“ctools" tutorial

Ulisses Barres de Almeida

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Ulisses Barres de Almeida

DISCLAIMER: I am not a developer! This tutorial is based on other lessons from where I learned CTA analysis tools. Specially by J. Knodelseder & F. Longo.

This presentation aims to be a short practical introduction to one set of tools being developed for CTA analysis.

“ctools" is similar to “fermi tools” in concept and after this you should be able to go and play with the tools yourself.

Prerequisites: Rodrigo’s “fermi tools” hands-on sessions + Gernot’s ACT analysis introduction

ctools
cherenkov telescope array
CTA
Cherenkov Telescope Array Science Analysis Software

What is ctools?

ctools is a project in development for CTA.
It consists on a set of fermi tools-like executables for step-wise data analysis by end-users.

Accessible from:

https://cta-redmine.irap.omp.eu/projects/ctools

check the wiki

Contact information:

subscribe to ctools@irap.omp.eu

ctools cherenkov telescope array CTA
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***ctools are based on GammaLib**, a toolbox for high-level analysis of gamma-ray data

GammaLib

A versatile toolbox for scientific analysis of astronomical gamma-ray data

What is provided by GammaLib?

High-level analysis functionalities tools — i.e., post-reconstruction events operations

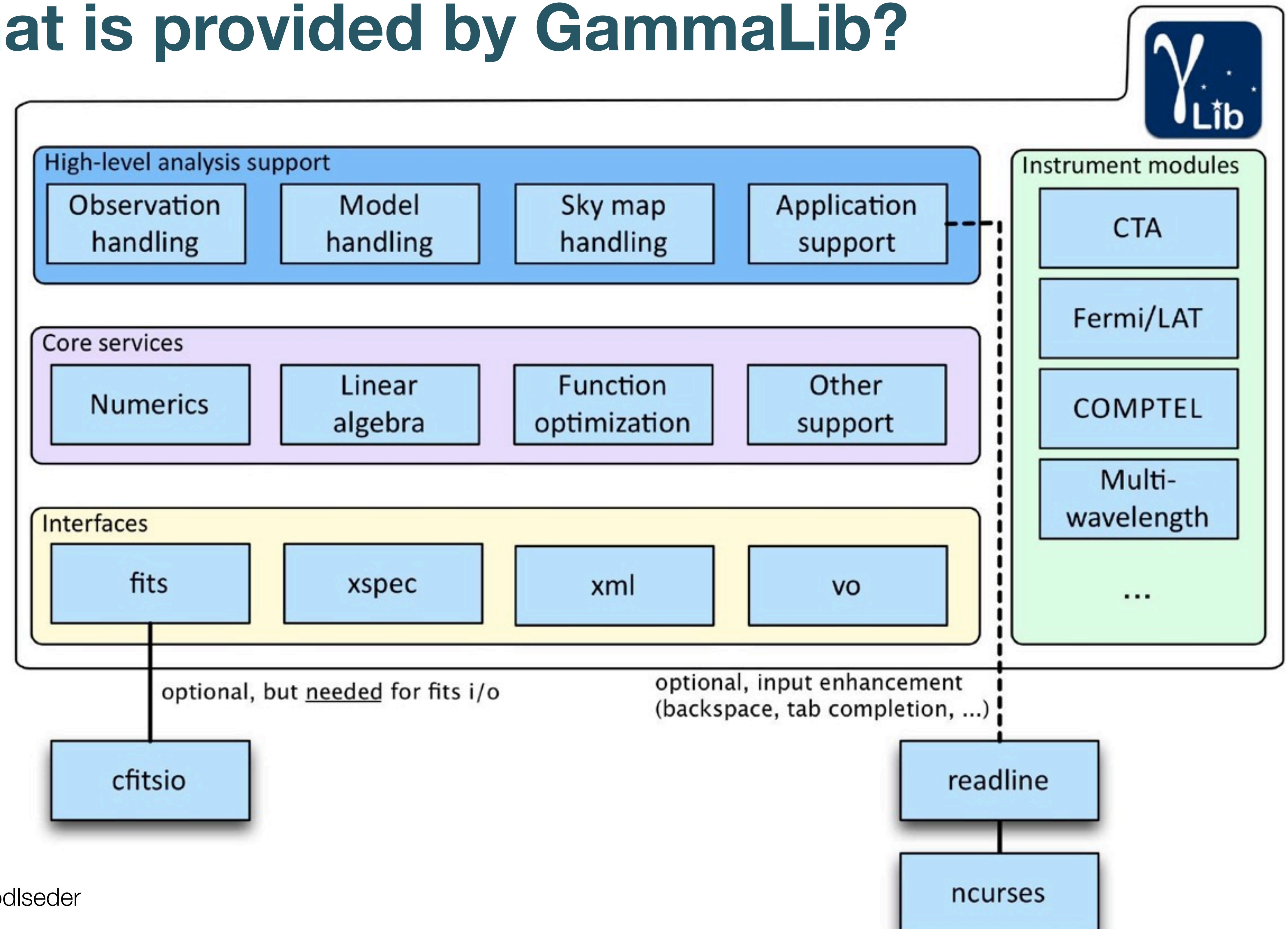
- event I/O
- IRF implementation
- data format
- parameter specifications
- versatile for multi-mission analysis*
- and joint multi-instrument data analysis

http://gammalib.sourceforge.net/

GammaLib

A versatile toolbox for scientific analysis of astronomical gamma-ray data

What is provided by GammaLib?



CTA

Cherenkov Telescope Array Science Analysis Software

Introduction

ctools is a collection of utilities for operating on CTA event data (photon lists) and IRFs in the FITS format, pretty much like the fools you operated at the hands-on yesterday.

Each routine performs specific tasks such as:

- binning
- event selection
- model fitting
- …

It shares all functionalities and interface capabilities of fermi tools, i.e. FITS files handling (”ftools”), python scripts, IRAF-style parameters files, HEASARC library packages, etc.

ctools
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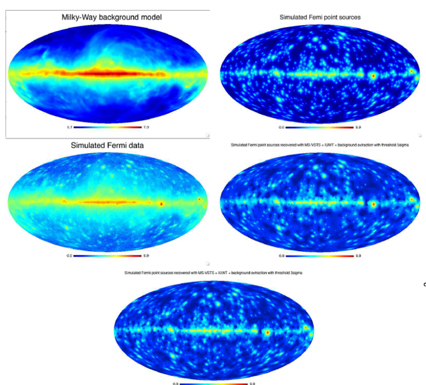
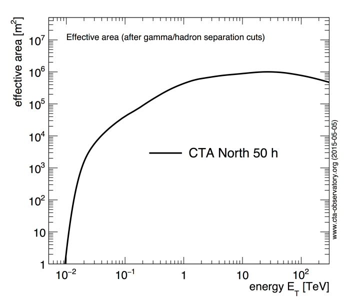
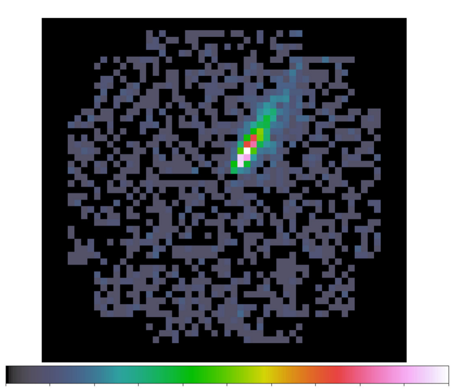
in practice…

background model



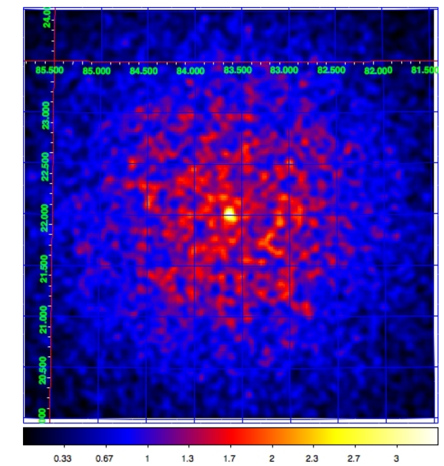


instrument
response functions

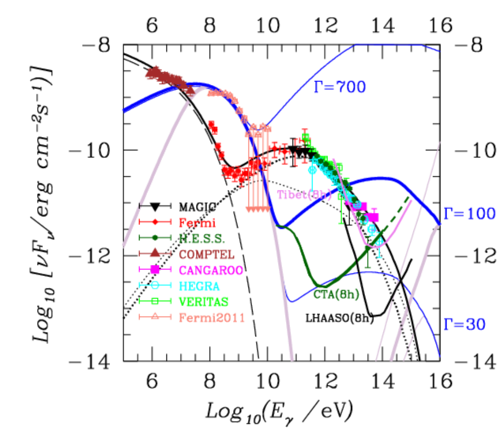


simulated (reconstructed)
event lists

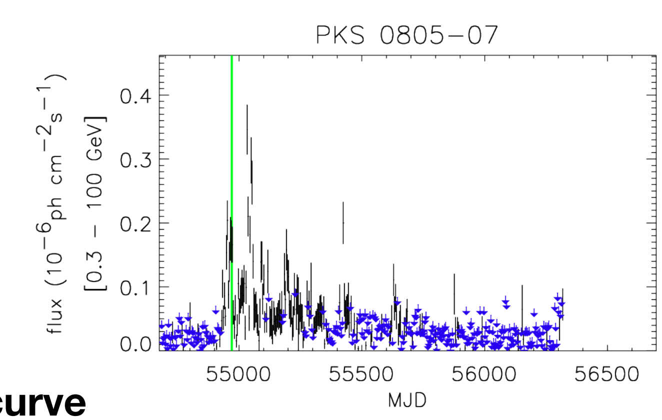
ctools
cherenkov telescope array



skymaps



spectra

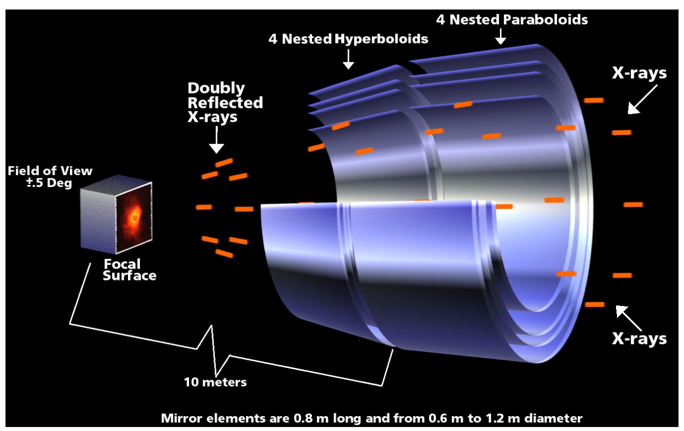


lightcurve

CTA

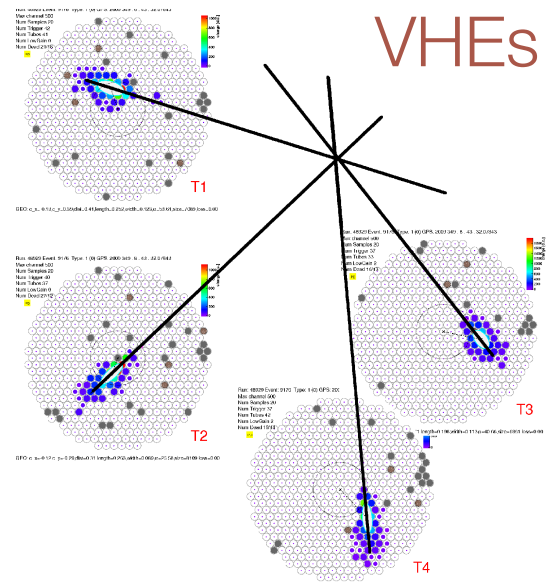
Cherenkov Telescope Array Science Analysis Software

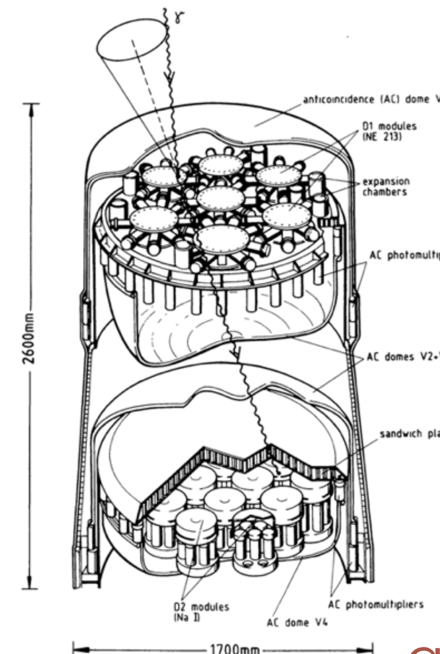
Across the borders



X-rays

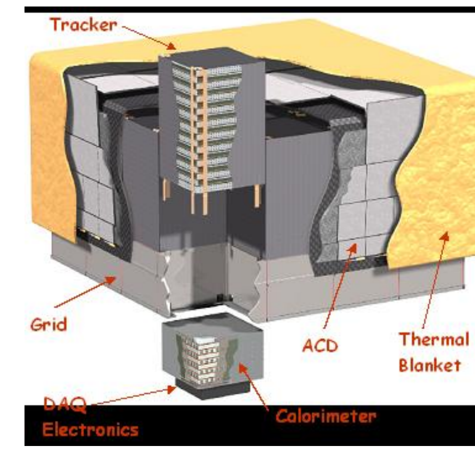
VHEs





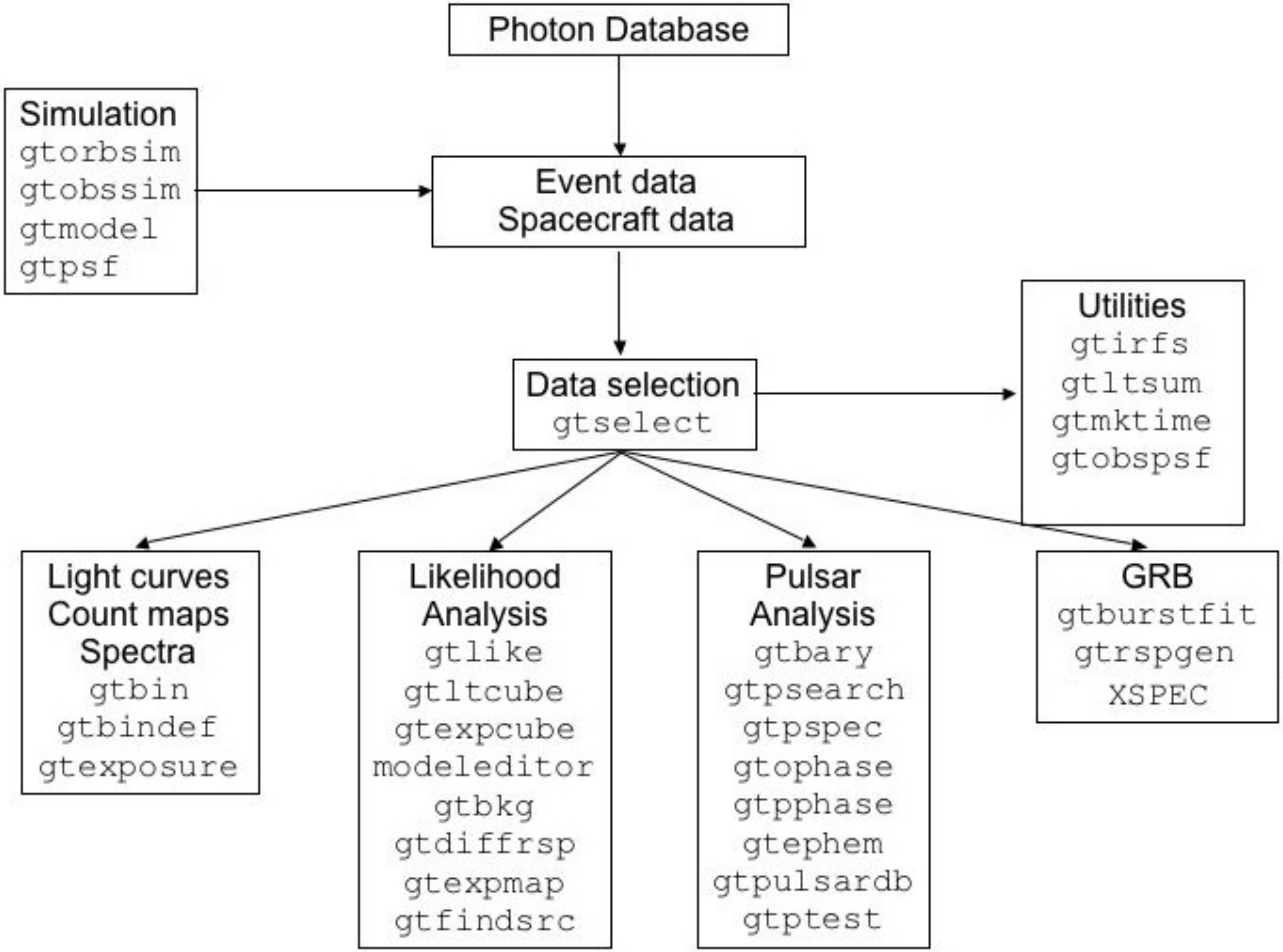
low-E gammas

GeV gammas



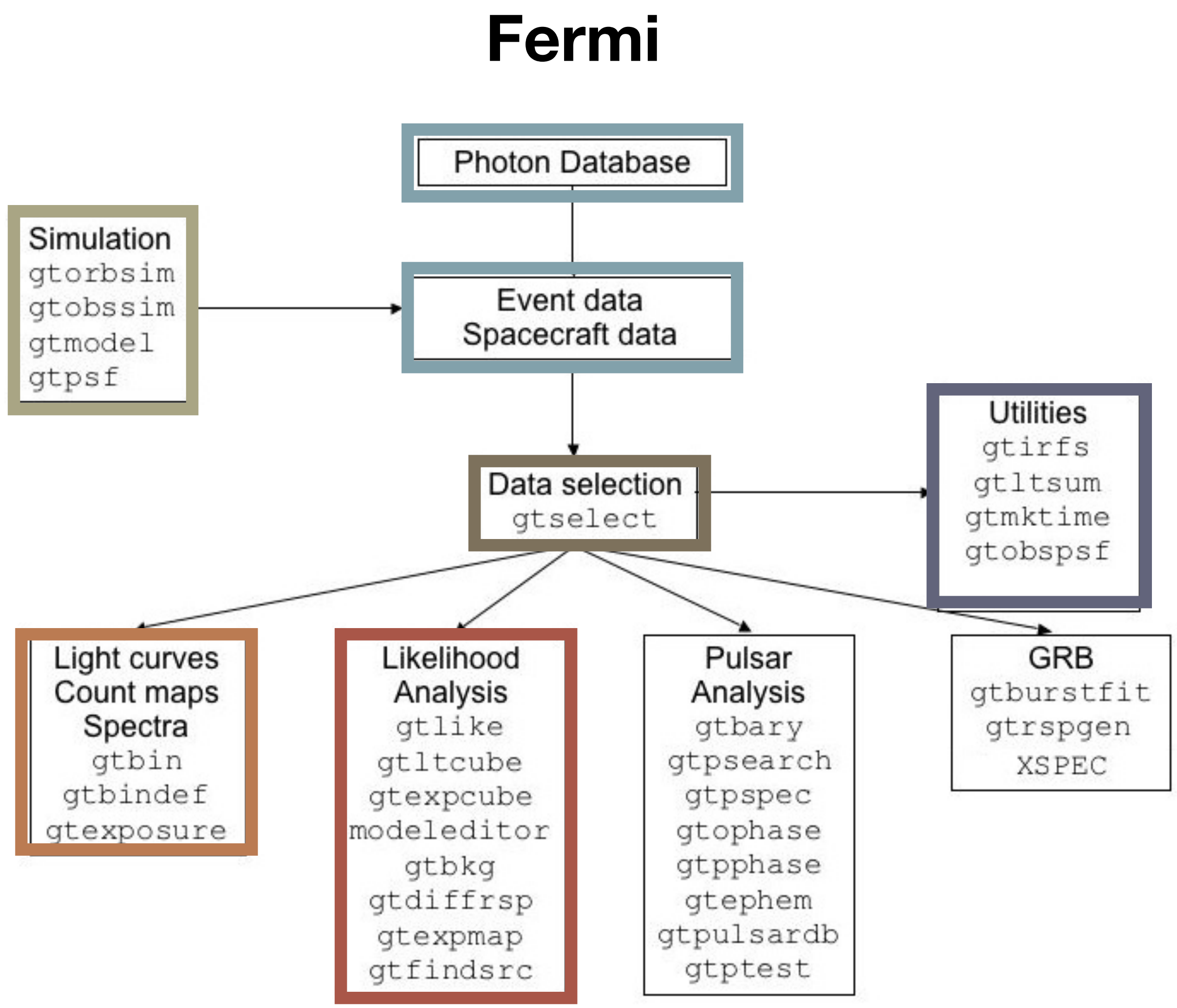
A common set of tools for high-energy photon-counting instruments

