FSSC Science Tools

Source Analysis

Science Tools: Documentation

- *Multi-Tier Documentation*

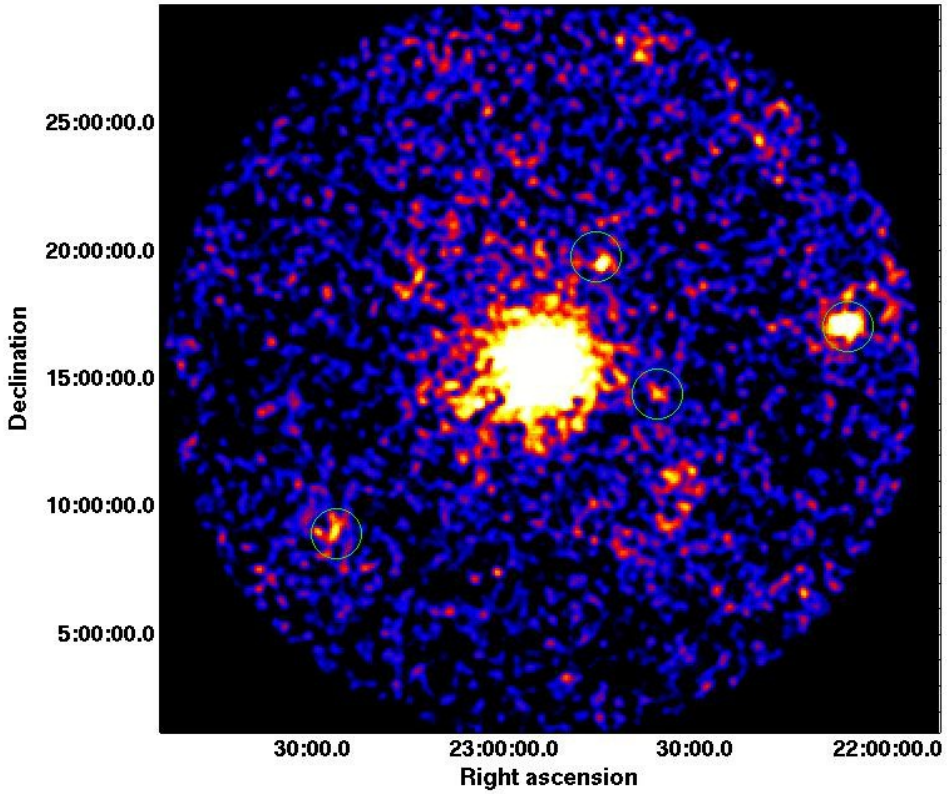
–Full set accompanies SW release

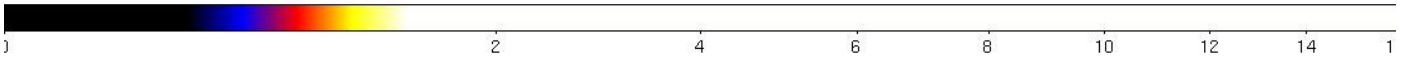
- *Fermi Mission Technical Handbook*

–Multiple levels:

- *Detailed analysis description ('Cicerone')*
- *Individual tool descriptions (like fhelp)*
- *Analysis threads (cook book examples)*
-

- *3c454 region*
-





Likelihood Analysis

- *Unbinned and binned modes are available. I'll describe unbinned analysis.*
- *Several tools are needed to define the model and prepare the data*
  - *modeleditor: GUI for preparing the xml model definition file*
  - *gtselect: applies region-of-interest cuts – sky acceptance cone, energy range (0.2 – 300 GeV), time range, zenith angles (< 105°)*
  - *gtmktime: constructs good time intervals (GTIs) based on pointing information selections and zenith angle cuts*
-
-

Likelihood Analysis cont.

