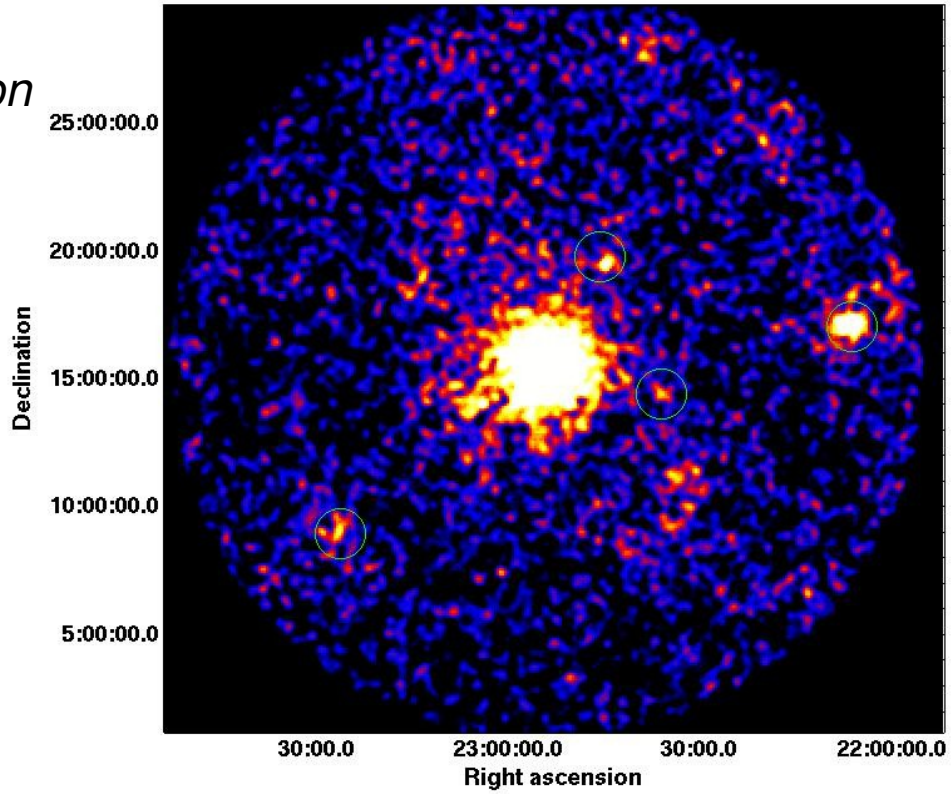
FSSC Science Tools

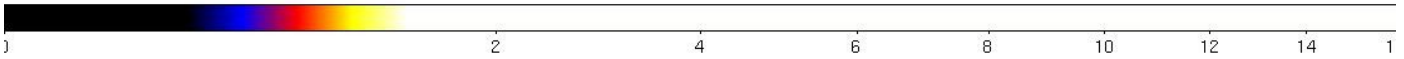
Source Analysis

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.