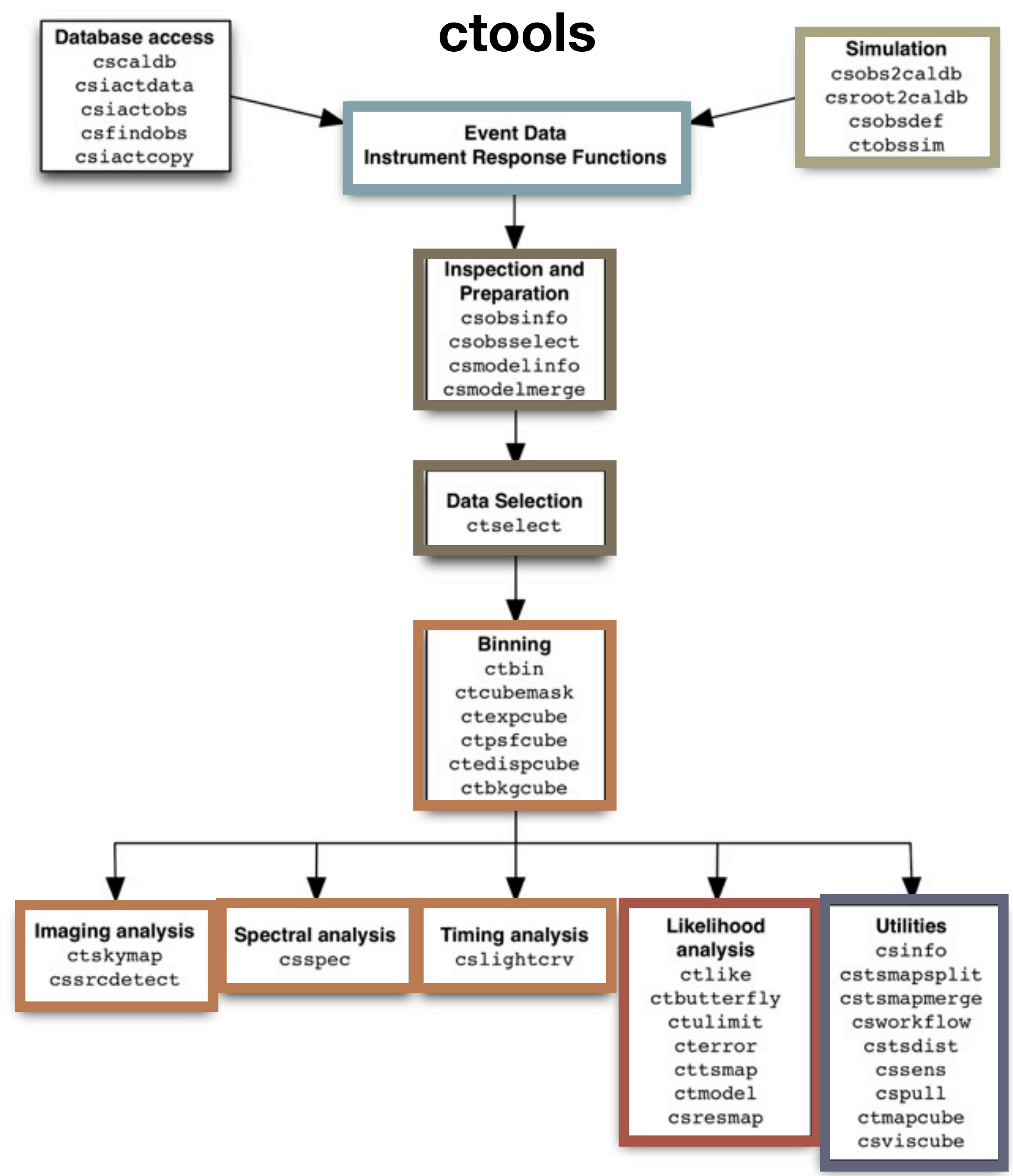
\+ HEASARC's cfitsio library



The Fermi/LAT example

from Rodrigo's hands on yesterday — if you are familiar with Fermi tools you can use ctools directly





Equivalence between Fermi and ctools

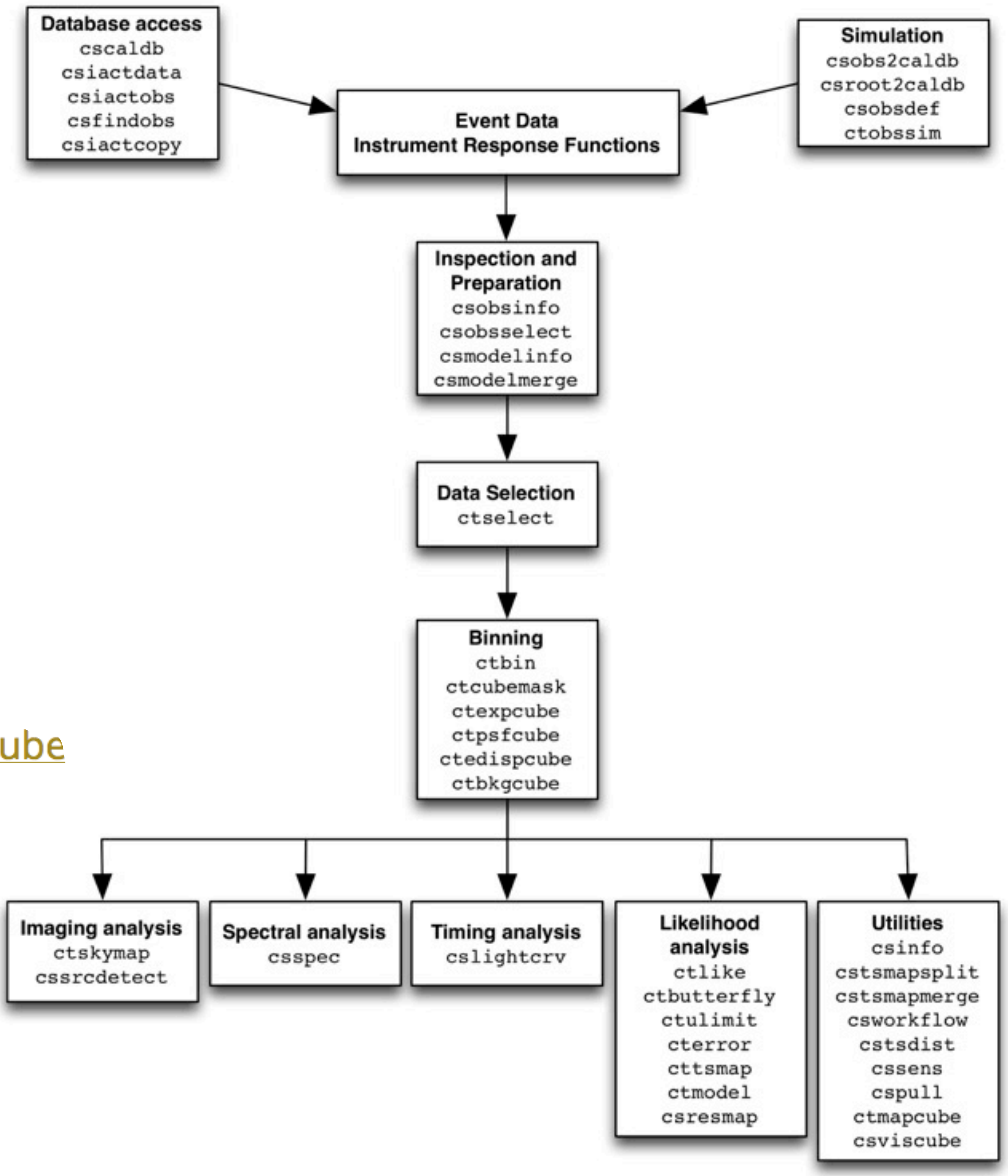
Equivalent modular structure for science data analysis

Some definitions

ctools

- ctbin — Generates counts cube
- ctbkgcube — Generates background cube
- ctbutterfly — Compute butterfly
- ctcubemask — Filter counts cube
- ctexpcube — Generates exposure cube
- ctlike — Performs maximum likelihood fitting
- ctmodel — Computes model counts cube
- ctobssim — Simulate CTA observations
- ctpsfcube — Generates point spread function cube
- ctselect — Selects event data
- ctskymap — Generates sky map
- cttsmap — Generates Test Statistics map
- ctulimit — Calculates upper limit

....



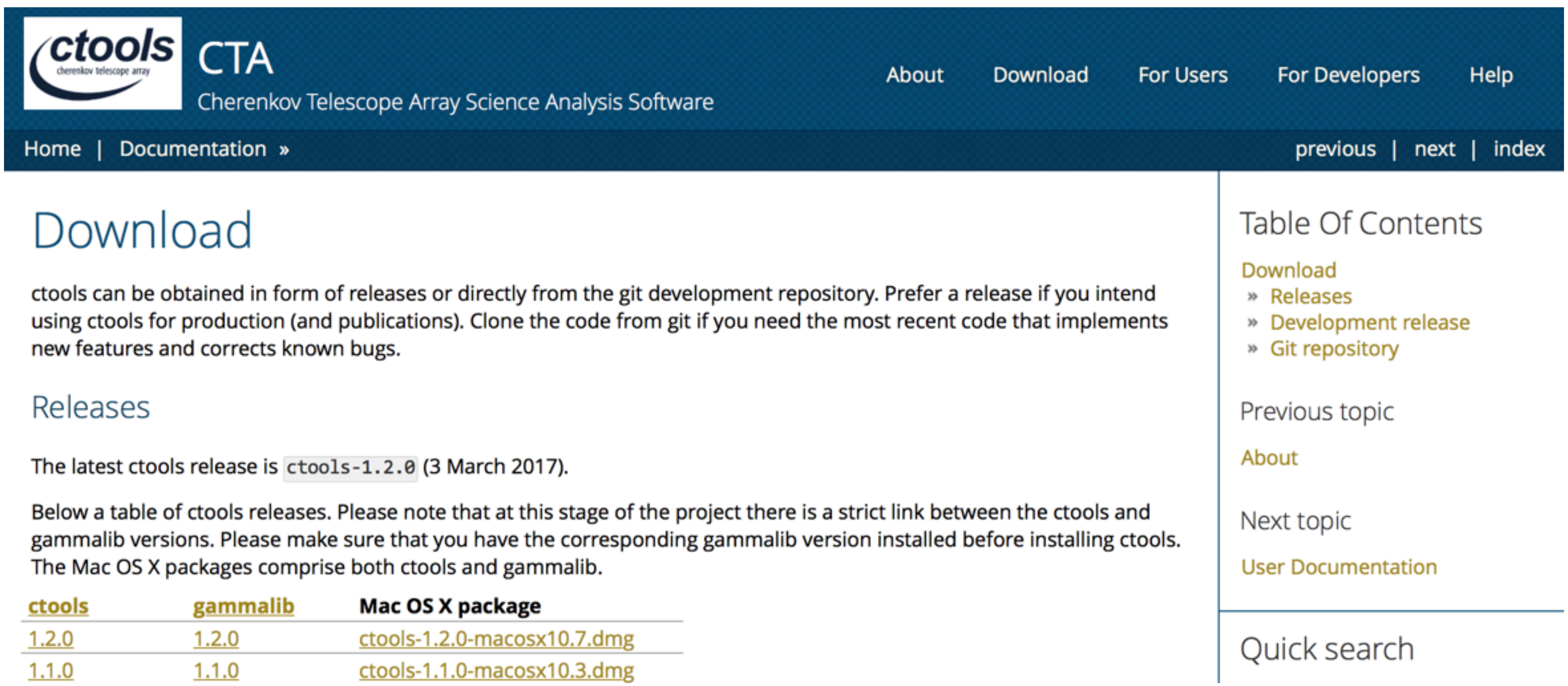
Equivalence between Fermi and ctools

Equivalent modular structure for science data analysis

Starting with ctools

download the code from
http://cta.irap.omp.eu/ctools/download.html

Get the source files and binary package for ctools and gammalib:


ctools cherenkov telescope array

CTA

Cherenkov Telescope Array Science Analysis Software

About | Download | For Users | For Developers | Help

Home | Documentation »

previous | next | index

Download

ctools can be obtained in form of releases or directly from the git development repository. Prefer a release if you intend using ctools for production (and publications). Clone the code from git if you need the most recent code that implements new features and corrects known bugs.

Releases

The latest ctools release is `ctools-1.2.0` (3 March 2017).

Below a table of ctools releases. Please note that at this stage of the project there is a strict link between the ctools and gammalib versions. Please make sure that you have the corresponding gammalib version installed before installing ctools. The Mac OS X packages comprise both ctools and gammalib.

ctools	gammalib	Mac OS X package
1.2.0	1.2.0	ctools-1.2.0-macosx10.7.dmg
1.1.0	1.1.0	ctools-1.1.0-macosx10.3.dmg

Table Of Contents

Previous topic

About

Next topic

User Documentation

Quick search

Installing ctools (you did not do it for Fermi!)

use mac binary package
or build from source

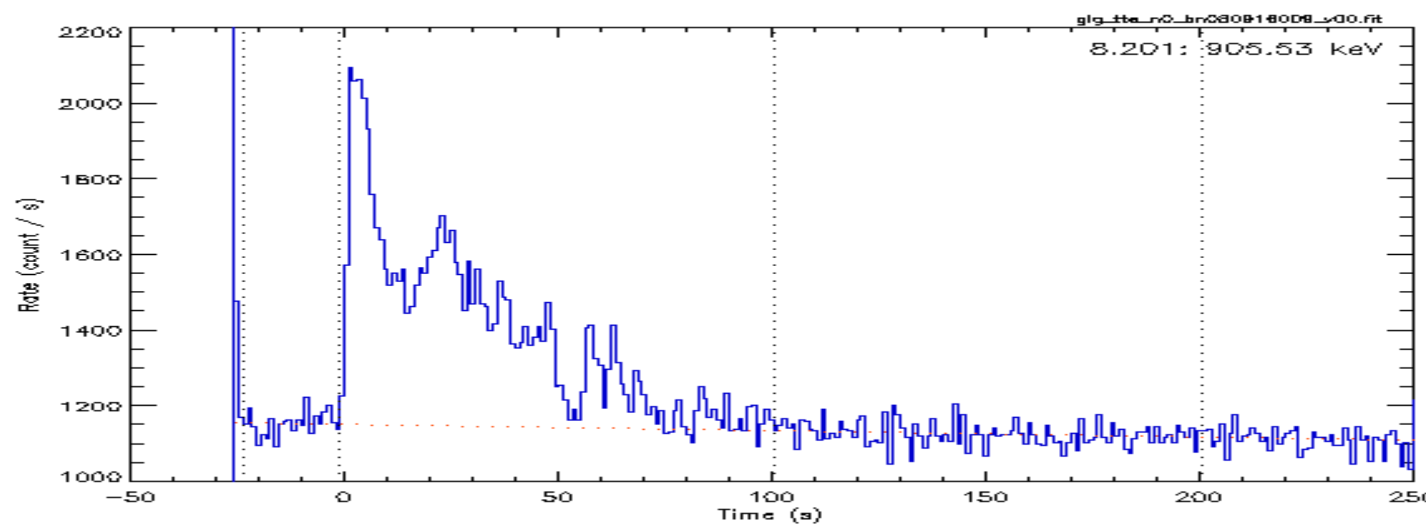
```
$ ./configure
$ make
$ make install
```

Configuring gammalib and ctools:

```
$ export GAMMALIB=/usr/local/gamma
$ source $GAMMALIB/bin/gammalib-init.sh
$ export CTOOLS=/usr/local/gamma
$ source $CTOOLS/bin/ctools-init.sh
```

this goes into your /.bashrc script…

Data structure



[TSART] [TSTOP]

GTI - good time interval

[energy range]

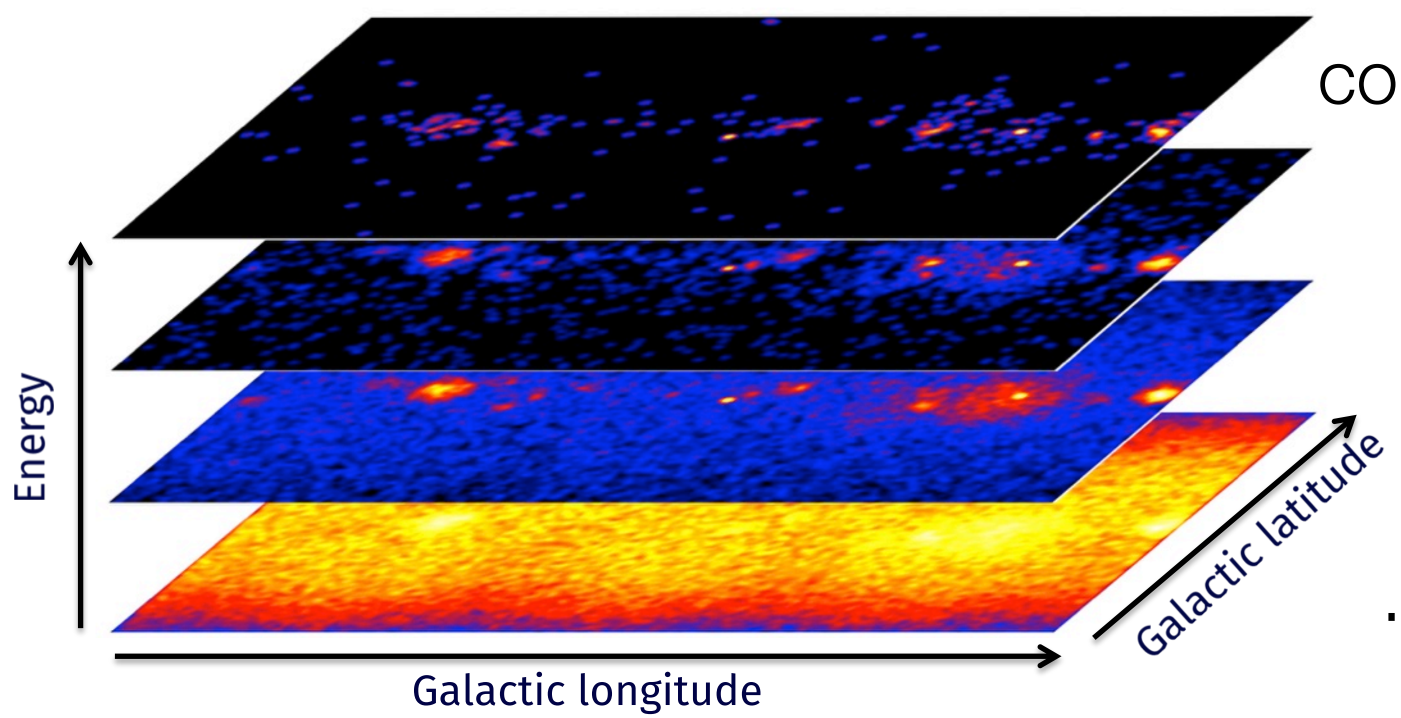
IRF

Event data

reconstructed direction;

reconstructed energy;

time tag



counts cube

…. for each time interval

Simulating CTA data

No real data yet for CTA

simulated CTA data is done with the tool “ctobssim”:

```
$ ctobssim
Model [$CTOOLS/share/models/crab.xml]
RA of pointing (degrees) (0-360) [83.63]
Dec of pointing (degrees) (-90-90) [22.01]
Calibration database [dummy]
Instrument response function [cta_dummy_irf]
Radius of FOV (degrees) (0-180) [5.0]
Start time (MET in s) (0) [0.0]
End time (MET in s) (0) [1800.0]
Lower energy limit (TeV) (0) [0.1]
Upper energy limit (TeV) (0) [100.0]
Output event data file or observation definition file [events.fits]
```