–

–*gtltcube*: *integrates LAT livetime as a function of sky position and off-axis angle*

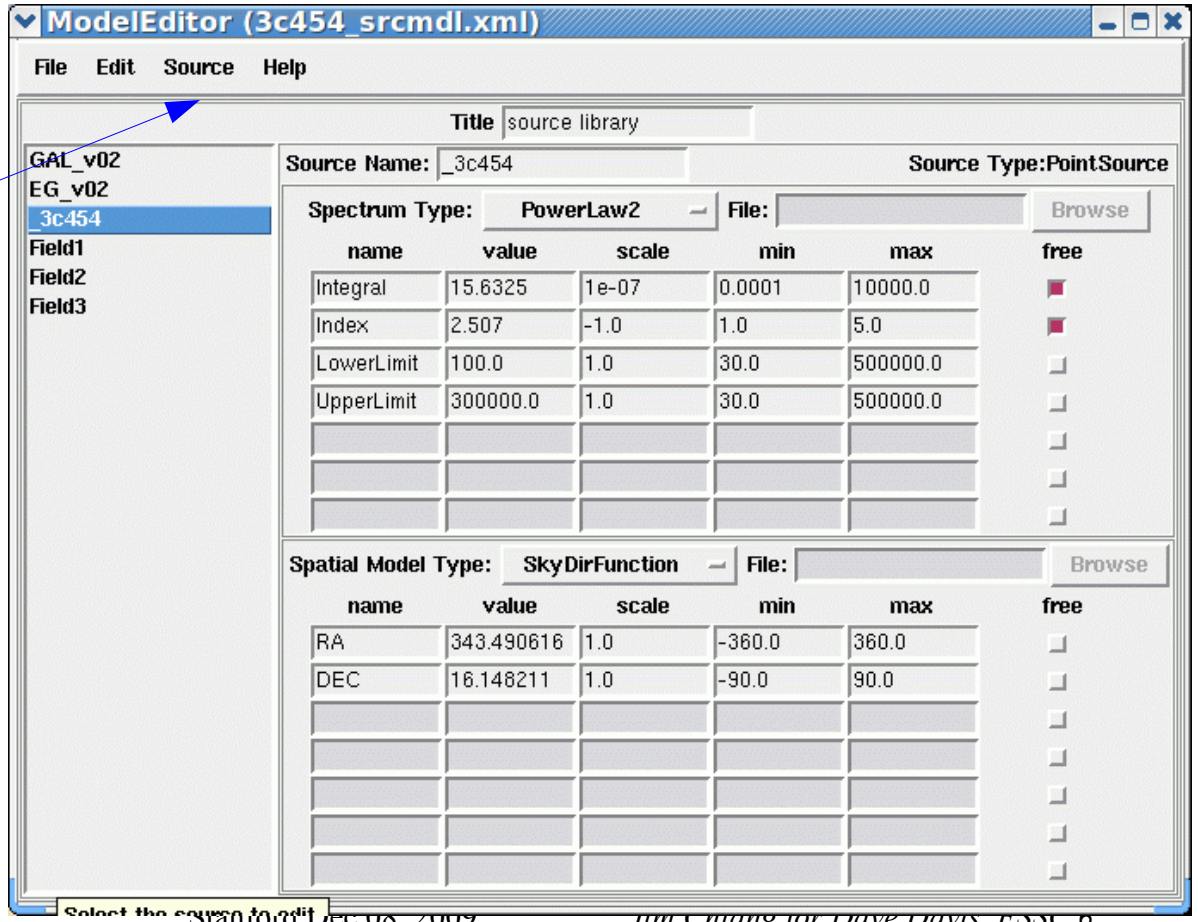
–*gtexpmap*: *computes RoI-specific exposure maps*

–*gtlike*: *fits model parameters using maximum likelihood*

►*Details of the method can be found in http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone*

Likelihood Analysis cont.