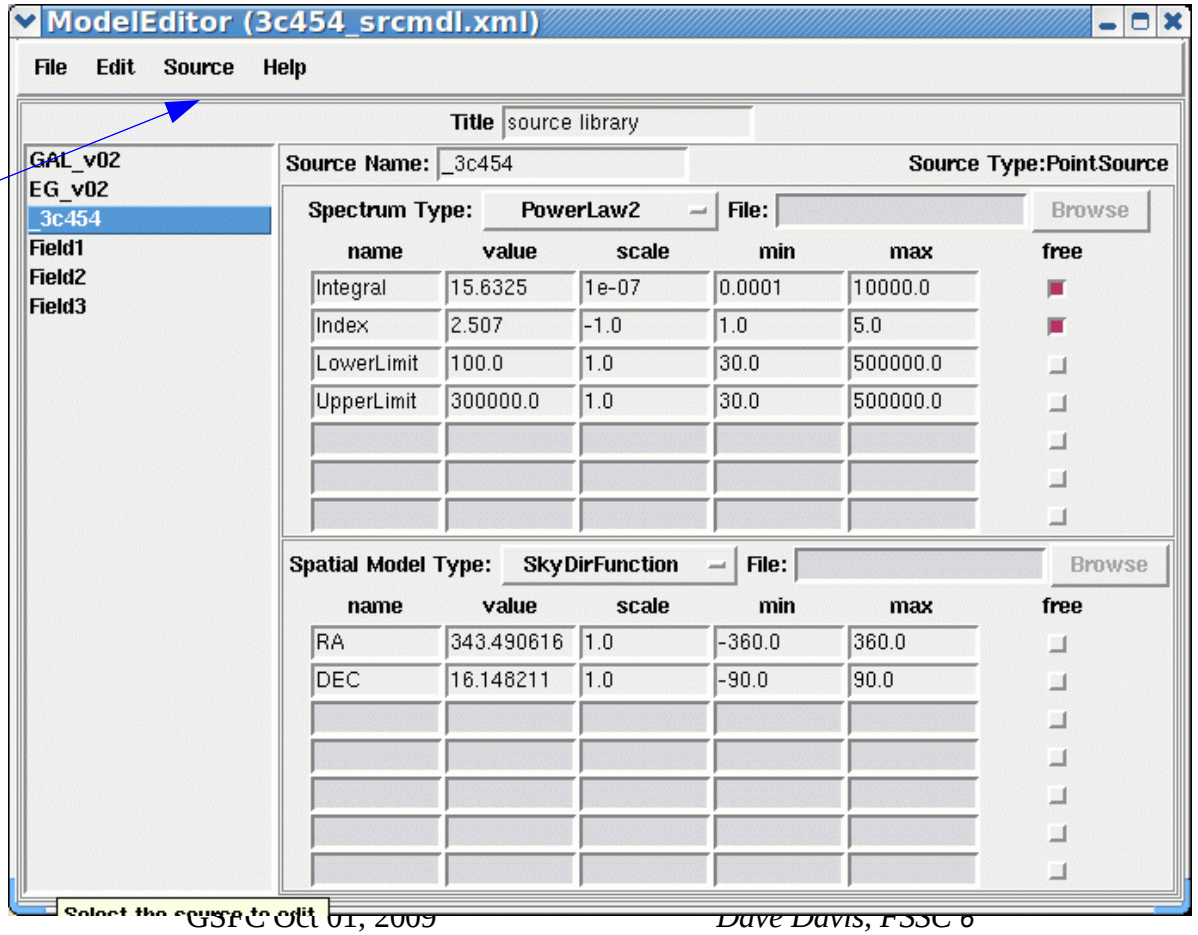
- *gtltcube: integrates LAT livetime as a function of sky position and off-axis angle*
- *gtexpmap: computes RoI-specific exposure maps*
- *gtlike: fits model parameters using maximum likelihood*

- *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:*

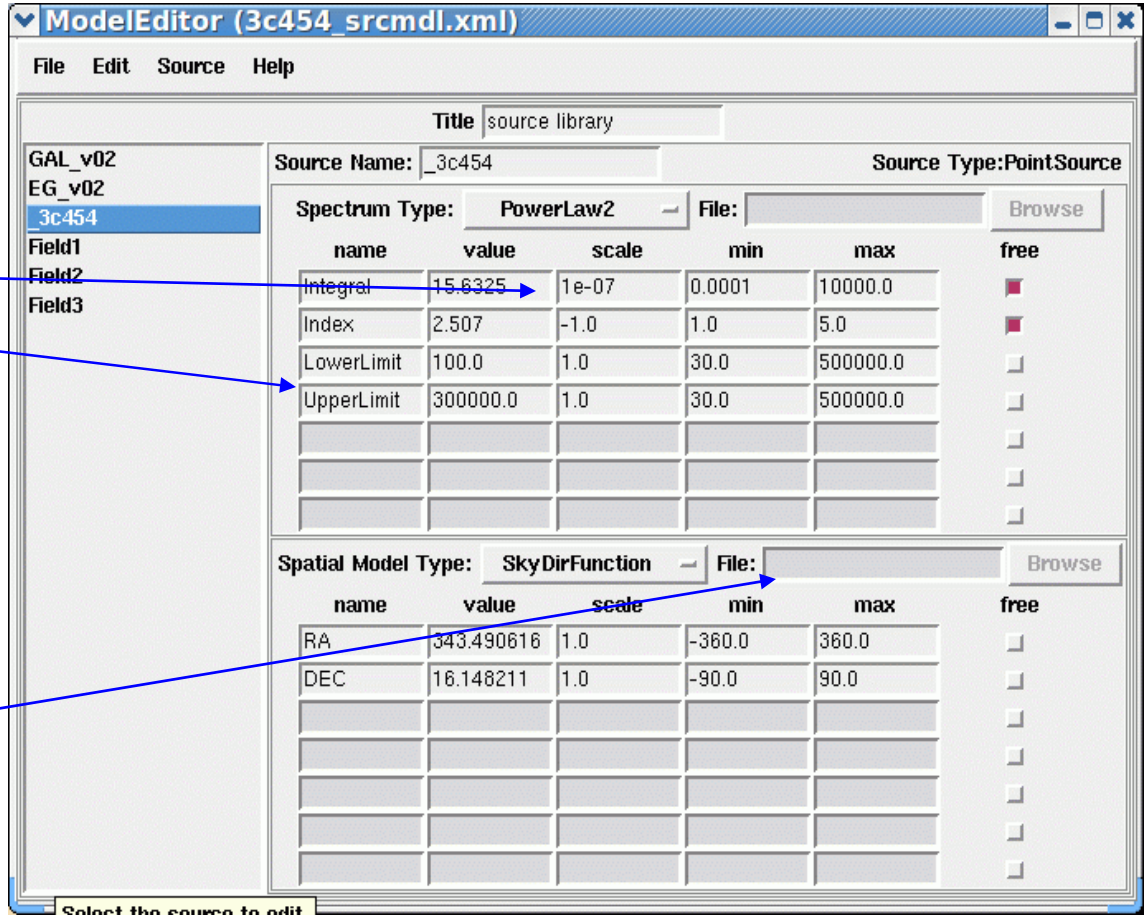
Add sources (point-like or diffuse) using the drop down menu