…as with Fermi tools, you are queried about each parameter [or leave it as default]

$CTOOLS is an alias for the environment variable path

The CTA IRFs (effective area, PSF width, etc.) are taken from a performance table at

$CTOOLS/share/caldb/cta

Simulating CTA data

An example IRAF parameter file

```
#
# General parameters
#====================
inobs,      f, h, NONE,,, "Input event list or observation definition XML file"
inmodel,    f, a, $CTOOLS/share/models/crab.xml,,, "Input model definition XML file"
caldb,      s, a, prod2,,, "Calibration database"
irf,        s, a, South_0.5h,,, "Instrument response function"
edisp,      b, h, no,,, "Apply energy dispersion?"
outevents,  f, a, events.fits,,, "Output event data file or observation definition XML file"
prefix,     s, h, sim_events_,,, "Prefix for event lists in observation definition XML file"
startindex, i, h, 1,,, "Start index for event lists in observation definition XML file"

#
# Simulation parameters
#=======================
seed,    i, h, 1,,, "Random number generator seed"
ra,      r, a, 83.63,0,360, "RA of pointing (degrees)"
dec,     r, a, 22.01,-90,90, "Dec of pointing (degrees)"
rad,     r, a, 5.0,0,180, "Radius of FOV (degrees)"
tmin,    r, a, 0.0,,, "Start time (MET in s)"
tmax,    r, a, 1800.0,,, "End time (MET in s)"
emin,    r, a, 0.1,,, "Lower energy limit (TeV)"
emax,    r, a, 100.0,,, "Upper energy limit (TeV)"
deadc,   r, h, 0.95,0,1, "Average deadtime correction factor"
maxrate, r, h, 1.0e6,,, "Maximum photon rate"
eslices, i, h, 10,1,100, "Number of energy slices"

#
# Standard parameters
#=====================
publish, b, h, no,,, "Publish event list on VO Hub?"
chatter, i, h, 2,0,4, "Chattiness of output"
clobber, b, h, yes,,, "Overwrite existing output files with new output files?"
debug,   b, h, no,,, "Debugging mode activated"
mode,    s, h, ql,,, "Mode of automatic parameters"
logfile, f, h, ctobssim.log,,, "Log filename"
```

Simulating CTA data

No real data yet for CTA

simulated CTA data is done with the tool “ctobssim”:

```
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Model [$CTOOLS/share/models/crab.xml]
RA of pointing (degrees) (0-360) [83.63]
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Instrument response function [cta_dummy_irf]
Radius of FOV (degrees) (0-180) [5.0]
Start time (MET in s) (0) [0.0]
End time (MET in s) (0) [1800.0]
Lower energy limit (TeV) (0) [0.1]
Upper energy limit (TeV) (0) [100.0]
Output event data file or observation definition file [events.fits]
```
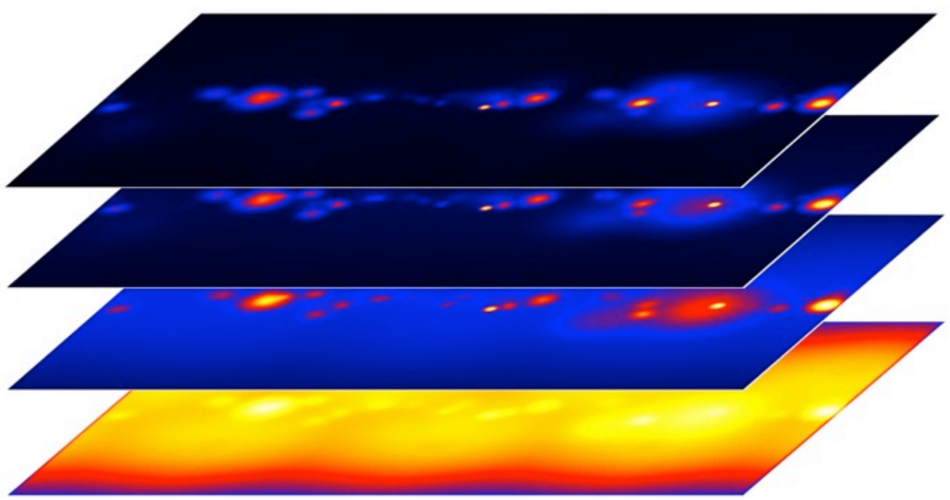

CTA events are simulated based on certain dummy instrument properties (the IRFs), plus a source and background model.

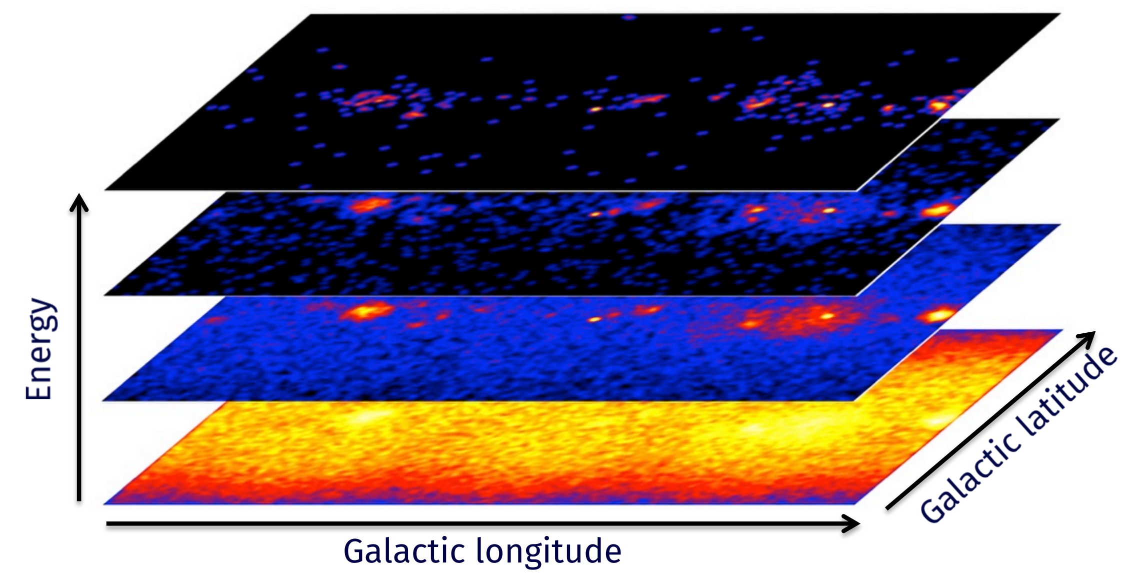
Simulating CTA data

No real data yet for CTA

CTA events are simulated based on certain dummy instrument properties (the IRFs), plus a source and background model.



CTA model data



the data cube…

The output events .fits file will contain all relevant event data within the specified circular ROI (region of interest).

The duration of a run (observation) is 30 min, and typical energy range is from 0.1 to 100 TeV

What is a data model?

The source model is specified in a XML file

$$M(x, y, E) = M_{\text{spectral}}(E) \times M_{\text{spatial}}(x, y)$$

Comprising of a spectral (Energy) and a spatial (map) model distribution

Containing both source and background.

In the previous example, we have a Crab model (PWL point source)
+ offset Gaussian background

What is a data model?

The source model is specified in a XML file

In the previous example, we have a Crab model (PWL point source)
+ offset Gaussian background

```xml
<?xml version="1.0" standalone="no"?>
<source_library title="source library">
  <source name="Crab" type="PointSource">
    <spectrum type="PowerLaw">
       <parameter name="Prefactor" scale="1e-16" value="5.7"  min="1e-07" max="1000.0" free="1"/>
       <parameter name="Index"     scale="-1"    value="2.48" min="0.0"   max="+5.0"   free="1"/>
       <parameter name="Scale"     scale="1e6"   value="0.3"  min="0.01"  max="1000.0" free="0"/>
    </spectrum>
    <spatialModel type="SkyDirFunction">
      <parameter name="RA"  scale="1.0" value="83.6331" min="-360" max="360" free="1"/>
      <parameter name="DEC" scale="1.0" value="22.0145" min="-90"  max="90"  free="1"/>
    </spatialModel>
  </source>
  <source name="Background" type="RadialAcceptance" instrument="CTA">
    <spectrum type="FileFunction" file="$CTOOLS/share/models/bkg_dummy.txt">
      <parameter name="Normalization" scale="1.0" value="1.0" min="0.0" max="1000.0" free="1"/>
    </spectrum>
    <radialModel type="Gaussian">
       <parameter name="Sigma" scale="1.0" value="3.0" min="0.01" max="10.0" free="1"/>
    </radialModel>
  </source>
</source_library>
```

What is a data model?

The source model

```xml
<?xml version="1.0" standalone="no"?>
<source_library title="source library">
  <source name="Crab" type="PointSource">
    <spectrum type="PowerLaw">
       <parameter name="Prefactor" scale="1e-16" value="5.7"  min="1e-07" max="1000.0" free="1"/>
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       <parameter name="Scale"     scale="1e6"   value="0.3"  min="0.01"  max="1000.0" free="0"/>
    </spectrum>
    <spatialModel type="SkyDirFunction">
      <parameter name="RA"  scale="1.0" value="83.6331" min="-360" max="360" free="1"/>
      <parameter name="DEC" scale="1.0" value="22.0145" min="-90"  max="90"  free="1"/>
    </spatialModel>
  </source>
  <source name="Background" type="RadialAcceptance" instrument="CTA">
    <spectrum type="FileFunction" file="$CTOOLS/share/models/bkg_dummy.txt">
      <parameter name="Normalization" scale="1.0" value="1.0" min="0.0" max="1000.0" free="1"/>
    </spectrum>
    <radialModel type="Gaussian">
       <parameter name="Sigma" scale="1.0" value="3.0" min="0.01" max="10.0" free="1"/>
    </radialModel>
  </source>
</source_library>
```

[PWL] : Prefactor + Index + Scale

parameter value = value*scale

[min, max] range + free = 1/0

$$\frac{dN}{dE} = \boxed{N_0}\left(\frac{E}{\boxed{E_0}}\right)^{\boxed{\gamma}}$$

(ph/cm2/s/MeV)

What is a data model?

The background model

```xml
<?xml version="1.0" standalone="no"?>
<source_library title="source library">
  <source name="Crab" type="PointSource">
    <spectrum type="PowerLaw">
       <parameter name="Prefactor" scale="1e-16" value="5.7"  min="1e-07" max="1000.0" free="1"/>
       <parameter name="Index"     scale="-1"    value="2.48" min="0.0"   max="+5.0"   free="1"/>
       <parameter name="Scale"     scale="1e6"   value="0.3"  min="0.01"  max="1000.0" free="0"/>
    </spectrum>
    <spatialModel type="SkyDirFunction">
      <parameter name="RA"  scale="1.0" value="83.6331" min="-360" max="360" free="1"/>
      <parameter name="DEC" scale="1.0" value="22.0145" min="-90"  max="90"  free="1"/>
    </spatialModel>
  </source>
  <source name="Background" type="RadialAcceptance" instrument="CTA">
    <spectrum type="FileFunction" file="$CTOOLS/share/models/bkg_dummy.txt">
      <parameter name="Normalization" scale="1.0" value="1.0" min="0.0" max="1000.0" free="1"/>
    </spectrum>
    <radialModel type="Gaussian">
       <parameter name="Sigma" scale="1.0" value="3.0" min="0.01" max="10.0" free="1"/>
    </radialModel>
  </source>
</source_library>
```

Spectrum = on axis background counting rate, per energy bin

(ph/s/sr/TeV)

RadialModel = describe radial variation of the count rate

Gaussian (width ~ deg2)

The data model library (J. Knodelseder)

- Spatial
  - Point source
  - Radial symmetric models
    - Gaussian
    - Disk
    - Shell
  - Elliptical models
    - Gaussian
    - Disk
  - "Diffuse" models
    - Map
    - Map cubes (energy dependent maps)
    - Isotropic
  - Composite
- Temporal
  - Constant
  - Light curve
  - Phase curve
- Spectral
  - Power law
  - Broken power law
  - Exponentially cut off power law
  - Super exponentially cut off power law
  - Log parabola
  - Gaussian (line)
  - File function (arbitrary spectrum)
  - Node function (arbitrary fit)
  - Constant
  - Composite
  - Multiplicative (useful for EBL)

And more to come (e.g. Dark Matter Halo)

The data model library (J. Knodelseder)

$$\frac{dN}{dE} = k_0 \left(\frac{E}{E_0} \right)^{\gamma}$$

```
<spectrum type="PowerLaw">
 <parameter name="Prefactor" scale="1e-16" value="5.7"  min="1e-07" max="1000.0" free="1"/>
 <parameter name="Index"     scale="-1"    value="2.48" min="0.0"   max="+5.0"   free="1"/>
 <parameter name="Scale"     scale="1e6"   value="0.3"  min="0.01"  max="1000.0" free="0"/>
</spectrum>
```

- Spectral
  - Power law
  - Broken power law
  - Exponentially cut off power law
  - Super exponentially cut off power law
  - Log parabola
  - Gaussian (line)
  - File function (arbitrary
  - Node function (arbitrary fit)
  - Constant
  - Composite
  - Multiplicative (useful for EBL)

$$\frac{dN}{dE} = k_0 \left(\frac{E}{E_0} \right)^{\gamma} \exp\left(\frac{-E}{E_{cut}} \right)$$

```
<spectrum type="ExpCutoff">
 <parameter name="Prefactor" scale="1e-16" value="5.7"  min="1e-07" max="1000.0" free="1"/>
 <parameter name="Index"     scale="-1"    value="2.48" min="0.0"   max="+5.0"   free="1"/>
 <parameter name="Cutoff"    scale="1e6"   value="1.0"  min="0.01"  max="1000.0" free="1"/>
 <parameter name="Scale"     scale="1e6"   value="0.3"  min="0.01"  max="1000.0" free="0"/>
</spectrum>
```

$$\frac{dN}{dE} = k_0 \times \begin{cases} \left(\frac{E}{E_b} \right)^{\gamma_1} & \text{if } E < E_b \\ \left(\frac{E}{E_b} \right)^{\gamma_2} & \text{otherwise} \end{cases}$$

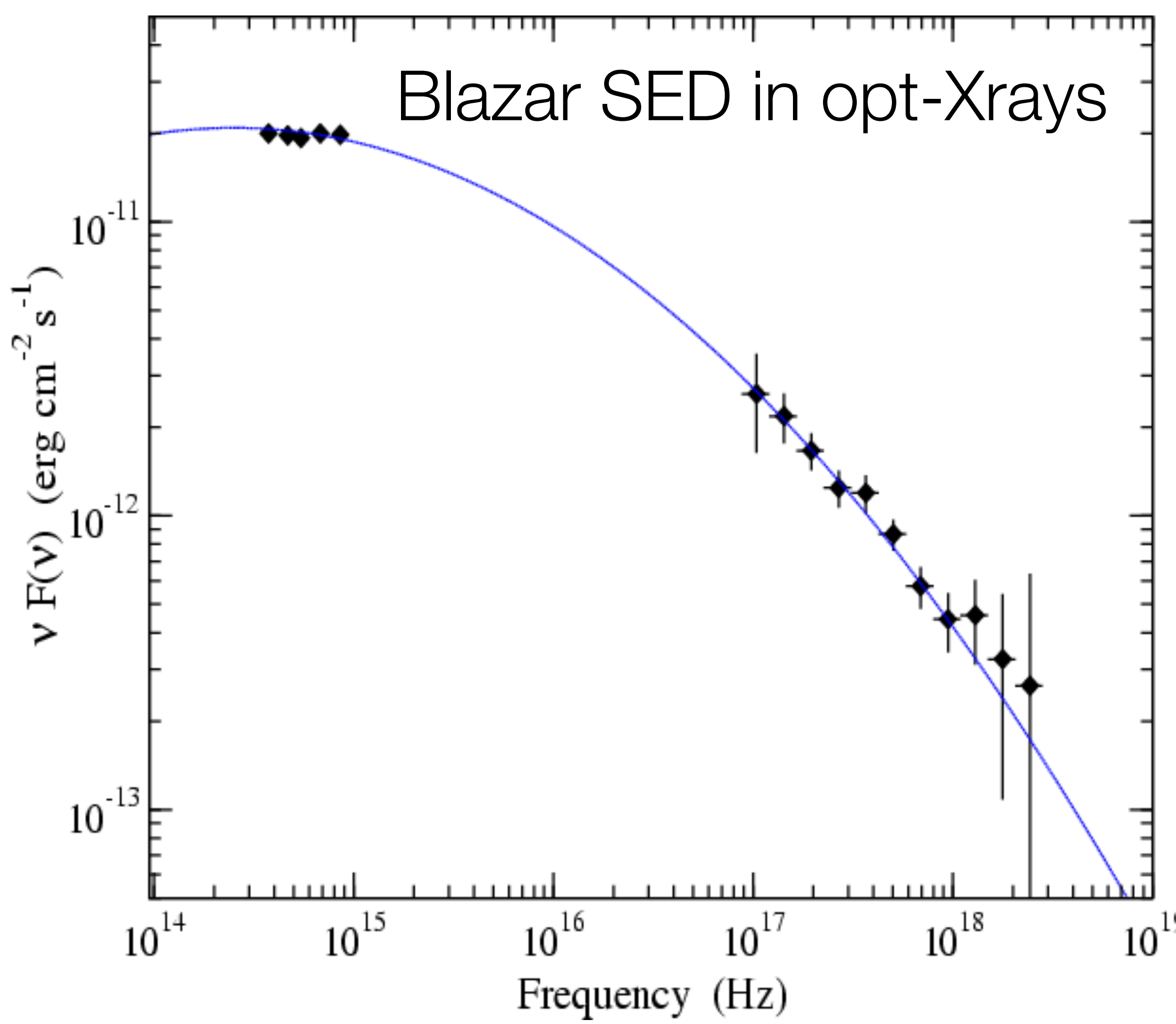
```
<spectrum type="BrokenPowerLaw">
 <parameter name="Prefactor"  scale="1e-16" value="5.7"  min="1e-07" max="1000.0" free="1"/>
 <parameter name="Index1"     scale="-1"    value="2.48" min="0.0"   max="+5.0"   free="1"/>
 <parameter name="BreakValue" scale="1e6"   value="0.3"  min="0.01"  max="1000.0" free="1"/>
 <parameter name="Index2"     scale="-1"    value="2.70" min="0.01"  max="1000.0" free="1"/>
</spectrum>
```

The data model library (J. Knodelseder)

$$\frac{dN}{dE} = k_0 \left(\frac{E}{E_0} \right)^{\gamma + \eta \ln(E/E_0)}$$

- Spectral
  - Power law
  - Broken power law
  - Exponentially cut off
  - Super exponentially cut off power law
  - $\boxed{\text{Log parabola}}$
  - Gaussian (line)
  - File function (arbitrary spectrum)
  - Node function (arbitrary fit)
  - Constant
  - Composite
  - Multiplicative (useful for EBL)

```
<spectrum type="LogParabola">
 <parameter name="Prefactor" scale="1e-17" value="5.878"   min="1e-07" max="1000.0" free="1"/>
 <parameter name="Index"     scale="-1"    value="2.32473" min="0.0"   max="+5.0"   free="1"/>
 <parameter name="Curvature" scale="-1"    value="0.074"   min="-5.0"  max="+5.0"   free="1"/>
 <parameter name="Scale"     scale="1e6"   value="1.0"     min="0.01"  max="1000.0" free="0"/>
</spectrum>
```



The data model library (J. Knodelseder)

- Spectral
  - Power law
  - Broken power law
  - Exponentially cut off power law
  - Super exponentially cut off power law
  - Log parabola
  - Gaussian (line)
  - File function (arbitrary spectrum)
  - Node function (arbitrary fit)
  - Constant
  - Composite
  - Multiplicative (useful for EBL)

On you can provide your own function file with (Energy, diff. Flux)

```
<spectrum type="FileFunction" file="data/filefunction.txt">
 <parameter scale="1.0" name="Normalization" min="0.0" max="1000.0" value="1.0" free="1"/>
</spectrum>
```

The simulated events.fits file

To read the events.fits file

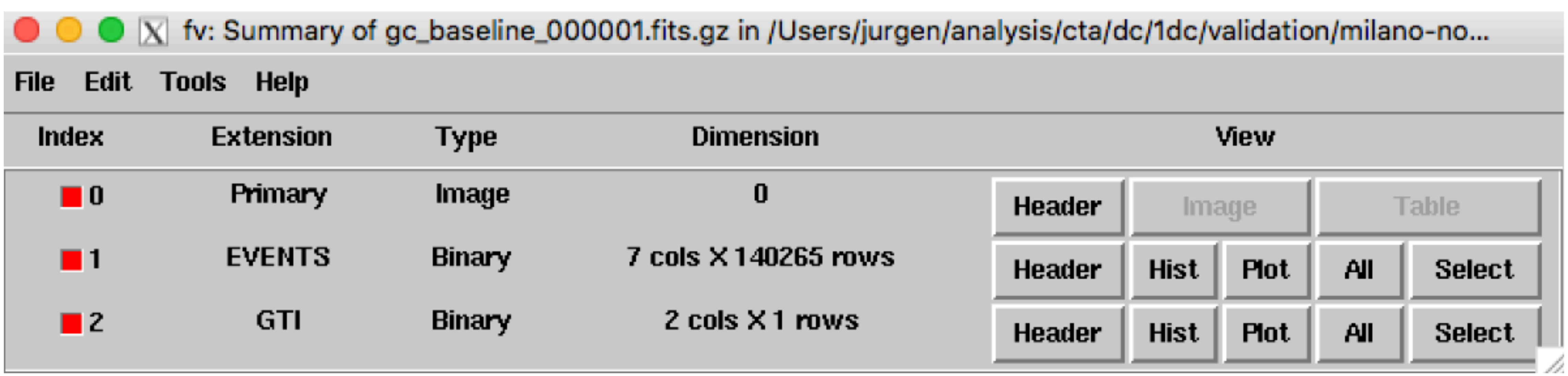
simply use fv (as you probably did with the fermi data!) or ds9

<u>structure info for the fits</u>:

metadata;

tabulated events;

binary table for GTI.