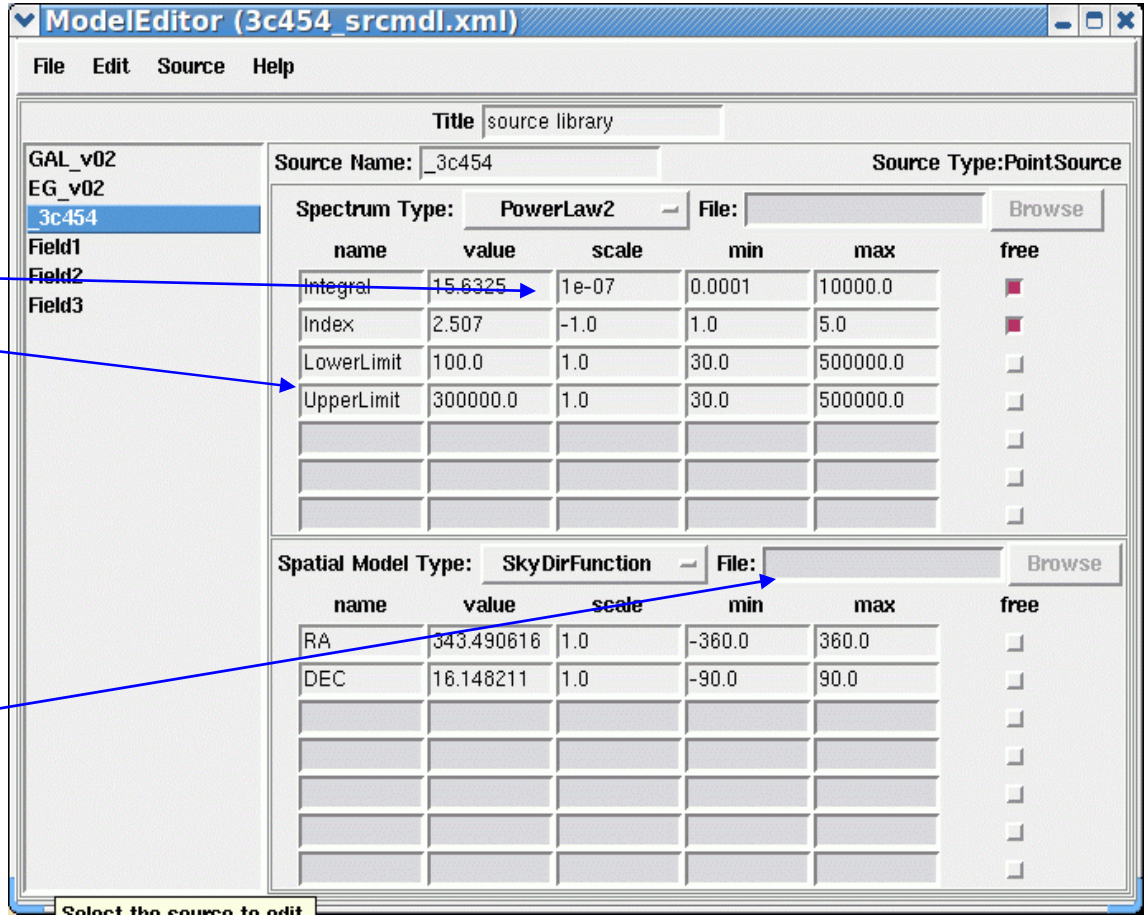
- *Using the modeleditor GUI:*
- Add sources (point-like or diffuse) using the drop down menu



Likelihood Analysis cont.

Edit source name, default fit parameters, bounds, scaling, etc.

If a model component requires a FITS image (e.g., Galactic diffuse, SNR), enter the filename here



Likelihood Analysis

- *gtmktime, gtltcube*

```
>gtmktime
Spacecraft data file[3c454_SC00.fits]
Filter expression[(IN_SAA!=T) && (DATA_QUAL==1)]
Apply ROI-based zenith angle cut[yes]
Event data file[3c454_100_300000_evt01.fits]
Output event file name[3c454_100_300000_evt02.fits]
```

This removes time intervals when the RoI is intersected by the zenith angle cut

```
>gtltcube
Event data file[3c454_100_300000_evt02.fits]
Spacecraft data file[3c454_SC00.fits]
Output file[3c454_100_300000_ExpCube.fits]
Step size in cos(theta) (0.:1.) [0.025]
Pixel size (degrees)[1]
```

Likelihood Analysis

- *gtexpmap*

```
>gtexpmap
The exposure maps generated by this tool are meant
to be used for *unbinned* likelihood analysis only.
Do not use them for binned analyses.
Event data file[3c454_100_300000_evt02.fits]
Spacecraft data file[3c454_SC00.fits]
Exposure hypercube file[3c454_100_300000_ExpCube.fits]
output file name[3c454_100_300000_ExpMap.fits]
Response functions[P6_V3_DIFFUSE]
Radius of the source region (in degrees)[25]
Number of longitude points (2:1000) [120]
Number of latitude points (2:1000) [120]
Number of energies (2:100) [20]
Computing the ExposureMap using 3c454_100_300000_ExpCube.fits
.....................!
```

Likelihood Analysis cont.