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]
```

```
>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]
```

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

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

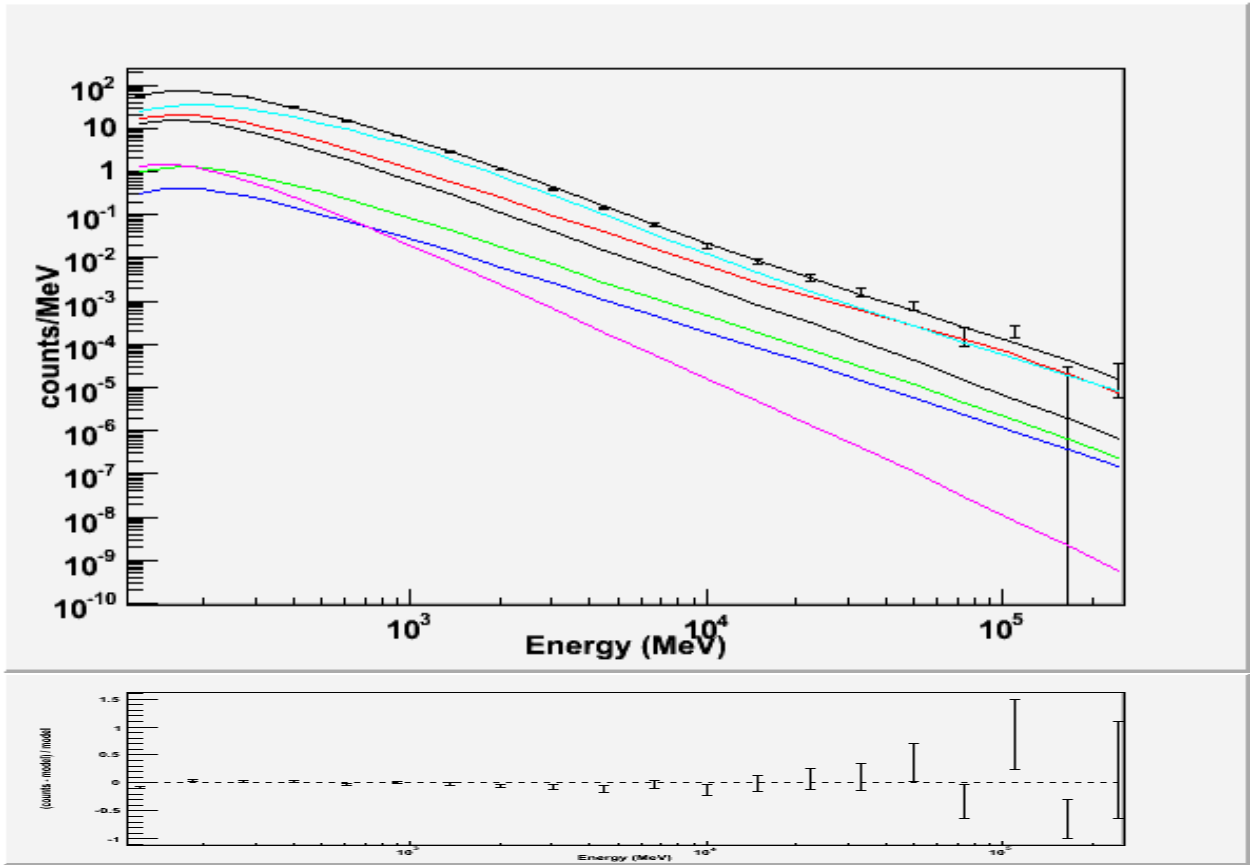
```
GAL_v02:
Prefactor: 1.29563 +/- 0.0426252
Index: 0
Scale: 100
Npred: 16076