The simulated events.fits file

The metadata (or header)

Data space

Date and time interval covered

Reference (zero) time

Exposure and livetime

Pointing

```
EXTNAME = 'EVENTS  '           / name of this extension
DSTYP1  = 'TIME    '           / Data sub-space type
DSUNI1  = 's       '           / Data sub-space unit
DSVAL1  = 'TABLE   '           / Data sub-space value
DSREF1  = ':GTI    '           / Data sub-space reference
DSTYP2  = 'ENERGY  '           / Data sub-space type
DSUNI2  = 'TeV     '           / Data sub-space unit
DSVAL2  = '0.03:120'           / Data sub-space value
DSTYP3  = 'POS(RA,DEC)'        / Data sub-space type
DSUNI3  = 'deg     '           / Data sub-space unit
DSVAL3  = 'CIRCLE(266.5963,-29.6233,5)' / Data sub-space value
NDSKEYS =                    3 / Number of data sub-space keys
CREATOR = 'GammaLib'           / Program which created the file
TELESCOP= 'CTA     '           / Telescope
OBS_ID  =                    1 / Observation identifier
DATE_OBS= '2021-01-01'         / Observation start date
TIME_OBS= '11:58:51'           / Observation start time
DATE_END= '2021-01-01'         / Observation end date
TIME_END= '12:28:51'           / Observation end time
TSTART  =     6.6277440000E+08 / [s] Mission time of start of observation
TSTOP   =     6.6277619200E+08 / [s] Mission time of end of observation
MJDREFI =                51544 / [days] Integer part of time reference MJD
MJDREFF =     5.0000000000E-01 / [days] Fractional part of time reference MJD
TIMEUNIT= 's       '           / Time unit
TIMESYS = 'TT      '           / Time system
TIMEREF = 'LOCAL   '           / Time reference
TELAPSE =     1.8000000000E+03 / [s] Mission elapsed time
ONTIME  =     1.8000000000E+03 / [s] Total good time including deadtime
LIVETIME=     1.7100000000E+03 / [s] Total livetime
DEADC   =     9.4999998808E-01 / Deadtime correction factor
TIMEDEL =                    1 / Time resolution
OBJECT  = 'Galactic Centre'    / Observed object
RA_OBJ  =                    0 / [deg] Target Right Ascension
DEC_OBJ =                    0 / [deg] Target Declination
RA_PNT  =     2.6659631348E+02 / [deg] Pointing Right Ascension
DEC_PNT =    -2.9623300000E+01 / [deg] Pointing Declination
ALT_PNT =     9.0000000000E+01 / [deg] Average altitude of pointing
AZ_PNT  =                    0 / [deg] Average azimuth of pointing
RADECSYS= 'FK5     '           / Coordinate system
EQUINOX =     2.0000000000E+03 / Epoch
CONV_DEP=                    0 / Convergence depth of telescopes
CONV_RA =                    0 / [deg] Convergence Right Ascension
CONV_DEC=                    0 / [deg] Convergence Declination
OBSERVER= 'CTA Consortium'     / Observer
N_TELS  =                    0 / Number of telescopes in event list
TELLIST = 'Baseline'           / Telescope IDs
GEOLAT  =    -2.4627200000E+01 / [deg] Geographic latitude of array centre
GEOLON  =     7.9404100000E+01 / [deg] Geographic longitude of array centre
```

The simulated events.fits file

The events table

Select	EVENT_ID	TIME	RA	DEC	ENERGY
	1J	1D	1E	1E	1E
All		s	deg	deg	TeV
Invert	Modify	Modify	Modify	Modify	Modify
1	1	6.627744000498E+08	-9.405807E+01	-2.784737E+01	5.627337E-02
2	2	6.627744010483E+08	-9.377232E+01	-2.844662E+01	5.071355E-02
3	3	6.627744034266E+08	-9.404257E+01	-2.938539E+01	6.434643E-02
4	4	6.627744045438E+08	-9.234396E+01	-2.806212E+01	4.878427E-02
5	5	6.627744046819E+08	-9.276145E+01	-2.820405E+01	5.366057E-02
6	6	6.627744058111E+08	-9.286028E+01	-2.878448E+01	3.335994E-02
7	7	6.627744064515E+08	-9.355147E+01	-2.979681E+01	5.617695E-02
8	8	6.627744064740E+08	-9.215580E+01	-2.850752E+01	3.454410E-02
9	9	6.627744081920E+08	-9.349898E+01	-2.983537E+01	4.598151E-02
10	10	6.627744108324E+08	-9.107692E+01	-2.937655E+01	5.357579E-02
11	11	6.627744149214E+08	-9.377290E+01	-2.840102E+01	4.272686E-02
12	12	6.627744151106E+08	-9.379184E+01	-2.953114E+01	4.552307E-02
13	13	6.627744237226E+08	-9.402613E+01	-2.963716E+01	3.766189E-02
14	14	6.627744241330E+08	-9.219877E+01	-2.837049E+01	4.888327E-02
15	15	6.627744256190E+08	-9.309956E+01	-2.851233E+01	6.779863E-02
16	16	6.627744264838E+08	-9.299536E+01	-2.847442E+01	5.936273E-02
17	17	6.627744267142E+08	-9.422894E+01	-2.947939E+01	6.393800E-02
18	18	6.627744289319E+08	-9.235310E+01	-2.797758E+01	5.678236E-02
19	19	6.627744293394E+08	-9.342340E+01	-3.030122E+01	3.447032E-02
20	20	6.627744303979E+08	-9.281480E+01	-2.855922E+01	4.564788E-02

The simulated events.fits file

The events table

Select / All / Invert	EVENT_ID (1J)	TIME (1D, s)	RA (1E, deg)	DEC (1E, deg)	ENERGY (1E, TeV)
1	1	6.627744000498E+08	-9.405807E+01	-2.784737E+01	5.627337E-02
2	2	6.627744010483E+08	-9.377232E+01	-2.844662E+01	5.071355E-02
3	3	6.627744034266E+08	-9.404257E+01	-2.938539E+01	6.434643E-02
4	4	6.627744045438E+08	-9.234396E+01	-2.806212E+01	4.878427E-02
5	5	6.627744046819E+08	-9.276145E+01	-2.820405E+01	5.366057E-02
6	6	6.627744058111E+08	-9.286028E+01	-2.878448E+01	3.335994E-02
7	7	6.627744064515E+08	-9.355147E+01	-2.979681E+01	5.617695E-02
8	8	6.627744064740E+08	-9.215580E+01	-2.850752E+01	3.454410E-02
9	9	6.627744081920E+08	-9.349898E+01	-2.983537E+01	4.598151E-02

+ GTIs

fv: Binary Table of gc_baseline_000001.fits....

File Edit Tools Help

Select / All / Invert	START (1D)	STOP (1D)
1	6.627744000000E+08	6.627762000000E+08

Go to: Edit cell:

The simulated log file…

There is also a log file…

```
2014-10-30T22:35:06: +======================+
2014-10-30T22:35:06: | Simulate observation |
2014-10-30T22:35:06: +======================+
2014-10-30T22:35:06: === Observation ===
2014-10-30T22:35:06:  Simulation area ...........: 1.9635e+11 cm2
2014-10-30T22:35:06:  Simulation cone ...........: RA=83.63 deg, Dec=22.01 deg, r=5.5 deg
2014-10-30T22:35:06:  Time interval .............: 0 - 1800 s
2014-10-30T22:35:06:  Photon energy range .......: 100 GeV - 100 TeV
2014-10-30T22:35:06:  Event energy range ........: 100 GeV - 100 TeV
2014-10-30T22:35:06:  MC source photons .........: 207547 [Crab]
2014-10-30T22:35:06:  MC source events ..........: 995 [Crab]
2014-10-30T22:35:06:  MC source events ..........: 995 (all source models)
2014-10-30T22:35:06:  MC background events ......: 5146
2014-10-30T22:35:06:  MC events .................: 6141 (all models)
2014-10-30T22:35:06:
2014-10-30T22:35:06: +==================+
2014-10-30T22:35:06: | Save observation |
2014-10-30T22:35:06: +==================+
2014-10-30T22:35:06:
2014-10-30T22:35:06: Application "ctobssim" terminated after 10 wall clock seconds, consuming 0.3604 seconds o
```

sim detector area

duration of sim

sim source events

current UTC time

The simulated log file…

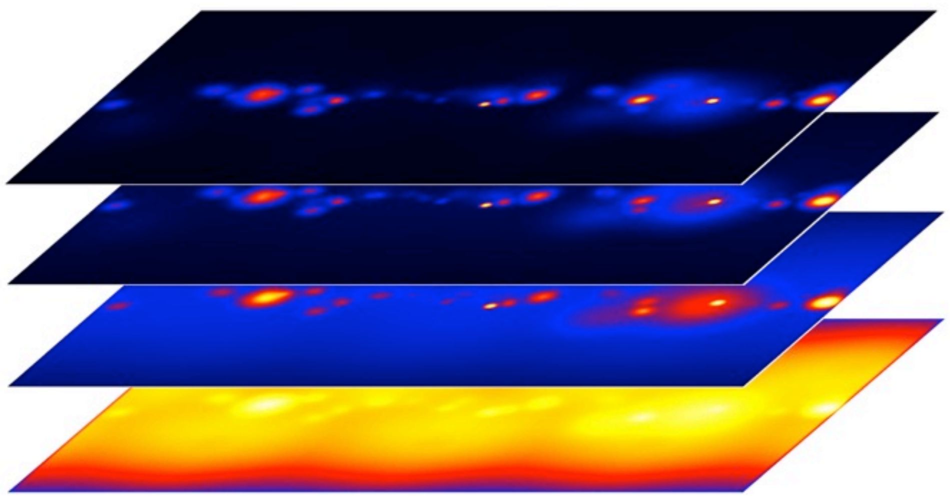
There is also a log file…

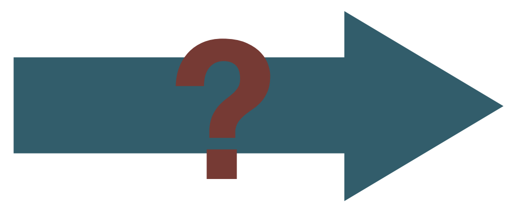
```
2014-10-30T22:35:06: +======================+
2014-10-30T22:35:06: | Simulate observation |
2014-10-30T22:35:06: +======================+
2014-10-30T22:35:06: === Observation ===
2014-10-30T22:35:06:  Simulation area ...........: 1.9635e+11 cm2
2014-10-30T22:35:06:  Simulation cone ...........: RA=83.63 deg, Dec=22.01 deg, r=5.5 deg
2014-10-30T22:35:06:  Time interval .............: 0 - 1800 s
2014-10-30T22:35:06:  Photon energy range .......: 100 GeV - 100 TeV
2014-10-30T22:35:06:  Event energy range ........: 100 GeV - 100 TeV
2014-10-30T22:35:06:  MC source photons .........: 207547 [Crab]
2014-10-30T22:35:06:  MC source events ..........: 995 [Crab]
2014-10-30T22:35:06:  MC source events ..........: 995 (all source models)
2014-10-30T22:35:06:  MC background events ......: 5146
2014-10-30T22:35:06:  MC events .................: 6141 (all models)
2014-10-30T22:35:06:
2014-10-30T22:35:06: +==================+
2014-10-30T22:35:06: | Save observation |
2014-10-30T22:35:06: +==================+
2014-10-30T22:35:06:
2014-10-30T22:35:06: Application "ctobssim" terminated after 10 wall clock seconds, consuming 0.3604 seconds o
```

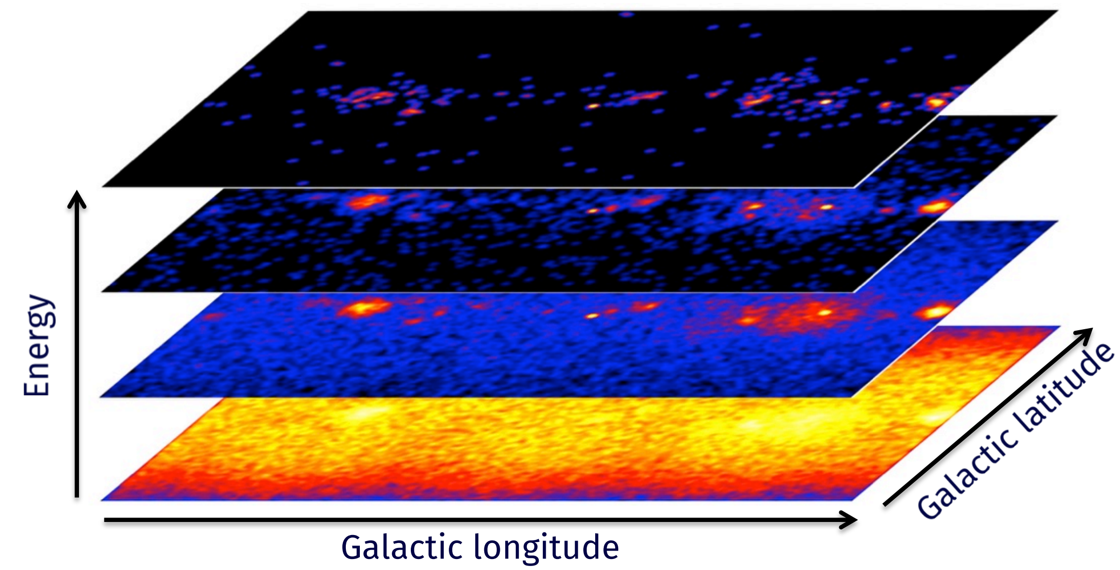
events detected

bkg events

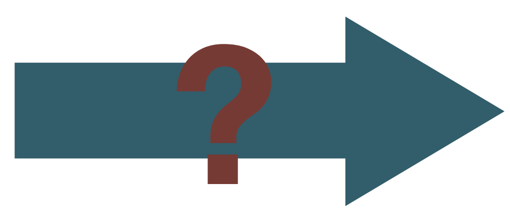
Instrument Response Functions

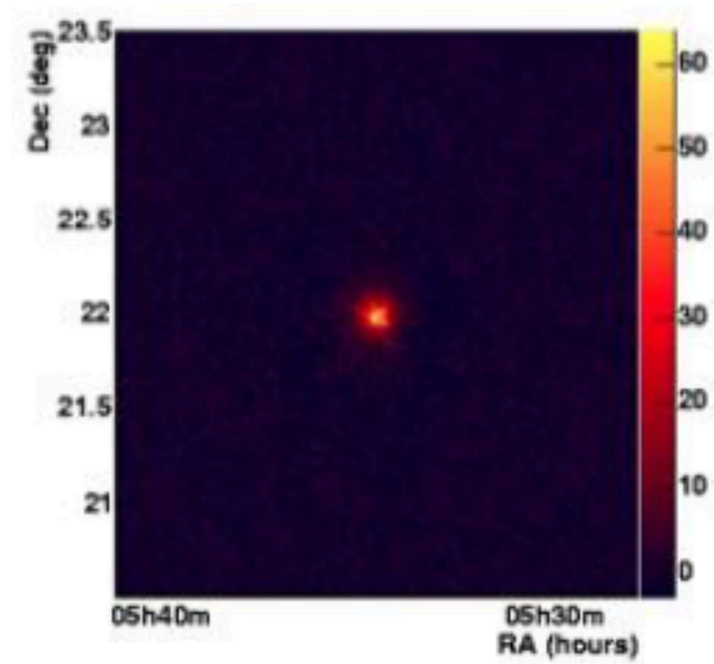




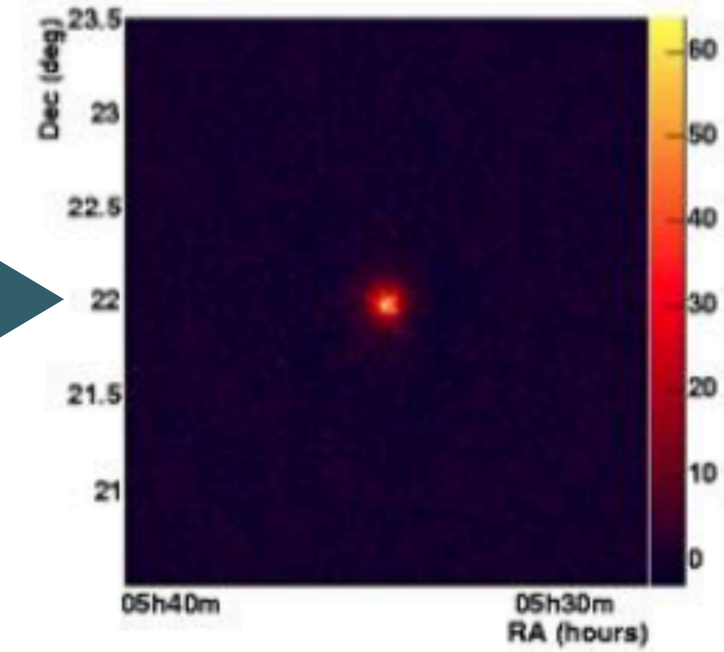


or better….