- *Finally, running gtlike:*
-

```
>gtlike
Statistic to use (BINNED|UNBINNED) [UNBINNED]
Spacecraft file[3c454_SC00.fits]
Event file[3c454_100_300000_evt02.fits]
Unbinned exposure map[3c454_100_300000_ExpMap.fits]
Exposure hypercube file[3c454_100_300000_ExpCube.fits]
Source model file[3c454_srcmdl.xml]
Response functions to use[P6_V3_DIFFUSE]
Optimizer (DRMNFB|NEWMINUIT|MINUIT|DRMNGB|LBFGS) [minuit]

...

Computing TS values for each source (6 total)
......!
```

This is the xml model file created using the modeleditor GUI

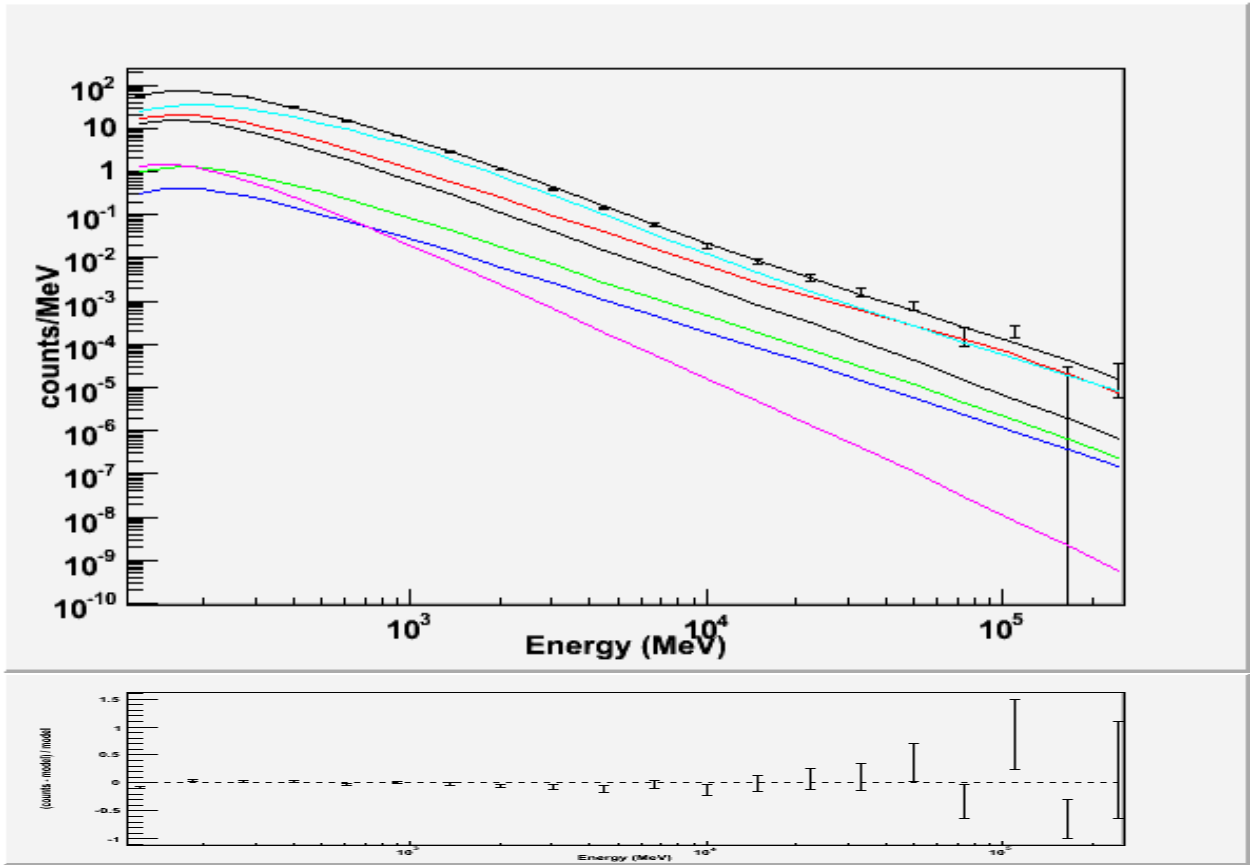
```
GAL_v02:
Prefactor: 1.29563 +/- 0.0426252
Index: 0
Scale: 100
Npred: 16076

_3c454:
Integral: 15.6539 +/- 0.34452
Index: 2.50803 +/- 0.0205473
LowerLimit: 100
UpperLimit: 300000
Npred: 4527.59
ROI distance: 0
TS value: 10656.9
WARNING: Fit may be bad in range [100, 222.696] (MeV)

Total number of observed counts: 28719
Total number of model events: 28719

-log(Likelihood): 325751.9386

Writing fitted model to 3c454_outmdl.xml
```