_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

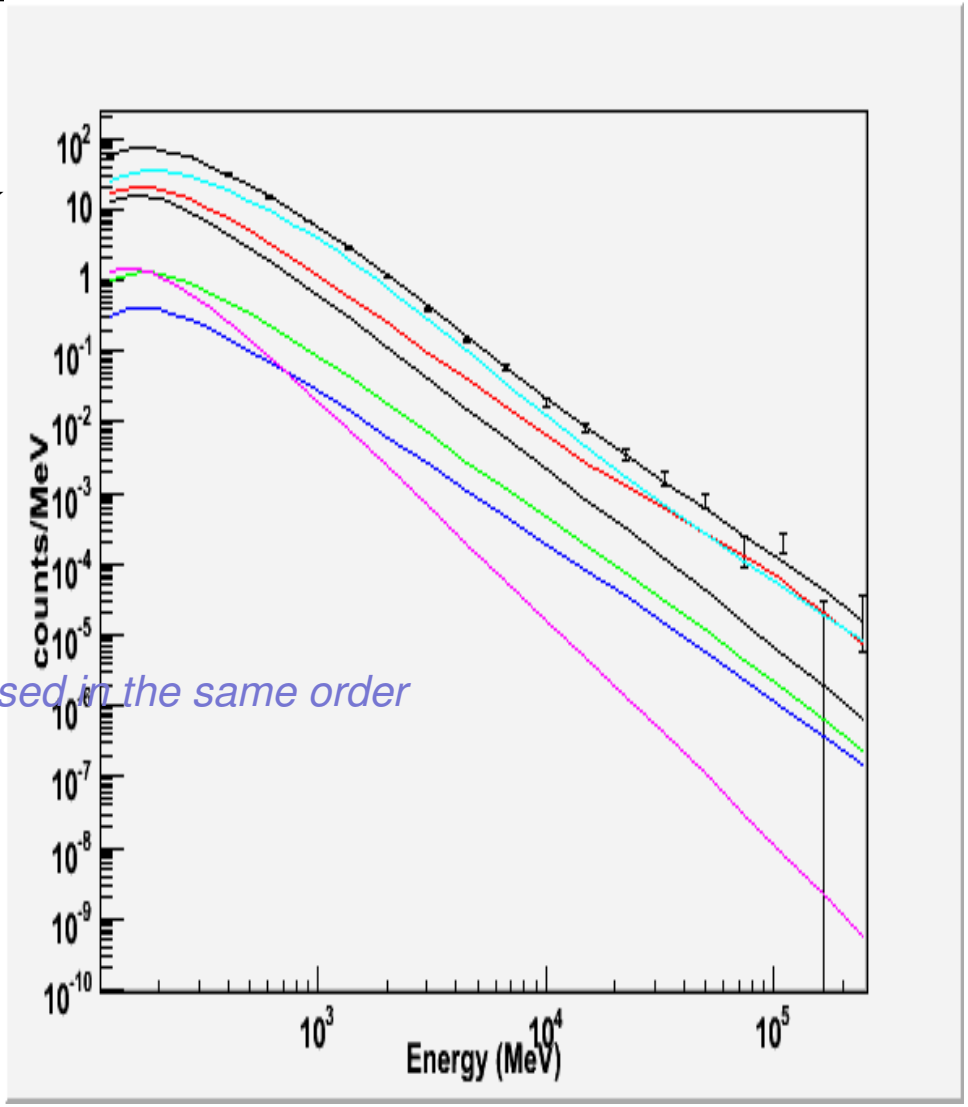
Likelihood Analysis cont.