Instrument Response Functions



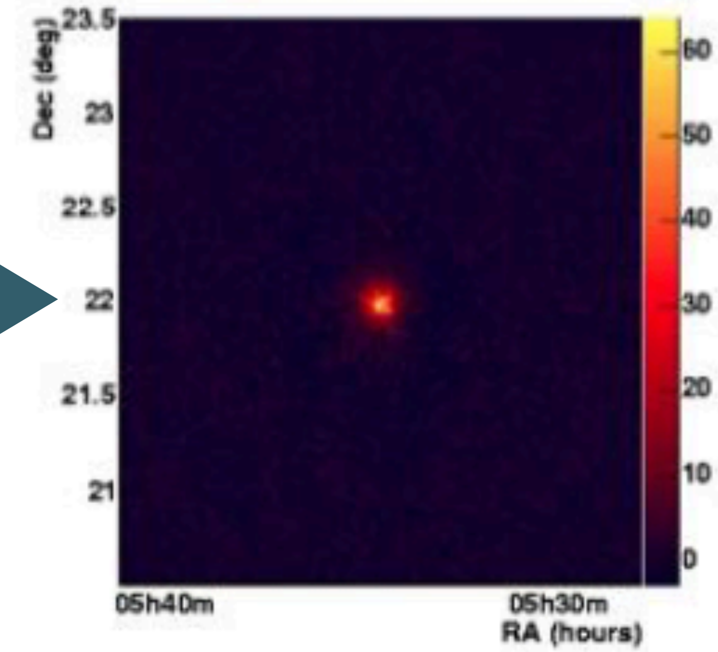
$$I(\vec{p}) \quad \times \quad \int d\vec{p}\; R(\vec{d}|\vec{p},\vec{a}) \quad = \quad e(\vec{d})$$

I = gamma-ray intensity at Earth as function of <u>true</u> properties (E, t, ra, dec)

e = gamma-ray (expected) event rate as function of <u>reconstructed</u> properties (E’, t’, ra', dec’)

R = instrument response to parameters “p”, where “a” are specific telescope parameters

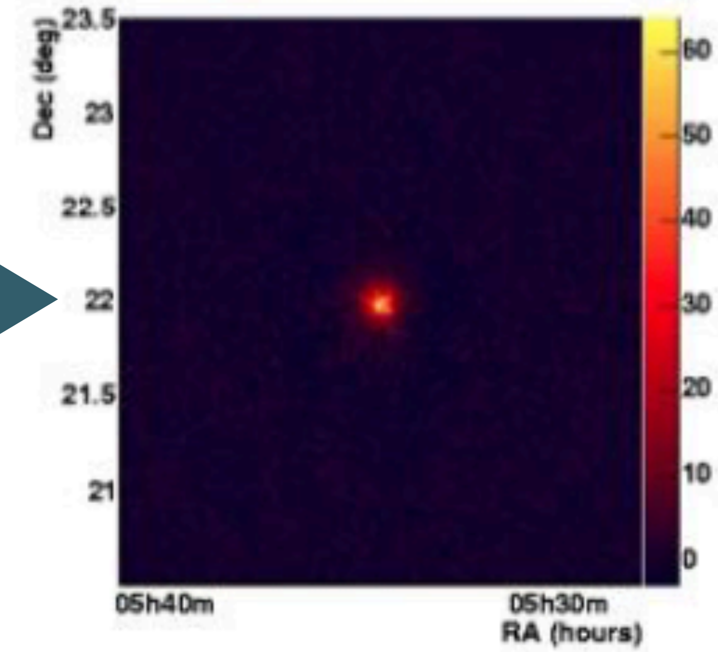
Instrument Response Functions



$$I(\vec{p}) \quad \times \quad \int d\vec{p}\; R(\vec{d}|\vec{p},\vec{a}) \quad = \quad e(\vec{d})$$

$$R(p', E', t'|d, p, E, t) = A_{\mathrm{eff}}(d, p, E, t) \times PSF(p'|d, p, E, t) \times E_{\mathrm{disp}}(E'|d, p, E, t)$$

Instrument Response Functions



$$I(\vec{p}) \quad \times \quad \int d\vec{p}\; R(\vec{d}|\vec{p},\vec{a}) \quad = \quad e(\vec{d})$$

Index	Extension	Type	Dimension	View				
0	Primary	Image	0	Header	Image		Table	
1	EFFECTIVE AREA	Binary	6 cols X 1 rows	Header	Hist	Plot	All	Select
2	POINT SPREAD FUNCTION	Binary	10 cols X 1 rows	Header	Hist	Plot	All	Select
3	ENERGY DISPERSION	Binary	7 cols X 1 rows	Header	Hist	Plot	All	Select
4	BACKGROUND	Binary	7 cols X 1 rows	Header	Hist	Plot	All	Select

N, S, 50 hrs, 5 hrs…

Instrument Response Functions

EFFECTIVE AREA

Select	ENERG_LO	ENERG_HI	THETA_LO	THETA_HI	EFFAREA
	21E	21E	6E	6E	126E
All	TeV	TeV	deg	deg	m2
Invert	Modify	Modify	Modify	Modify	Modify
1	Plot	Plot	Plot	Plot	Image

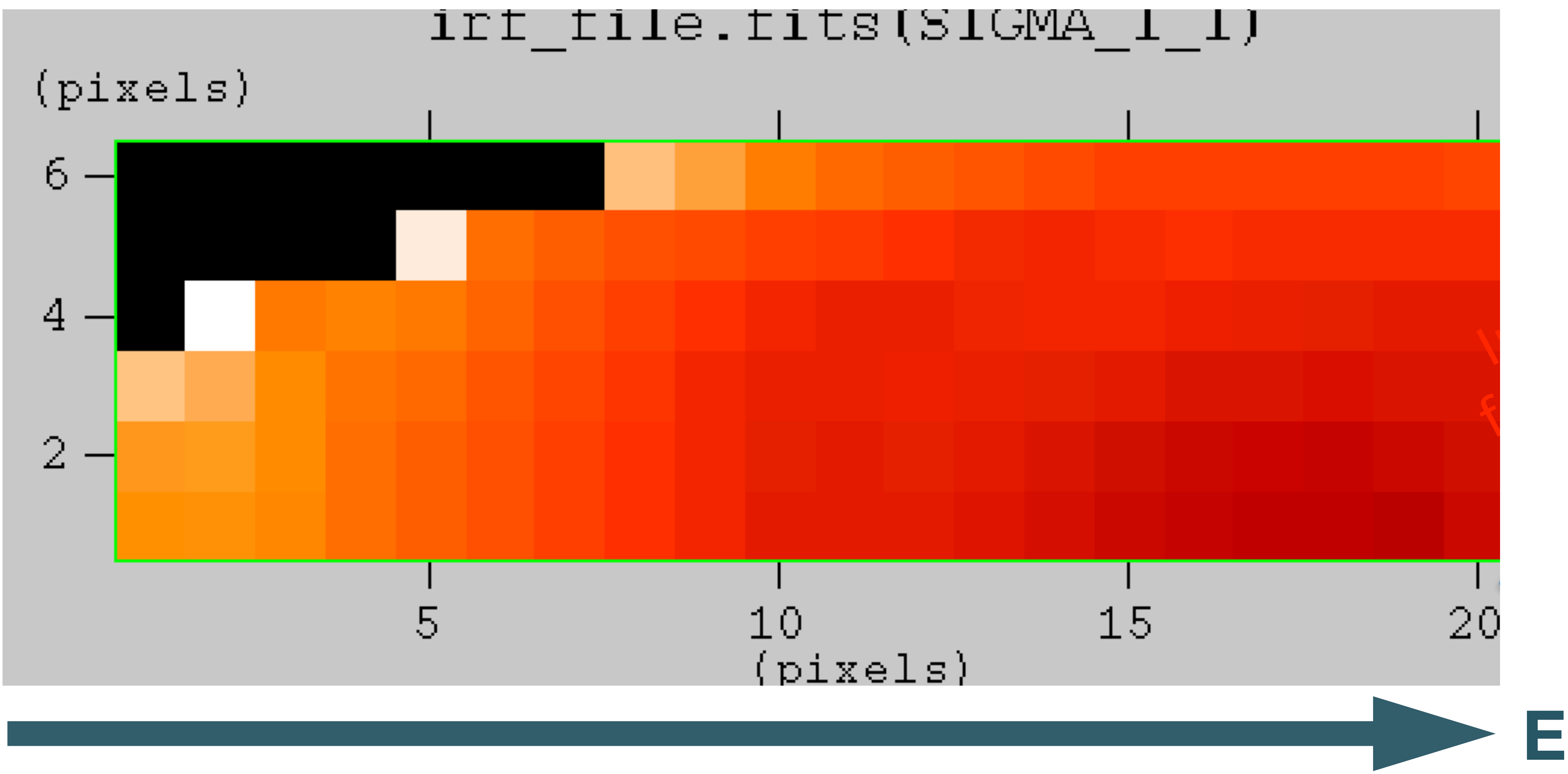
PSF

Select	ENERG_LO	ENERG_HI	THETA_LO	THETA_HI	SCALE	SIGMA_1	AMPL_2	SIGMA_2	AMPL_3	SIGMA_3
	21E	21E	6E	6E	126E	126E	126E	126E	126E	126E
All	TeV	TeV	deg	deg		deg		deg		deg
Invert	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify
1	Plot	Plot	Plot	Plot	Image	Image	Image	Image	Image	Image

Instrument Response Functions

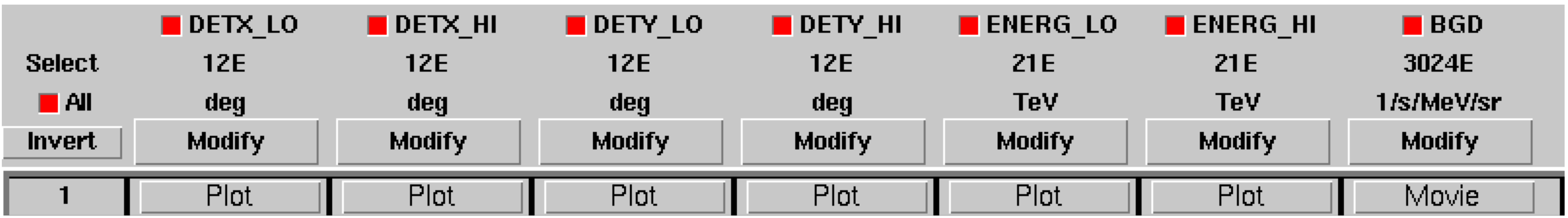
PSF

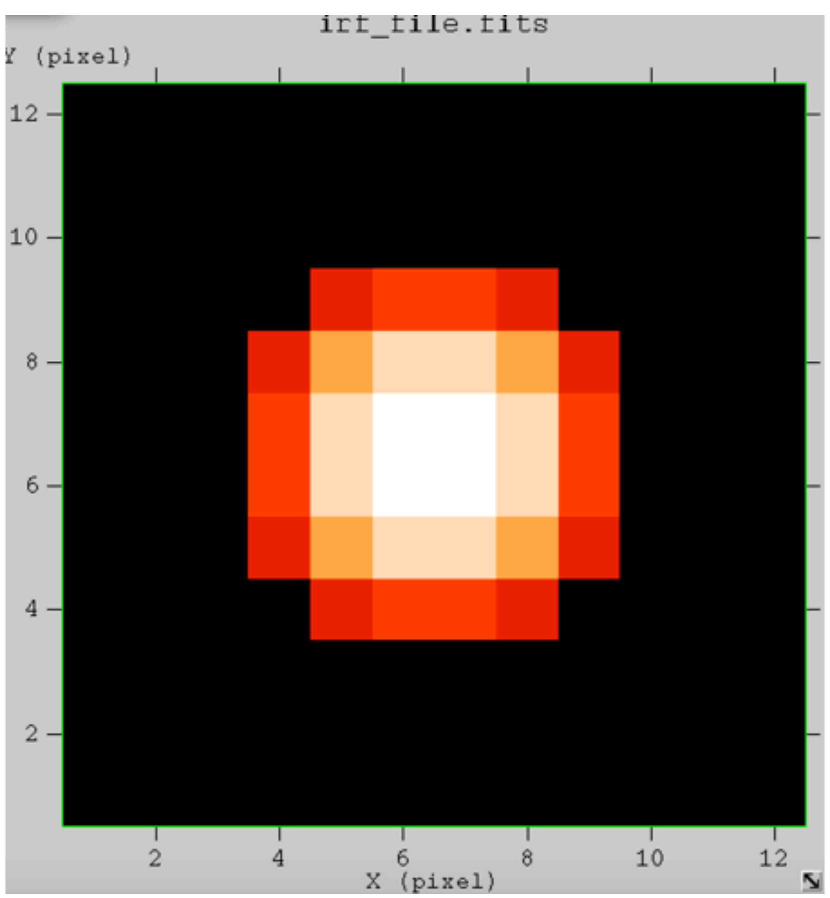
Select	ENERG_LO	ENERG_HI	THETA_LO	THETA_HI	SCALE	SIGMA_1	AMPL_2	SIGMA_2	AMPL_3	SIGMA_3
All	21E	21E	6E	6E	126E	126E	126E	126E	126E	126E
	TeV	TeV	deg	deg		deg		deg		deg
Invert	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify
1	Plot	Plot	Plot	Plot	Image	Image	Image	Image	Image	Image



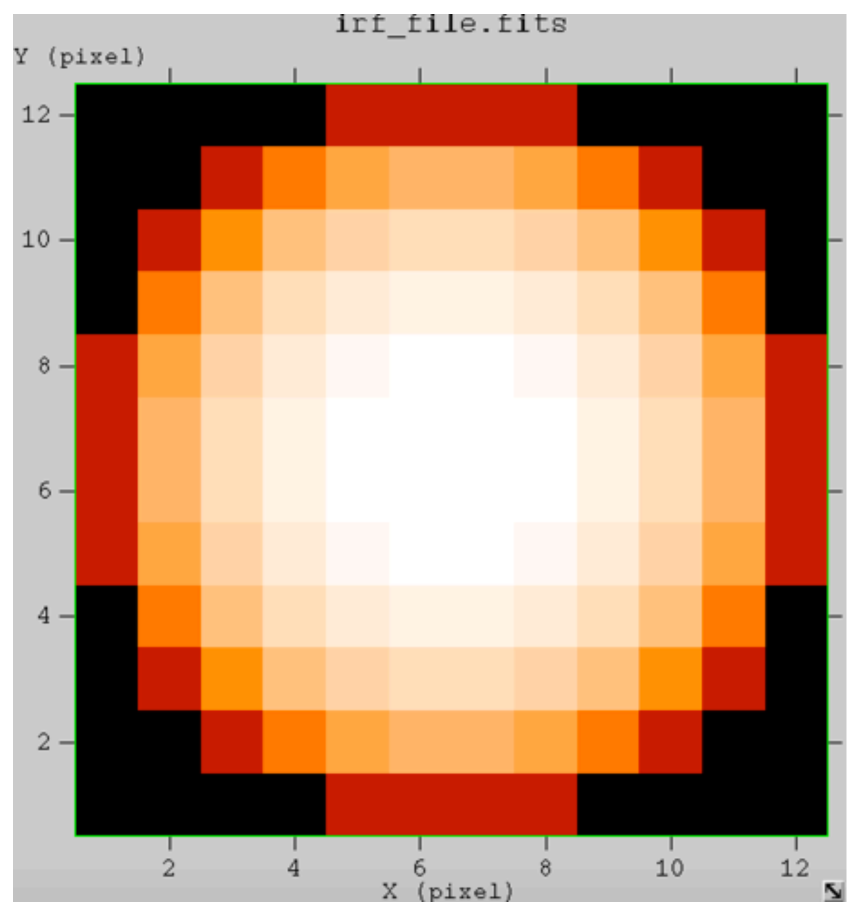
Instrument Response Functions

BACKGROUND TEMPLATE





[E1,E2]



[E3,E4]

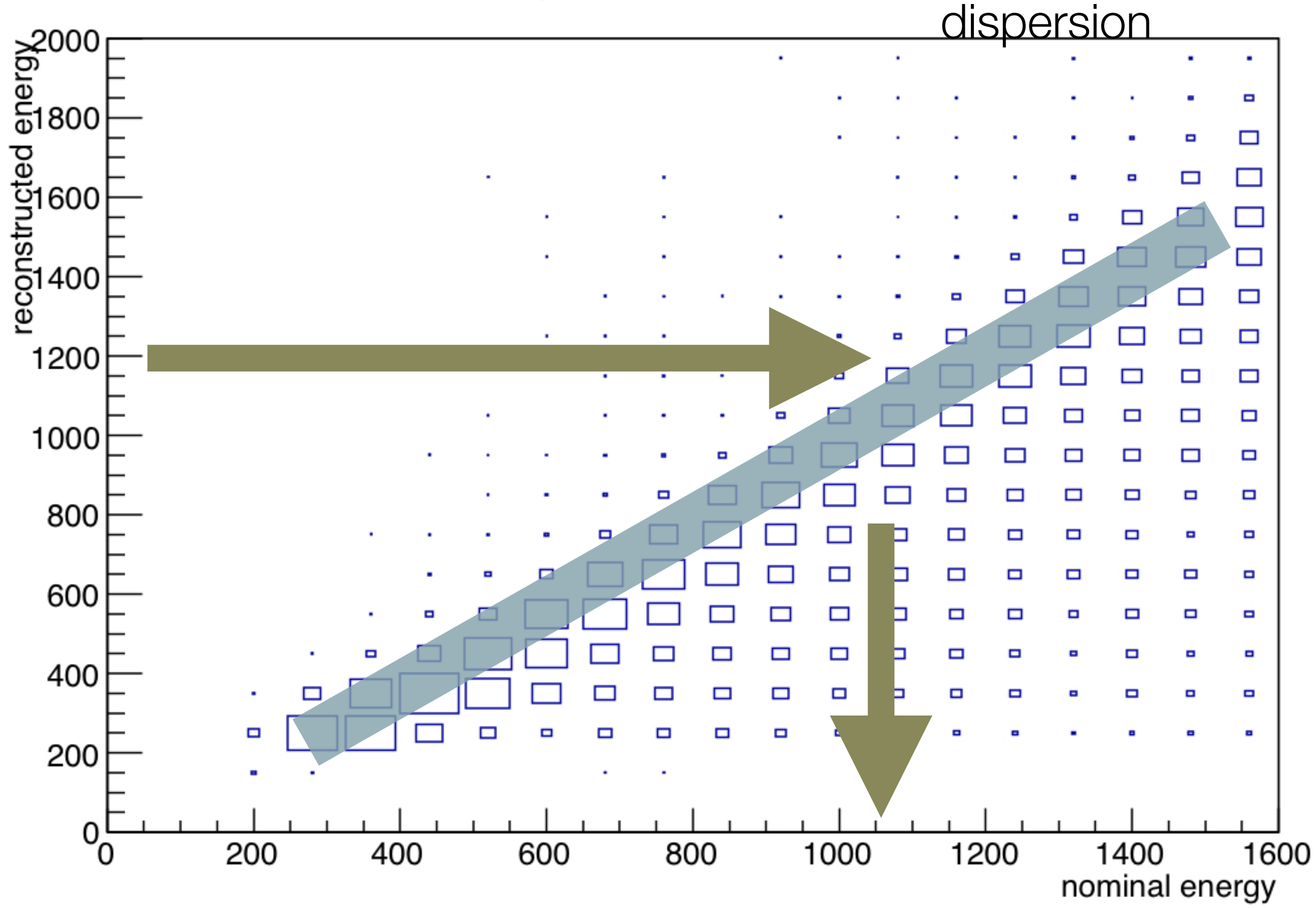
shown is counts versus position for two different energy ranges….