The Test Statistic (TS) is distributed as χ^2 for n dof. For a power law model TS = 25 is roughly 5σ

Warning messages based on Poisson probability of observed counts given the model prediction in these bands

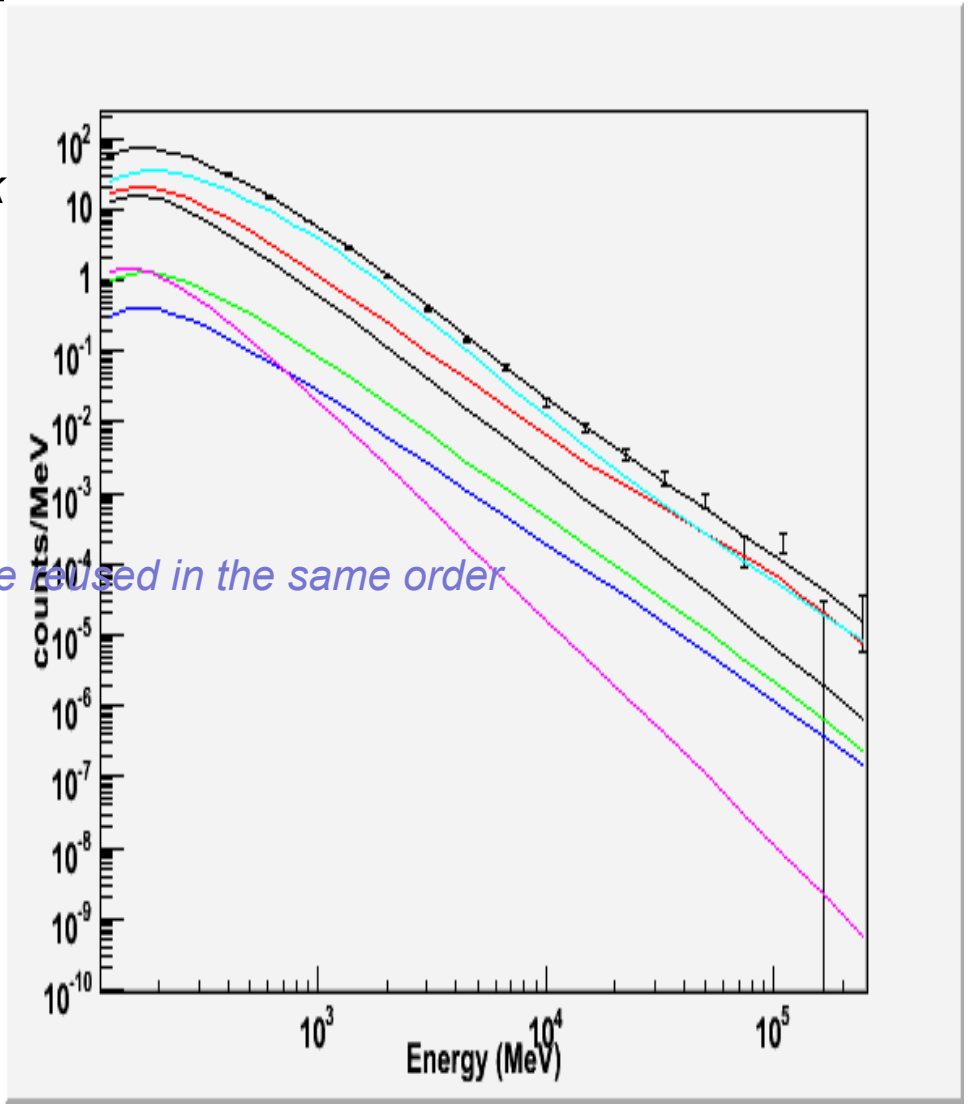
Likelihood Analysis cont.