- *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*



Now from Python

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

```
import glob
from UnbinnedAnalysis import *
my_obs = unbinnedAnalysis('3c454_100_300000_evt02.fits',
                          '3c454_SC00.fits',
                           expMap='3c454_100_300000_ExpMap.fits',
                           expCube='3c454_100_300000_ExpCube.fits',
                           irfs='P6_V3_DIFFUSE',
                           optimizer='MINUIT')
```

Now from Python cont.

- *setup model*

```
>>> analysis = unbinnedAnalysis(my_obs, "3c454_srcmdl.xml")
>>> 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
```

Now from Python cont.

- *setup model*

```
>>> analysis = unbinnedAnalysis(my_obs, "3c454_srcmdl.xml")
>>> 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
```

Now from Python cont.

- *fit model (verbosity=0)*

```
>>> analysis.fit(verbosity=0)
325751.93858041393
```

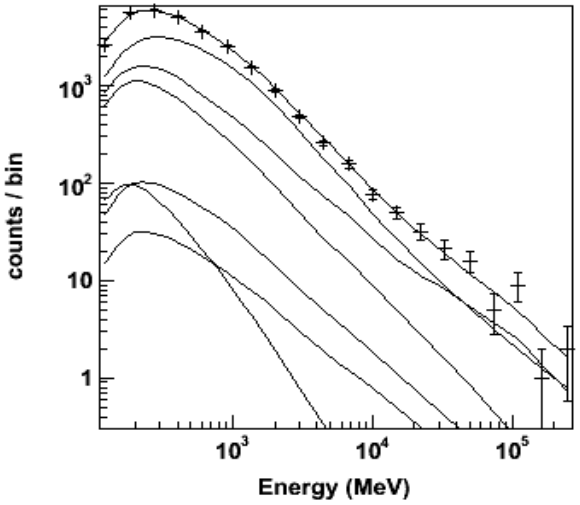
- *fit model (verbosity=1) Much more output*

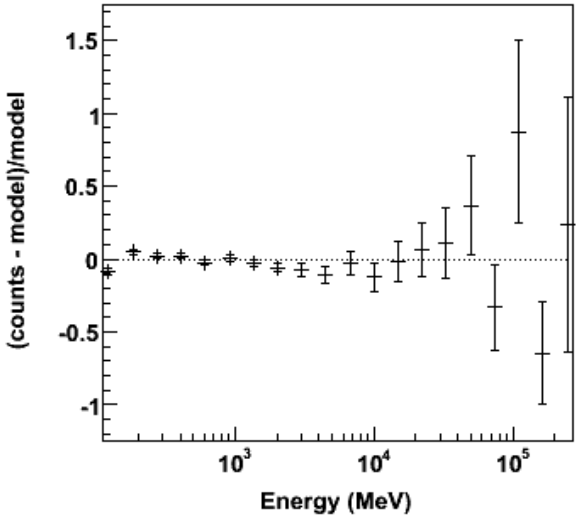
```
>>> analysis.fit(verbosity=1)
 **********
 **     1 **SET PRINT      .000
 **********
 **********
 **     2 **SET NOWARN
 **********

 PARAMETER DEFINITIONS:
    NO.   NAME         VALUE       STEP SIZE       LIMITS
      1 'Normalizat'     .60995        1.0000          .10000E-01    10.000
      2 'Integral   '    1.5776        1.0000          .10000E-03    10000.
      3 'Index      '    2.3203        1.0000          1.0000        5.0000

<skip output>

Minuit parameter uncertainties:
....
   8   0.0426301
   9   0.34453
  10   0.0205469
325751.93858041393
```

Now from Python cont.

- *Plot fitted model*

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





Now from Python cont.

- *view model*

```
>>> analysis.model
EG_v02
   Spectrum: FileFunction
0     Normalization:  1.000e+00  0.000e+00  1.000e-02  1.000e+01 ( 1.000e+00)

<skip some models>

GAL_v02
   Spectrum: PowerLaw
13     Prefactor:  1.220e+00  0.000e+00  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:  1.563e+01  0.000e+00  1.000e-04  1.000e+04 ( 1.000e-07)
17         Index:  2.507e+00  0.000e+00  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
```