Instrument Response Functions

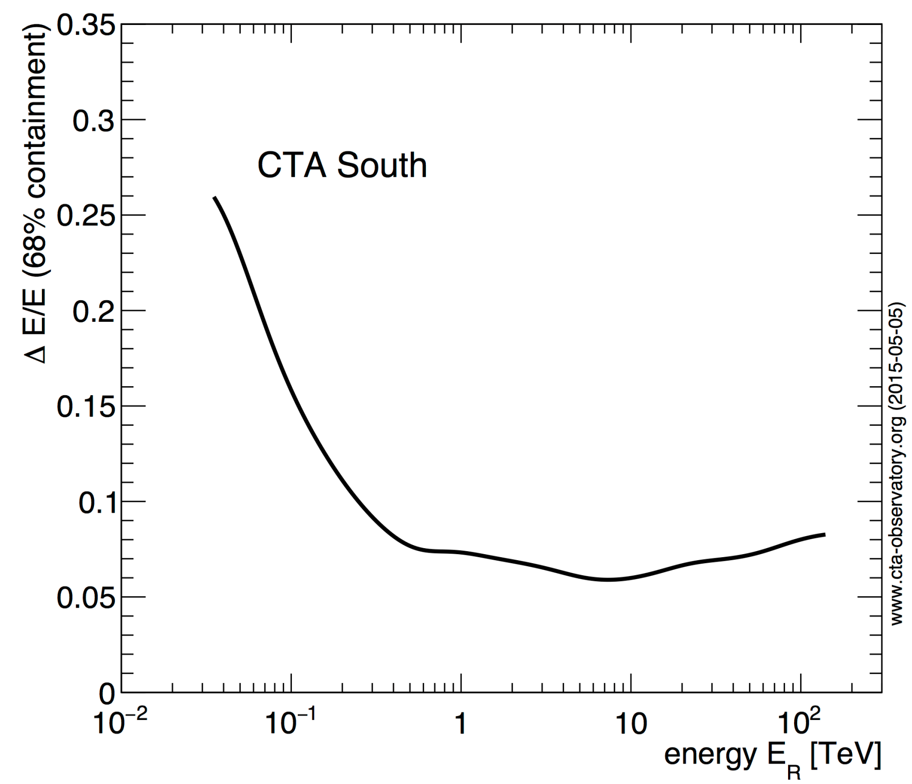
ENERGY RECONSTRUCTION

Select	ETRUE_LO	ETRUE_HI	MIGRA_LO	MIGRA_HI	THETA_LO	THETA_HI	MATRIX
	60E	60E	300E	300E	6E	6E	108000E
All	TeV	TeV			deg	deg	
Invert	Modify	Modify	Modify	Modify	Modify	Modify	Modify
1	Plot	Plot	Plot	Plot	Plot	Plot	Movie

Migration matrix ...with a lot of dispersion



From which you derive Erec/Et:



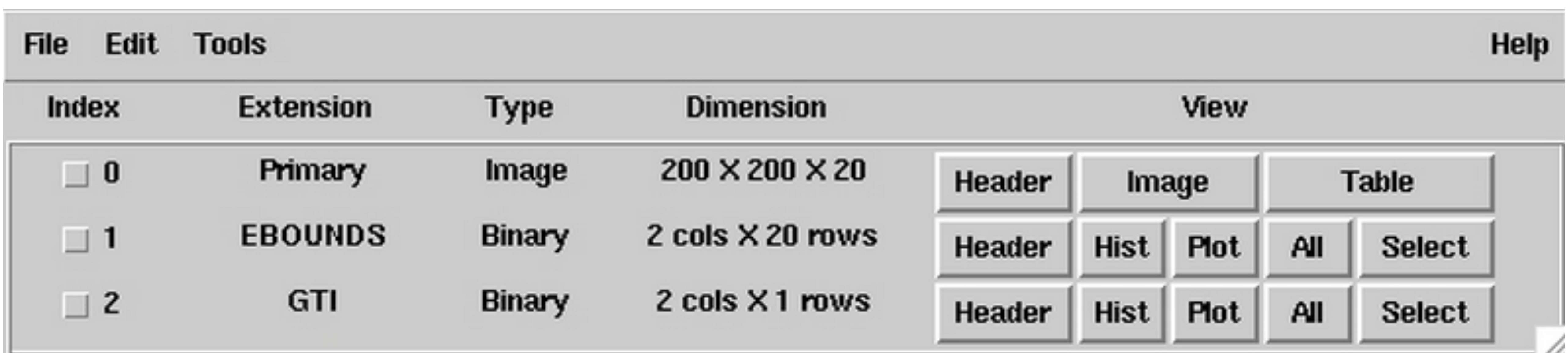
How to for a few tools…

ctbin : binning CTA data

A data cube with RA, DEC and E.

multiple maps for different energy ranges

```
$ ctbin
Input event list or observation definition file [events.fits]
First coordinate of image center in degrees (RA or galactic l) [83.63]
Second coordinate of image center in degrees (DEC or galactic b) [22.01]
Projection method e.g. AIT|AZP|CAR|MER|STG|TAN (AIT|AZP|CAR|MER|STG|TAN) [CAR]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL]
Image scale (in degrees/pixel) [0.02]
Size of the X axis in pixels [200]
Size of the Y axis in pixels [200]
Algorithm for defining energy bins (FILE|LIN|LOG) [LOG]
Start value for first energy bin in TeV [0.1]
Stop value for last energy bin in TeV [100.0]
Number of energy bins [20]
Output counts cube [cntmap.fits]
```



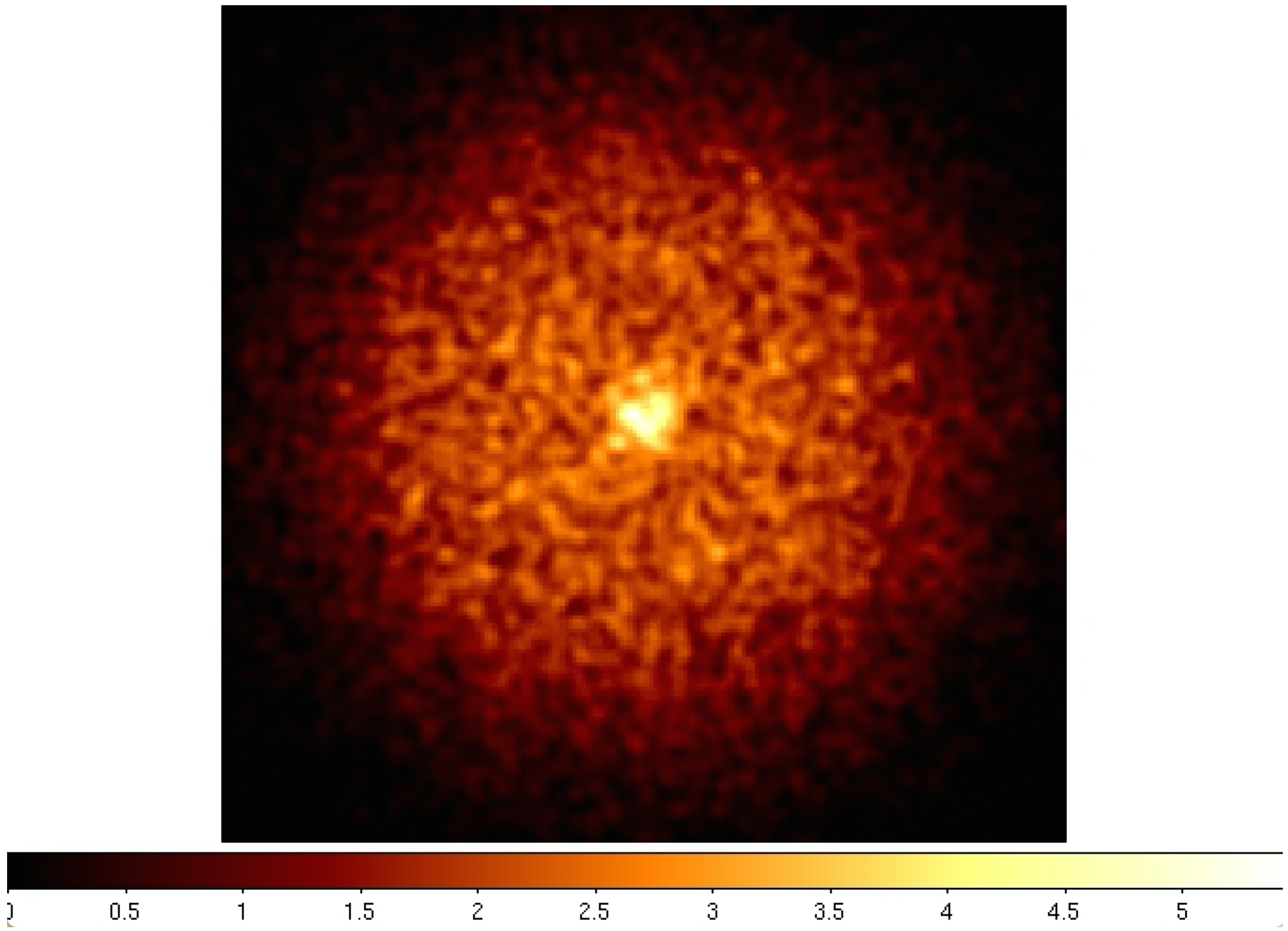
How to for a few tools…

ctbin : binning CTA data

A data cube with RA, DEC and E.

multiple maps for different energy ranges

```
$ ctbin
Input event list or observation definition file [events.fits]
First coordinate of image center in degrees (RA or galactic l) [83.63]
Second coordinate of image center in degrees (DEC or galactic b) [22.01]
Projection method e.g. AIT|AZP|CAR|MER|STG|TAN (AIT|AZP|CAR|MER|STG|TAN) [CAR]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL]
Image scale (in degrees/pixel) [0.02]
Size of the X axis in pixels [200]
Size of the Y axis in pixels [200]
Algorithm for defining energy bins (FILE|LIN|LOG) [LOG]
Start value for first energy bin in TeV [0.1]
Stop value for last energy bin in TeV [100.0]
Number of energy bins [20]
Output counts cube [cntmap.fits]
```



How to for a few tools…

ctlike : fitting CTA data

Log-likelihood model-fitting over **binned** data

```
$ ctlike
Event list, counts cube or observation definition file [events.fits] cntmap.fits
Calibration database [dummy]
Instrument response function [cta_dummy_irf]
Source model [$CTOOLS/share/models/crab.xml]
Source model output file [crab_results.xml]
```

How to for a few tools…

ctlike : fitting CTA data

Log-likelihood model-fitting over **binned** data

```
$ ctlike
Event list, counts cube or observation definition file [events.fits] cntmap.fits
Calibration database [dummy]
Instrument response function [cta_dummy_irf]
Source model [$CTOOLS/share/models/crab.xml]
Source model output file [crab_results.xml]
```

un-**binned** analysis can also be performed and is more powerful

ctselect : the first step to work directly on the events file

```
$ ctselect
Input event list or observation definition file [events.fits]
RA for ROI centre (degrees) (0-360) [83.63]
Dec for ROI centre (degrees) (-90-90) [22.01]
Radius of ROI (degrees) (0-180) [3.0]
Start time (CTA MET in seconds) (0) [0.0]
End time (CTA MET in seconds) (0) [0.0]
Lower energy limit (TeV) (0) [0.1]
Upper energy limit (TeV) (0) [100.0]
Output event list or observation definition file [selected_events.fits]
```

- first define the ROI (circular acceptance cone)
- plus time and energy span
- then run **ctlike…**

How to for a few tools…

ctlike : TS calculation

$$L(\theta; X) = \prod_{i=1}^{N} f_i(x_i; \theta)$$
$$= f_1(x_1; \theta) f_2(x_2; \theta) \ldots f_N(x_N; \theta)$$

$$\boxed{TS = 2 \text{ x } (\log L - \log L_{null})}$$

or…

$$\boxed{\text{sqrt(TS)} \sim \text{sigma(Gauss)}}$$

ctlike : use “tscalc = 1”

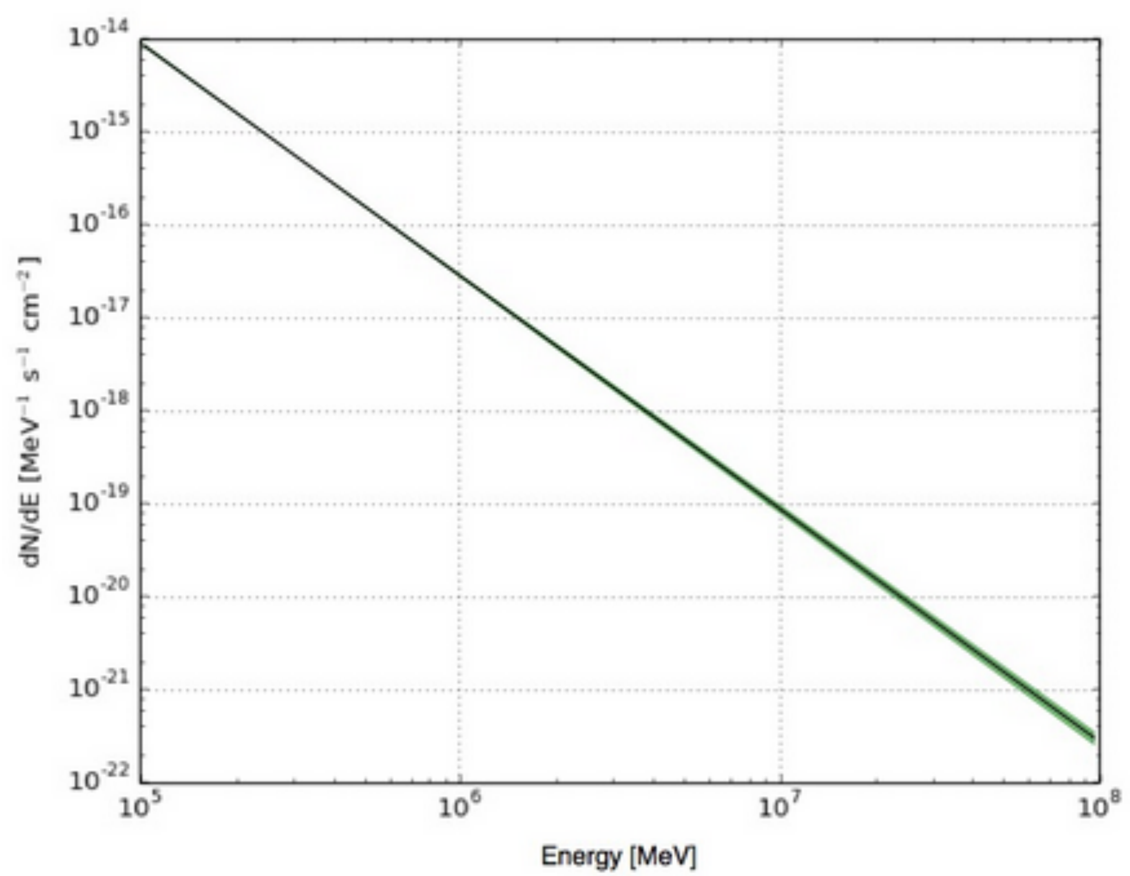
```
2015-05-22T19:58:43: === GModelSky ===
2015-05-22T19:58:43:  Name ......................: Crab
2015-05-22T19:58:43:  Instruments ...............: all
2015-05-22T19:58:43:  Test Statistic ............: 18662.6
```

How to for a few tools…

ctbutterfly : for spectra estimation - a complex procedure…

```
$ ctbutterfly
Input event list, cube or observation definition file [events.fits]
Calibration database [dummy]
Instrument response function [cta_dummy_irf]
Source model [$CTOOLS/share/models/crab.xml] crab_results.xml
Source of interest [Crab]
Start value for first energy bin in TeV [0.1]
Stop value for last energy bin in TeV [100.0]
Output ascii file [butterfly.txt]
```

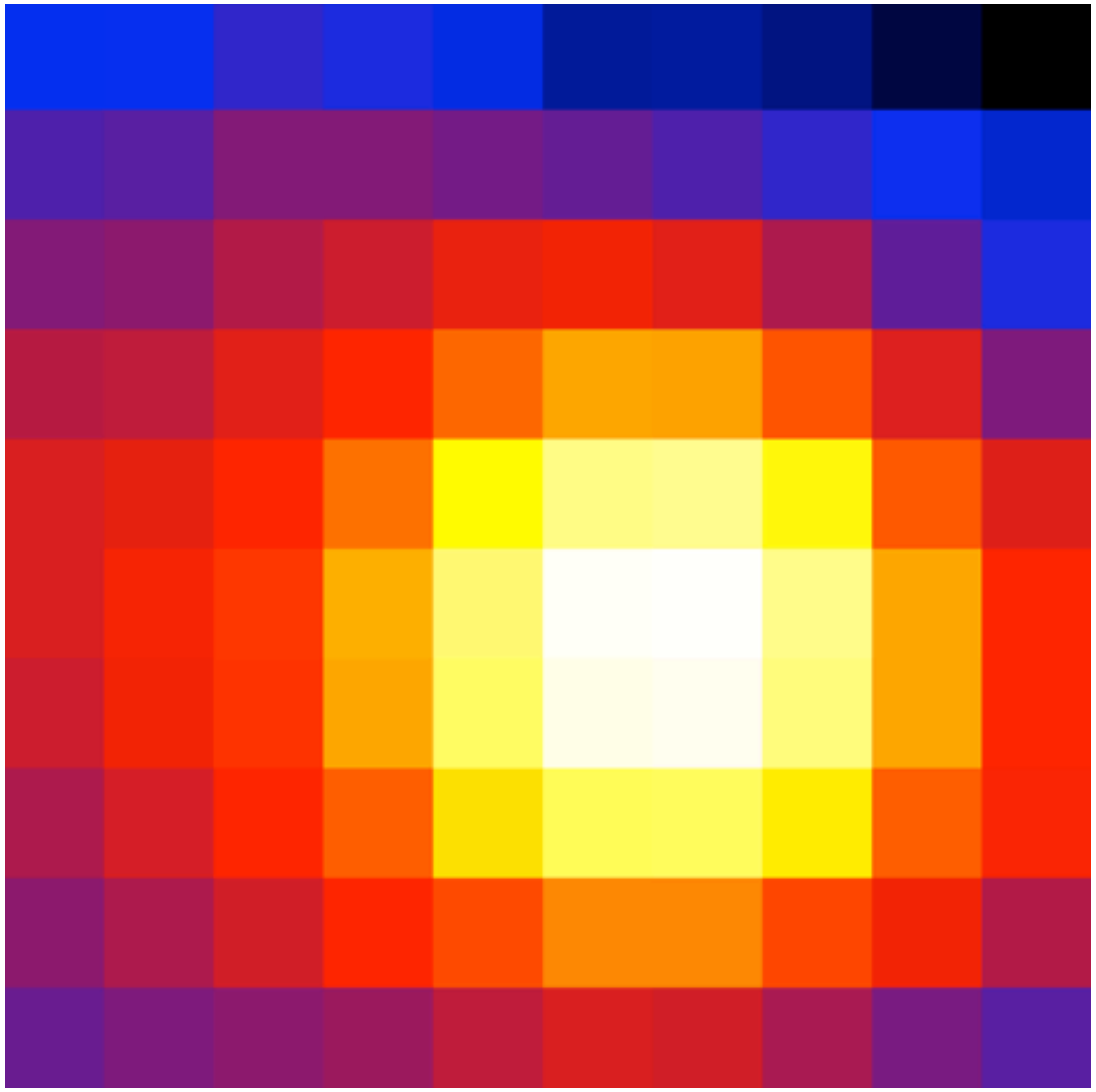
plot using e.g. python from your butterfly.txt



Combining observations : maps

cttsmap : to produce a test statistics map (TS map)