- *Plot the results (gtlike plot=yes)*



Plot Colors

- *The summed model is black*
- *The first source is red*
- *the second, green*
- *the third, blue*
- *the fourth, magenta*
- *the fifth, cyan*
  - *after this the colors are reused in the same order*



Using the Python interface

- *setup FSSC science tools*
- *setup python & data files*

```
from UnbinnedAnalysis import *

my_obs = UnbinnedObs('3c454_100_300000_evt02.fits',
                     scFile='3c454_SC00.fits',
                     expMap='3c454_100_300000_ExpMap.fits',
                     expCube='3c454_100_300000_ExpCube.fits',
                     irfs='P6_V3_DIFFUSE')

analysis = UnbinnedAnalysis(my_obs, '3c454_srcmdl.xml',
                            optimizer='MINUIT')
```

Python interface (cont.)

- *A parfile interface can also be used:*

```
like = unbinnedAnalysis(evfile='3c454_100_300000_evt02.fits',
                        scfile='3c454_SC00.fits',
                        expmap='3c454_100_300000_ExpMap.fits',
                        expcube='3c454_100_300000_ExpCube.fits',
                        irfs='P6_V3_DIFFUSE',
                        optimizer='MINUIT',
                        srcmdl='3c454_srcmdl.xml')
```

- *From the python prompt, missing elements are prompted for:*

```
>>> like = unbinnedAnalysis(evfile='3c454_100_300000_evt02.fits',
...                         scfile='3c454_SC00.fits',
...                         expmap='3c454_100_300000_ExpMap.fits',
...                         expcube='3c454_100_300000_ExpCube.fits',
...                         irfs='P6_V3_DIFFUSE',
...                         optimizer='MINUIT')
Source model file[3c454_srcmdl.xml]
>>>
```

Python interface (cont.)

- *File introspection*

```
>>> print analysis
Event file(s): 3c454_100_300000_evt02.fits
Spacecraft file(s): 3c454_SC00.fits
Exposure map: 3c454_100_300000_ExpMap.fits
Exposure cube: 3c454_100_300000_ExpCube.fits
IRFs: P6_V3_DIFFUSE
Source model file: 3c454_srcmdl.xml
Optimizer: MINUIT
>>>
```

Python interface (cont.)

- *fit model (verbosity=0)*

```
>>> analysis.fit(verbosity=0)
325751.52498131531
>>>
```

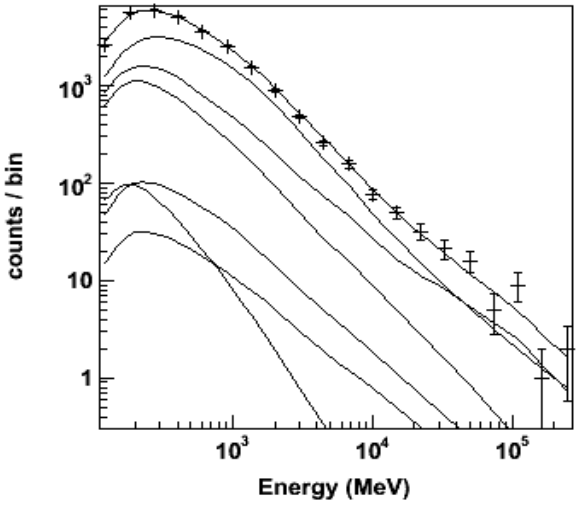
- *fit model (verbosity=1) Much more output*

