem_v06
-I iso_P8R2_SOURCE_V6_v06.txt -i iso_P8R2_SOURCE_V6_v06
-r 0.001 -e .
```

In this case we have 2 *extended* sources (IC443 and S147) that we have to include in the current directory

- ▶ `$ cp /media/sf_Shared/Crab_Flare_2014/IC443.fits .`
- ▶ `$ cp /media/sf_Shared/Crab_Flare_2014/S147.fits .`

The already created `Crab_1GeV.xml` model file include three sources (3FGL J0534.5+2201, 3FGL J0534.5+2201i and 3FGL J0534.5+2201s) that seems to be the same because very close to the Crab Nebula sky coordinates. The best choice is to replace these 3 sources with an adequate spectral model (https://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/source_models.html).

In this acas we use a PowerLaw spectral model:

```
<source name="CrabNebula" type="PointSource">
  <!-- point source units are cm^-2 s^-1 MeV^-1 -->
  <spectrum type="PowerLaw">
    <parameter free="1" max="1000.0" min="0.001" name="Prefactor" scale="1e-09" value="1"/>
    <parameter free="1" max="-1.0" min="-5." name="Index" scale="1.0" value="-2.1"/>
    <parameter free="0" max="2000.0" min="30.0" name="Scale" scale="1.0" value="100.0"/>
  </spectrum>
  <spatialModel type="SkyDirFunction">
    <parameter free="0" max="360." min="-360." name="RA" scale="1.0" value="83.633"/>
    <parameter free="0" max="90." min="-90." name="DEC" scale="1.0" value="22.014"/>
  </spatialModel>
</source>
```

DATA ANALYSIS STAGES

▶ gtlcube

```
$gtlcube evfile=Crab_selection_mkt.fits  
scfile=L1707191130548796F97338_SC00.fits  
outfile=Crab_selection_mkt_ltcube.fits dcostheta=0.025  
binsz=1
```

▶ gtexpmap

```
$gtexpmap evfile=Crab_selection_mkt.fits  
scfile=L1707191130548796F97338_SC00.fits  
expcube=Crab_selection_mkt_ltcube.fits  
outfile=Crab_selection_mkt_expmap.fits irfs=CALDB  
srcrad=30 nlong=120 nlat=120 nenergies=20
```

▶ gtdiffrsp

```
$gtdiffrsp evfile=Crab_selection_mkt.fits  
scfile=L1707191130548796F97338_SC00.fits  
srcmdl=Crab_1GeV.xml irfs=CALDB
```

PREPARATION...

We have to download the script files from the NASA site, extract them and copy inside our work folder SED

- ▶ `$ wget https://fermi.gsfc.nasa.gov/ssc/data/analysis/user/SED_scripts_v13.1.tgz`
- ▶ `$ tar -zxvf SED_scripts_v13.1.tgz`
- ▶ `$ cp SED_scripts_v13.1/likeSED.p* .`

PYTHON LIKELIHOOD SCRIPT

Let's continue the analysis inside the python shell with the already generated ingredients `Crab_selection_mkt.fits`, `Crab_selection_mkt_ltcube.fits`, `Crab_selection_mkt_expmap.fits`, `Crab_1GeV.xml` ... so type `python` in your shell ...

```
>> import pyLikelihood
```

```
>> from UnbinnedAnalysis import *
```

```
>> obs=UnbinnedObs('Crab_selection_mkt.fits',  
, 'L1707191130548796F97338_SC00.fits',  
, expMap='Crab_selection_mkt_expmap.fits',  
, expCube='Crab_selection_mkt_ltcube.fits',  
, irfs='CALDB')
```

```
>> like=UnbinnedAnalysis(obs, 'Crab_1GeV.xml',  
, optimizer='NewMinuit')
```

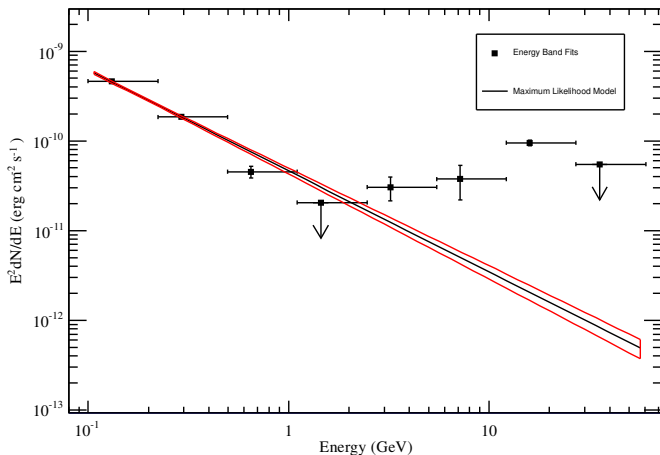
PYTHON SED SCRIPT

All the possible parameters are summarized in the document guide (https://fermi.gsfc.nasa.gov/ssc/data/analysis/user/likeSEDMacros_UsageNotes_v13.pdf)

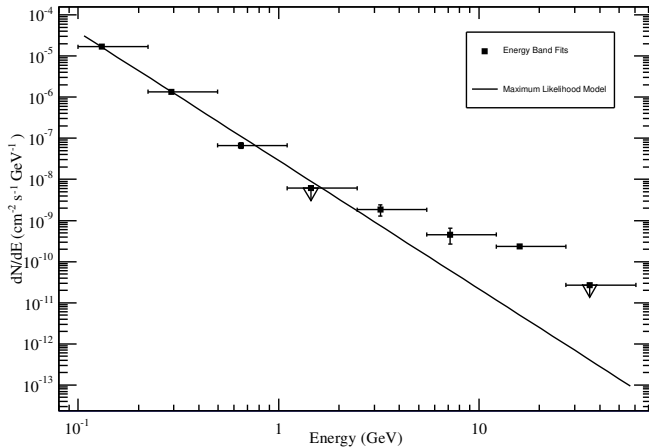
```
>> from likeSED import *
>> inputs=likeInput(like, 'CrabNebula', nbins=5)
>> inputs.plotBins()
>> inputs.fullFit(CoVar=True)
>> sed=likeSED(inputs)
>> sed.getECent()
>> sed.fitBands()
>> sed.Plot()
```

BUTTERFLY SED PLOT

This is only an example of how the SED plots look like... not that one with the previous selected data because of the very lack of time during the exercises!



SED PLOT



TS PLOT