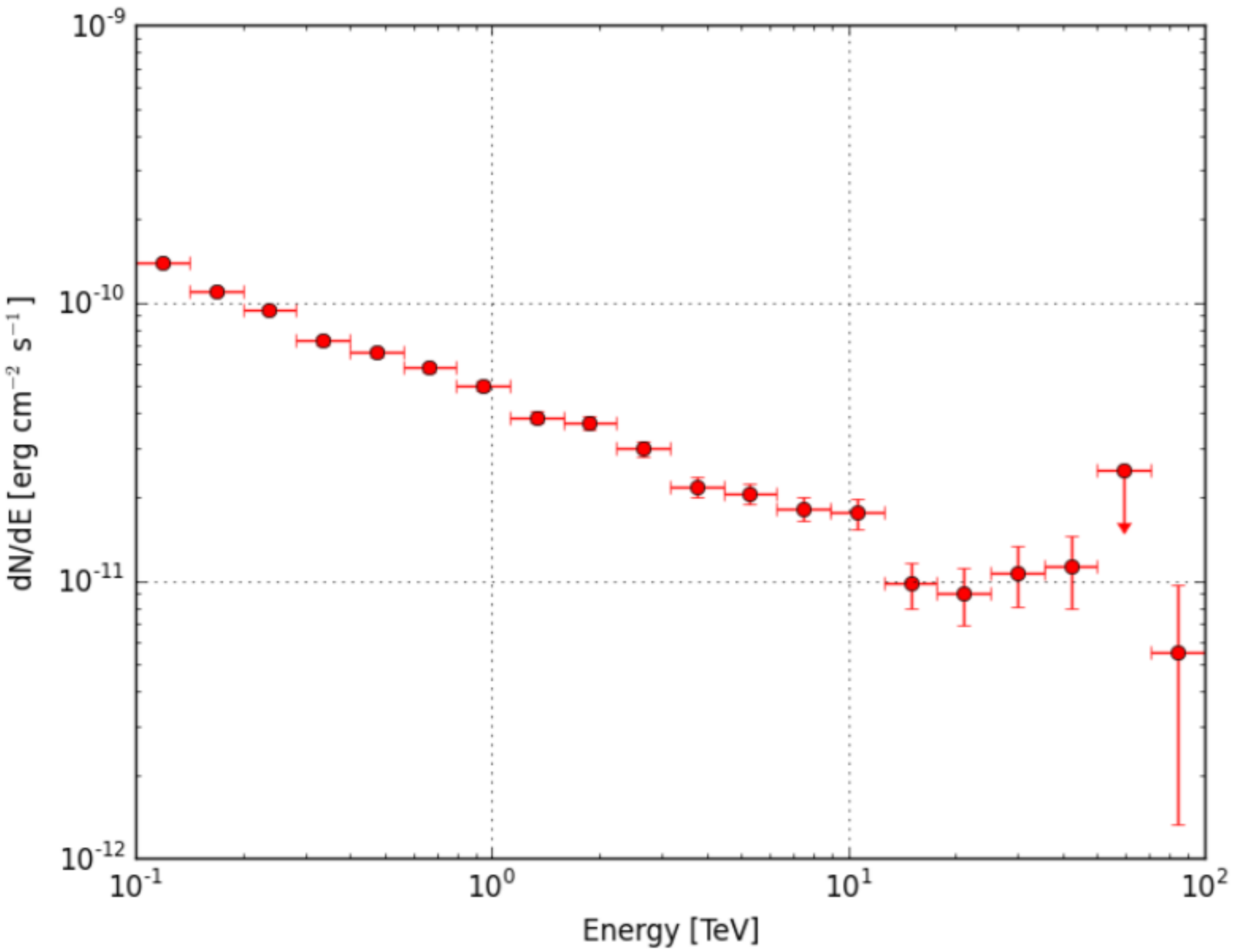
$$\boxed{TS = 2 \times (\log L - \log L_{null})}$$



Script tools : SEDs

csspec : produces a broad-band spectrum by running ctlike over several energy bins

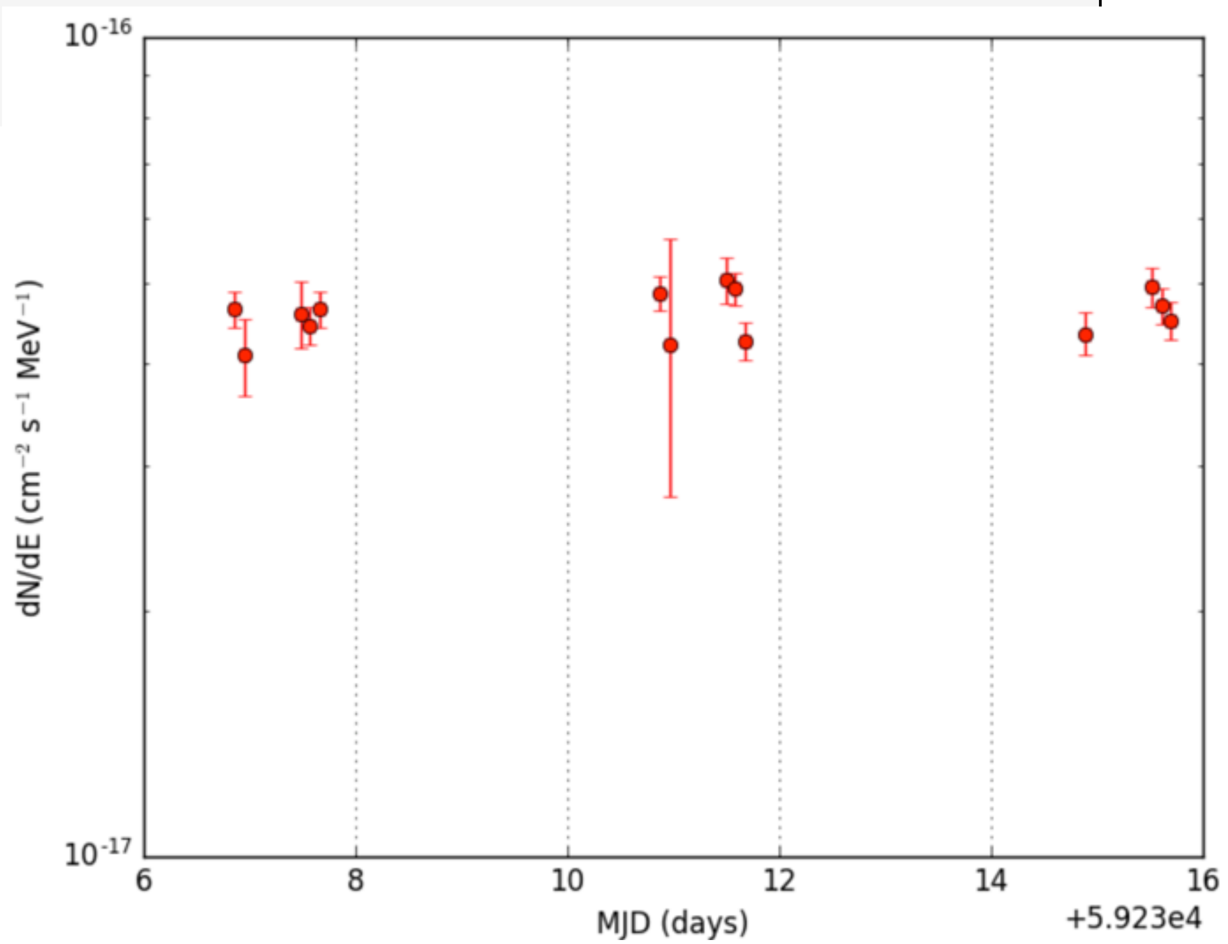
```
$ csspec
Parfile csspec.par not found. Create default parfile.
Event list, counts cube, or observation definition file [events.fits] obs.xml
Source model [$CTOOLS/share/models/crab.xml]
Source name [Crab]
Number of spectral points [20]
Use binned analysis in each energy bin (yes|no) [no]
Output file name [spectrum.fits]
```



Script tools : light-curves…

cslightcrv :

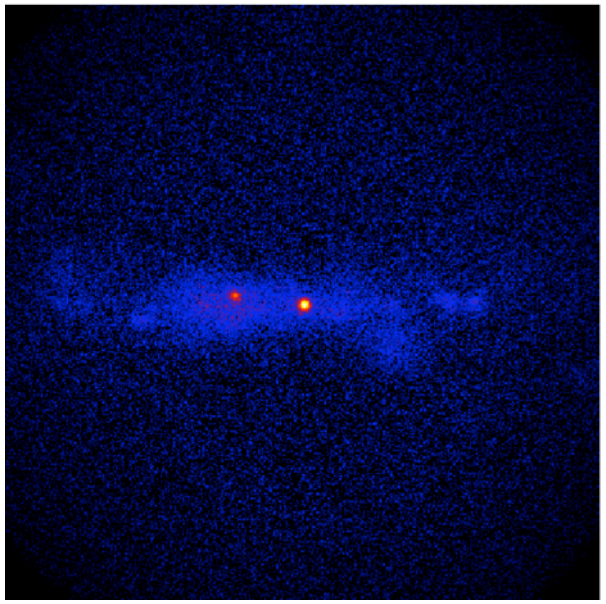
```
$ cslightcrv
Input event list or observation definition XML file [events.fits] obs_selected.xml
Input model definition XML file [$CTOOLS/share/models/crab.xml] models.xml
Source name [Crab] Src001
Algorithm for defining time bins (FILE|LIN|GTI) [GTI] LIN
Lightcurve start time (MJD) [51544.5] 59236.810
Lightcurve stop time (MJD) [51544.6] 59245.742
Number of time bins (1-10000) [5] 100
Number of energy bins for binned (0=unbinned)
```

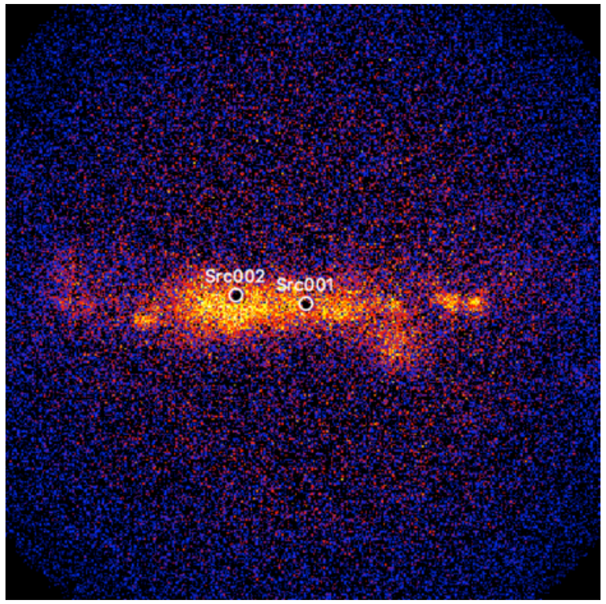


Script tools : SEDs

csresmap : to inspect the residuals of the fitted skymaps…

```
$ csresmap
Input event list, counts cube, or observation definition XML file [events.fits] obs_selected.xml
Input model definition XML file [$CTOOLS/share/models/crab.xml] results.xml
First coordinate of image center in degrees (RA or galactic l) (0-360) [83.63] 0.0
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Coordinate System (CEL|GAL) [CEL] GAL
Projection method (AIT|AZP|CAR|MER|MOL|STG|TAN) [CAR]
Size of the X axis in pixels [200] 400
Size of the Y axis in pixels [200] 400
Pixel size (deg/pixel) [0.02] 0.02
Residual map computation algorithm (SUB|SUBDIV|SUBDIVSQRT) [SUBDIV] SUB
Output residual map file [resmap.fits]
```

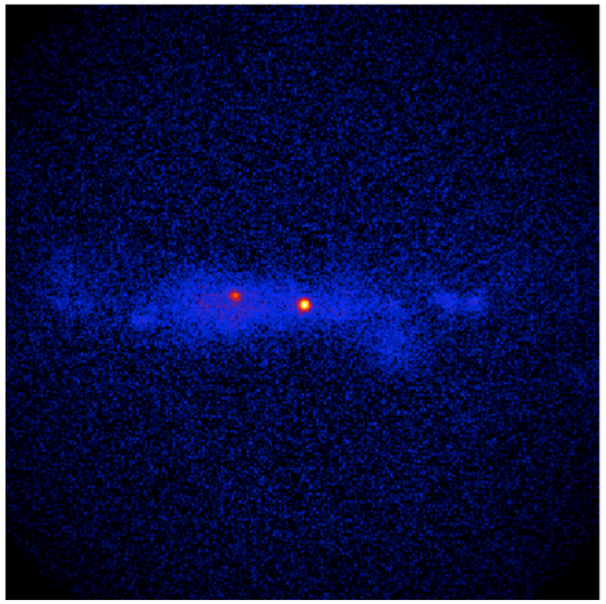




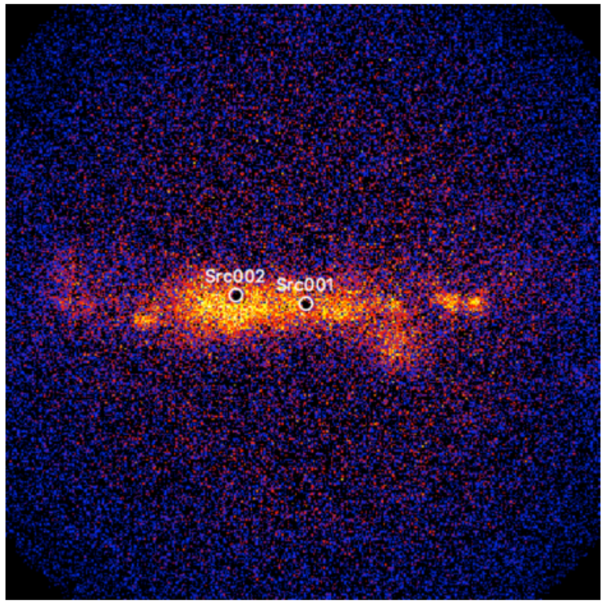
Script tools : SEDs

csresmap : to inspect the residuals of the fitted skymaps…

```
$ csresmap
Input event list, counts cube, or observation definition XML file [events.fits] obs_selected.xml
Input model definition XML file [$CTOOLS/share/models/crab.xml] results.xml
First coordinate of image center in degrees (RA or galactic l) (0-360) [83.63] 0.0
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Coordinate System (CEL|GAL) [CEL] GAL
Projection method (AIT|AZP|CAR|MER|MOL|STG|TAN) [CAR]
Size of the X axis in pixels [200] 400
Size of the Y axis in pixels [200] 400
Pixel size (deg/pixel) [0.02] 0.02
Residual map computation algorithm (SUB|SUBDIV|SUBDIVSQRT) [SUBDIV] SUB
Output residual map file [resmap.fits]
```



clearly a residual is remaining…



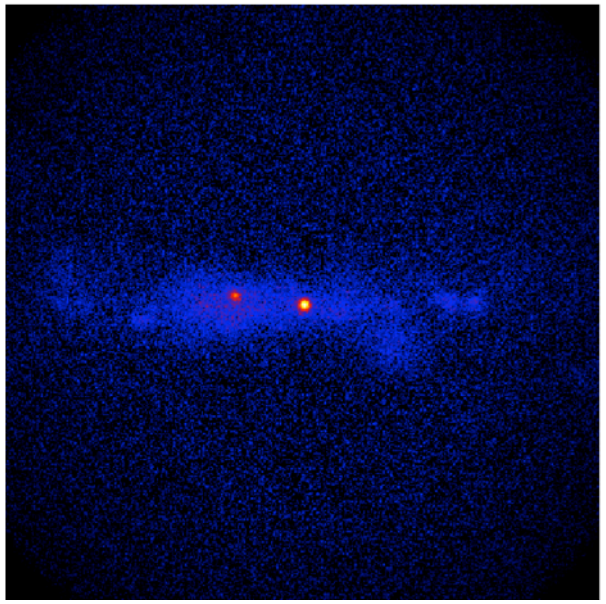
Diffuse emission model!

```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<source_library title="source library">
  <source name="Src001" type="PointSource">
    <spectrum type="PowerLaw">
      <parameter name="Prefactor" value="1" error="0" scale="5.7e-18" min="0" free="1" />
      <parameter name="Index" value="1" error="-0" scale="-2.48" min="-4.03225806451613" max="4.03225806451
      <parameter name="PivotEnergy" value="1" scale="300000" free="0" />
    </spectrum>
    <spatialModel type="PointSource">
      <parameter name="RA" value="266.424004498437" error="0" scale="1" free="1" />
      <parameter name="DEC" value="-29.0049010253548" error="0" scale="1" free="1" />
    </spatialModel>
  </source>
  <source name="Src002" type="PointSource">
    <spectrum type="PowerLaw">
      <parameter name="Prefactor" value="1" error="0" scale="5.7e-18" min="0" free="1" />
      <parameter name="Index" value="1" error="-0" scale="-2.48" min="-4.03225806451613" max="4.03225806451
      <parameter name="PivotEnergy" value="1" scale="300000" free="0" />
    </spectrum>
    <spatialModel type="PointSource">
      <parameter name="RA" value="266.831945177213" error="0" scale="1" free="1" />
      <parameter name="DEC" value="-28.1460284439951" error="0" scale="1" free="1" />
    </spatialModel>
  </source>
  <source name="IEM" type="DiffuseSource">
    <spectrum type="ConstantValue">
      <parameter name="Value" value="1" error="0" scale="1" min="1e-05" max="100000" free="1" />
    </spectrum>
    <spatialModel type="MapCubeFunction" file="$CTADATA/models/cube_iem.fits.gz">
      <parameter name="Normalization" value="1" scale="1" min="0.001" max="1000" free="0" />
    </spatialModel>
  </source>
  <source name="Background" type="CTAIrfBackground">
    <spectrum type="PowerLaw">
      <parameter name="Prefactor" value="1" error="0" scale="1" min="0" free="1" />
      <parameter name="Index" value="0" error="0" scale="1" min="-10" max="10" free="1" />
      <parameter name="PivotEnergy" value="1" scale="1000000" free="0" />
    </spectrum>
  </source>
</source_library>
```

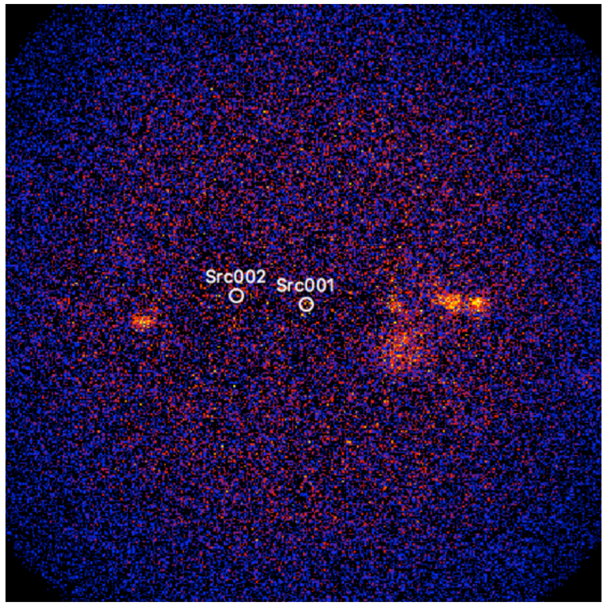
Script tools : SEDs

csresmap : to inspect the residuals of the fitted skymaps…

```
$ csresmap
Input event list, counts cube, or observation definition XML file [events.fits] obs_selected.xml
Input model definition XML file [$CTOOLS/share/models/crab.xml] results.xml
First coordinate of image center in degrees (RA or galactic l) (0-360) [83.63] 0.0
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Coordinate System (CEL|GAL) [CEL] GAL
Projection method (AIT|AZP|CAR|MER|MOL|STG|TAN) [CAR]
Size of the X axis in pixels [200] 400
Size of the Y axis in pixels [200] 400
Pixel size (deg/pixel) [0.02] 0.02
Residual map computation algorithm (SUB|SUBDIV|SUBDIVSQRT) [SUBDIV] SUB
Output residual map file [resmap.fits]
```