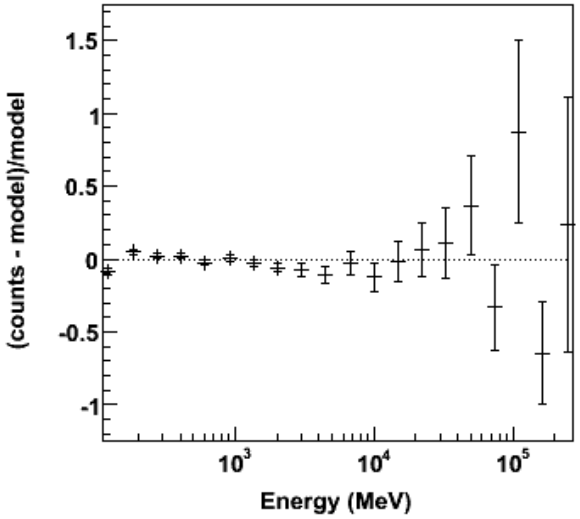
```
>>> analysis.fit(verbosity=1)
 **********
 **    1 **SET PRINT    0.000
 **********
 **********
 **    2 **SET NOWARN
 **********

 PARAMETER DEFINITIONS:
    NO.   NAME         VALUE      STEP SIZE      LIMITS
     1 'Normalizat'   0.60998       1.0000        0.10000E-01   10.000
     2 'Integral  '    1.5807       1.0000        0.10000E-03   10000.
     3 'Index     '    2.3212       1.0000         1.0000       5.0000
<...skip output...>
Minuit parameter uncertainties:
<...skip output...>
  8   0.0426301
  9   0.344517
  10   0.0205484
325751.52497285616
```

Python interface (cont.)

- *Plotting the fitted model (in counts space)*

```
>>> analysis.plot()
>>>
```





Python interface (cont.)

- *Model fit introspection:*

```
>>> analysis.model
EG_v02
   Spectrum: FileFunction
0     Normalization:  6.099e-01  4.543e-02  1.000e-02  1.000e+01 ( 1.000e+00)
<...skip output...>
GAL_v02
   Spectrum: PowerLaw
13     Prefactor:  1.296e+00  4.263e-02  0.000e+00  1.000e+01 ( 1.000e+00)
14         Index:  0.000e+00  0.000e+00 -1.000e+00  1.000e+00 ( 1.000e+00) fixed
15         Scale:  1.000e+02  0.000e+00  5.000e+01  2.000e+02 ( 1.000e+00) fixed

_3c454
   Spectrum: PowerLaw2
16      Integral:  1.565e+01  3.445e-01  1.000e-04  1.000e+04 ( 1.000e-07)
17         Index:  2.508e+00  2.055e-02  1.000e+00  5.000e+00 (-1.000e+00)
18    LowerLimit:  1.000e+02  0.000e+00  3.000e+01  5.000e+05 ( 1.000e+00) fixed
19    UpperLimit:  3.000e+05  0.000e+00  3.000e+01  5.000e+05 ( 1.000e+00) fixed
```

Python interface (cont.)

- *Setting, freezing, thawing parameters:*

```
>>> analysis[16] = 7

>>> print analysis['_3c454']
_3c454
   Spectrum: PowerLaw2
16      Integral:  7.000e+00  0.000e+00  1.000e-04  1.000e+04 ( 1.000e-07)
17         Index:  2.508e+00  2.055e-02  1.000e+00  5.000e+00 (-1.000e+00)
18    LowerLimit:  1.000e+02  0.000e+00  3.000e+01  5.000e+05 ( 1.000e+00) fixed
19    UpperLimit:  3.000e+05  0.000e+00  3.000e+01  5.000e+05 ( 1.000e+00) fixed

>>> analysis.freeze(17)

>>> print analysis['_3c454']
   Spectrum: PowerLaw2
16      Integral:  7.000e+00  0.000e+00  1.000e-04  1.000e+04 ( 1.000e-07)
17         Index:  2.508e+00  2.055e-02  1.000e+00  5.000e+00 (-1.000e+00) fixed
18    LowerLimit:  1.000e+02  0.000e+00  3.000e+01  5.000e+05 ( 1.000e+00) fixed
19    UpperLimit:  3.000e+05  0.000e+00  3.000e+01  5.000e+05 ( 1.000e+00) fixed

>>> analysis.freeze((16, 17))
>>> analysis.thaw((16, 17))

>>> analysis.freeze(range(20))
>>> analysis.thaw(range(20))
```

Python interface (cont.)

- *Over plotting alternative fit results:*

```
>>> analysis.oplot(color='red')
```