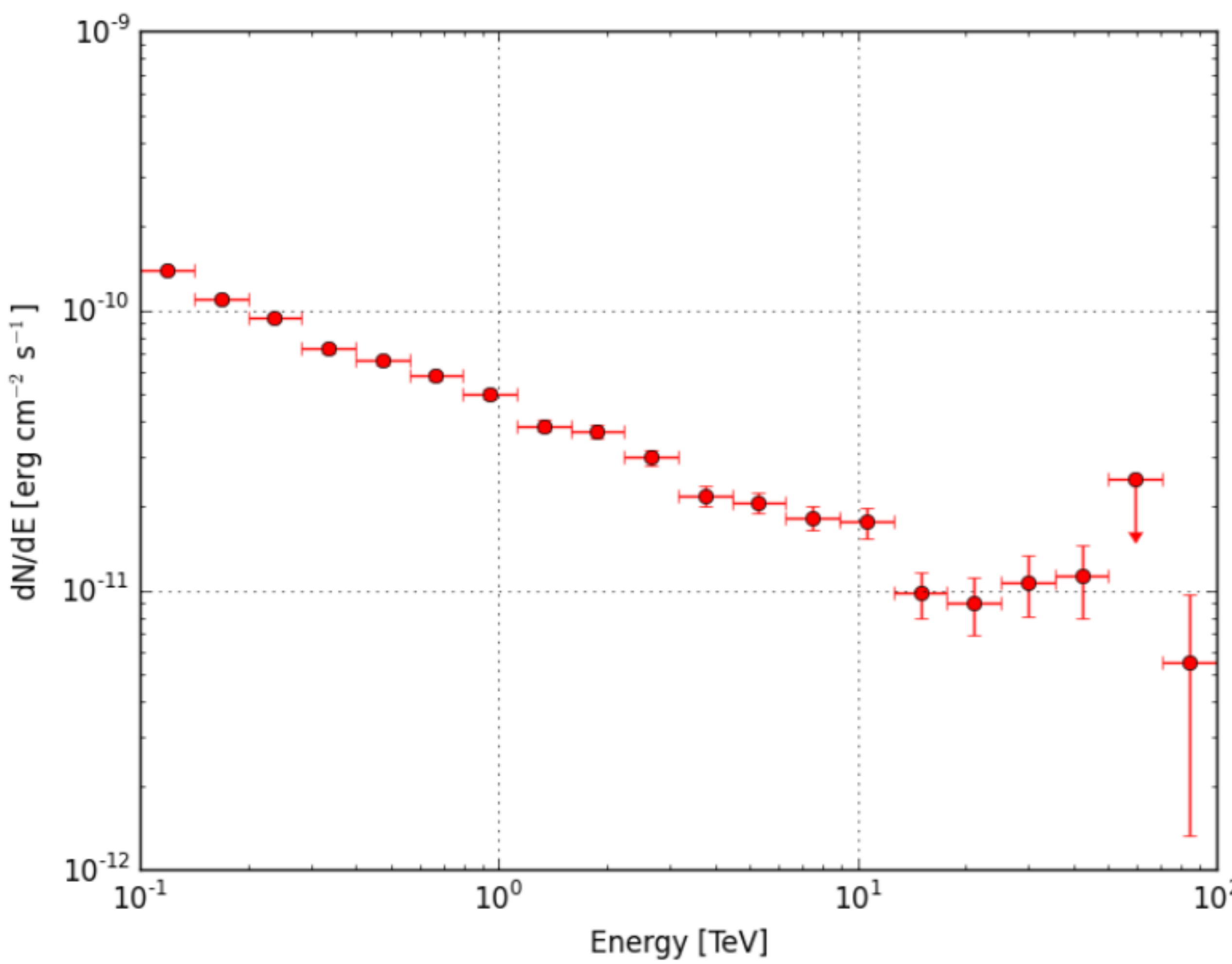
with diffuse model…



Script tools : SEDs

csspec : produces a broad-band spectrum by running ctlike over several energy bins

```
$ csspec
Parfile csspec.par not found. Create default parfile.
Event list, counts cube, or observation definition file [events.fits] obs.xml
Source model [$CTOOLS/share/models/crab.xml]
Source name [Crab]
Number of spectral points [20]
Use binned analysis in each energy bin (yes|no) [no]
Output file name [spectrum.fits]
```

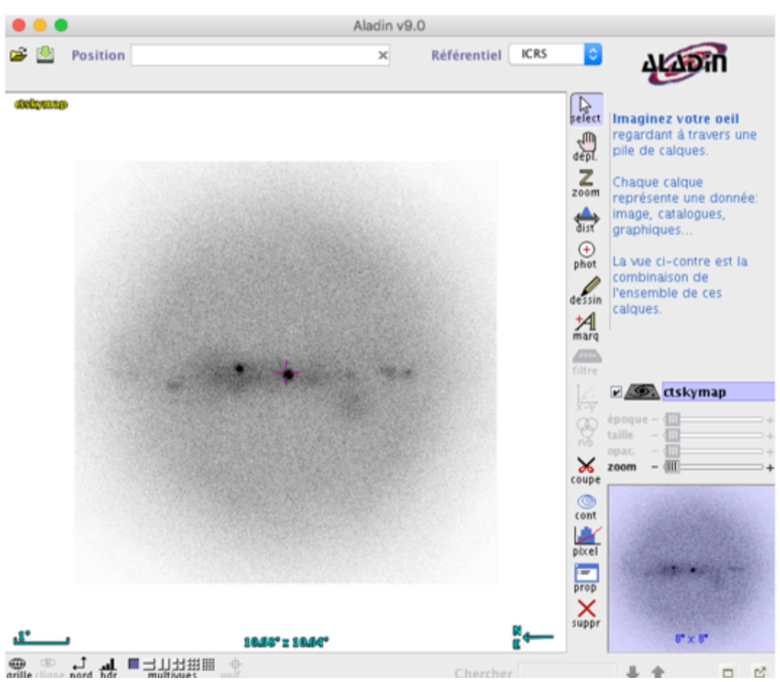


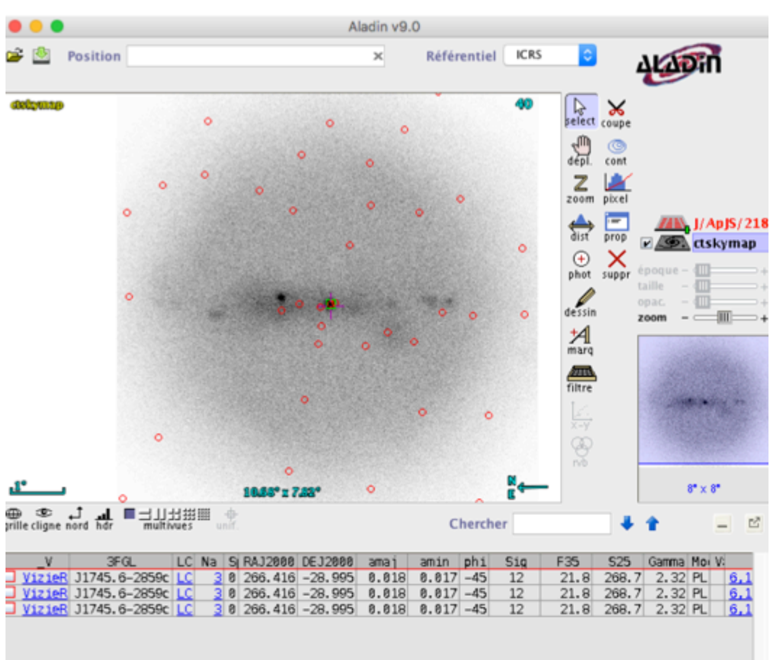
plus… :

- cscaldb — Lists available instrument response functions
- csobsdef — Generates observation definition file
- cslightcrv — Computes lightcurve
- cspull — Generates pull distribution
- cssens — Computes CTA sensitivity
- csspec — Computes spectral points
- csresmap — Generates residual map
- cstsdist — Generates TS distribution

VO tools : Important!

```
$ ctskymap publish=yes
Input event list or observation definition XML file [events.fits] obs_selected.xml
First coordinate of image center in degrees (RA or galactic l) (0-360) [83.63] 0.0
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0
Projection method (AIT|AZP|CAR|MER|MOL|STG|TAN) [CAR]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL] GAL
Image scale (in degrees/pixel) [0.02]
Size of the X axis in pixels [200] 400
Size of the Y axis in pixels [200] 400
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Background subtraction method (NONE|IRF) [NONE]
Output skymap file [skymap.fits]
```





play with other tools like CDS's Aladin, etc…

If you have a simulated sky already…

csobselect : selected from simulated observations all pointing with 0.1deg of GC, for example

```
$ csobsselect
Input event list or observation definition XML file [obs.xml] $CTADATA/obs/obs_gc_baseline.xml
Pointing selection region shape (CIRCLE|BOX) [CIRCLE]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL] GAL
Galactic longitude of selection centre (deg) (0-360) [184.56] 0.0
Galactic latitude of selection centre (deg) (-90-90) [-5.79] 0.0
Radius of selection circle (deg) (0-180) [5.0] 0.1
Output observation definition XML file [outobs.xml] obs.xml
```

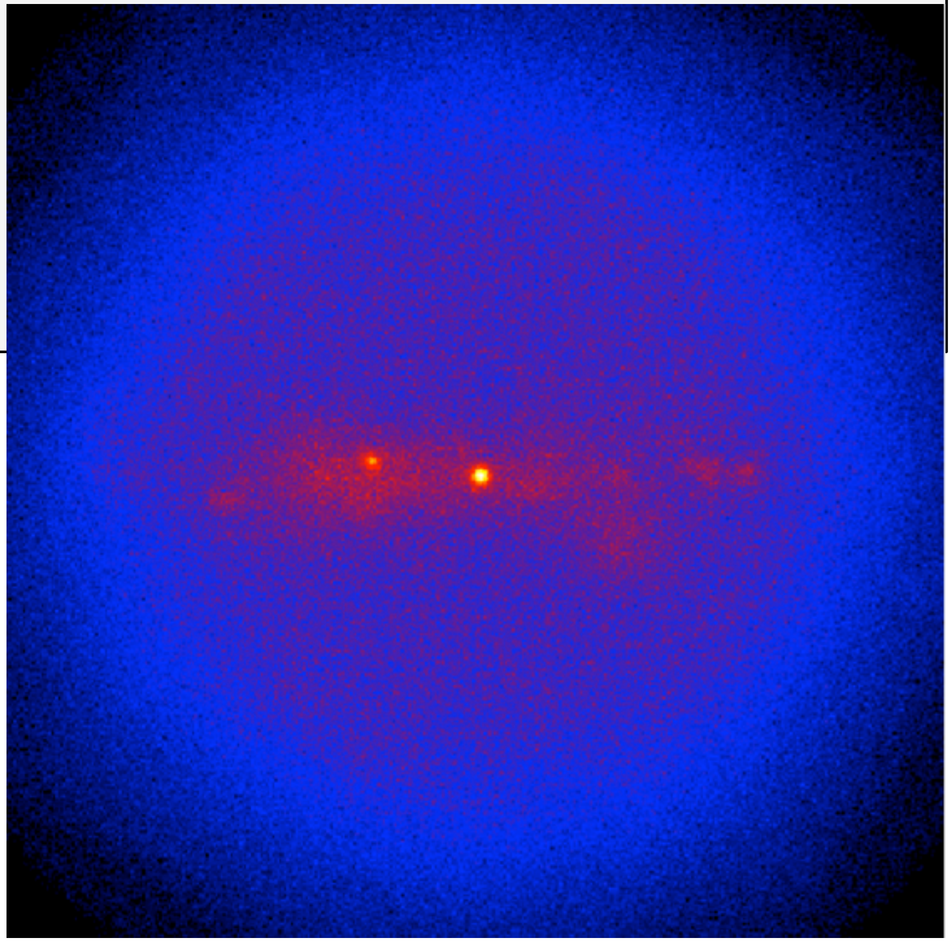
ctselect : selected from these only events between 100 GeV and 100 Tev, e.g.

```
$ ctselect
Input event list or observation definition XML file [events.fits] obs.xml
RA for ROI centre (degrees) (0-360) [83.63] UNDEFINED
Start time (CTA MET in seconds) [0.0] UNDEFINED
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Output event list or observation definition XML file [selected_events.fits] obs_selected.xml
```

If you have a simulated sky already…

ctskymap : create a sky map from your selected event files

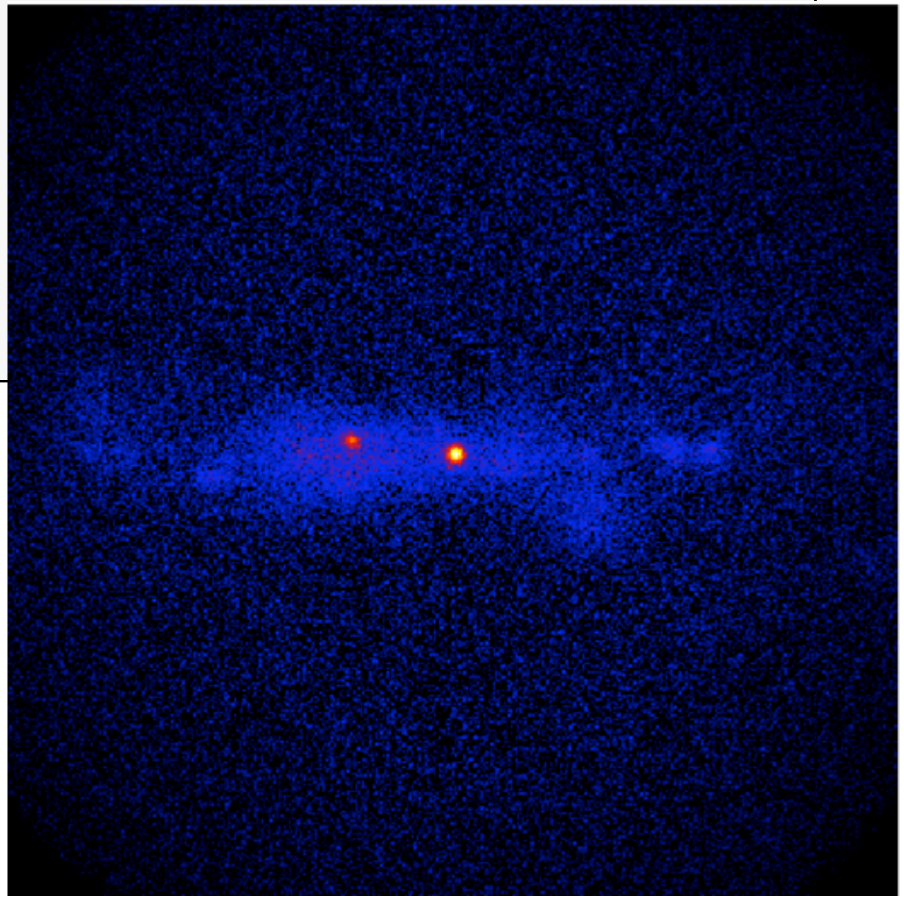
```
$ ctskymap
Input event list or observation definition XML file [events.fits] obs_selected.xml
First coordinate of image center in degrees (RA or galactic l) (0-360) [83.63] 0.0
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0
Projection method (AIT|AZP|CAR|MER|MOL|STG|TAN) [CAR]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL] GAL
Image scale (in degrees/pixel) [0.02]
Size of the X axis in pixels [200] 400
Size of the Y axis in pixels [200] 400
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Background subtraction method (NONE|IRF) [NONE]
Output skymap file [skymap.fits]
```

If you have a simulated sky already…

ctskymap : …or a background subtracted skymap

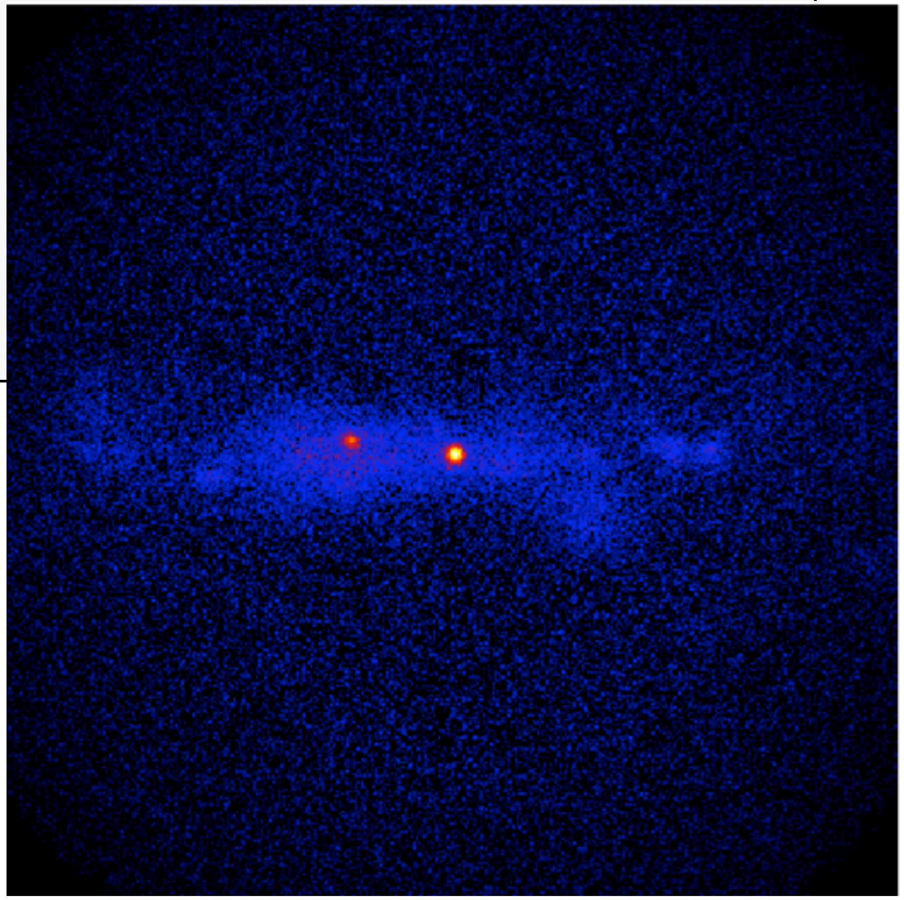
```
$ ctskymap
Input event list or observation definition XML file [events.fits] obs_selected.xml
First coordinate of image center in degrees (RA or galactic l) (0-360) [83.63] 0.0
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0
Projection method (AIT|AZP|CAR|MER|MOL|STG|TAN) [CAR]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL] GAL
Image scale (in degrees/pixel) [0.02]
Size of the X axis in pixels [400]
Size of the Y axis in pixels [400]
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Background subtraction method (NONE|IRF) [NONE] IRF
Output skymap file [skymap.fits] skymap_bkgsubtract.fits
```



If you have a simulated sky already…

ctskymap : …or a background subtracted skymap

```
$ ctskymap
Input event list or observation definition XML file [events.fits] obs_selected.xml
First coordinate of image center in degrees (RA or galactic l) (0-360) [83.63] 0.0
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0
Projection method (AIT|AZP|CAR|MER|MOL|STG|TAN) [CAR]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL] GAL
Image scale (in degrees/pixel) [0.02]
Size of the X axis in pixels [400]
Size of the Y axis in pixels [400]
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Background subtraction method (NONE|IRF) [NONE] IRF
Output skymap file [skymap.fits] skymap_bkgsubtract.fits
```

cssrdetect : detecting source candidates within sky map selected events

> detection threshold?

If you have a simulated sky already…

ctskymap : …the significance of a source

```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<source_library title="source library">
  <source name="Src001" type="PointSource" tscalc="1">
    <spectrum type="PowerLaw">
      <parameter name="Prefactor" value="1" error="0" scale="5.7e-18" min="0" free="1" />
      <parameter name="Index" value="1" error="-0" scale="-2.48" min="-4.03225806451613" max="4.03225806451
      <parameter name="PivotEnergy" value="1" scale="300000" free="0" />
    </spectrum>
    <spatialModel type="PointSource">
      <parameter name="RA" value="266.424004498437" error="0" scale="1" free="1" />
      <parameter name="DEC" value="-29.0049010253548" error="0" scale="1" free="1" />
    </spatialModel>
  </source>
  ...
</source_library>
```

Will be given in terms of a TS (see below!)

```
=== GModelSky ===
 Name ......................: Src001
 Instruments ...............: all
 Test Statistic ............: 12650.600597267

=== GModelSky ===
 Name ......................: Src002
 Instruments ...............: all
 Test Statistic ............: 2154.31897658715

=== GModelSky ===
 Name ......................: IEM
 Instruments ...............: all
 Test Statistic ............: 43070.3063685261
```