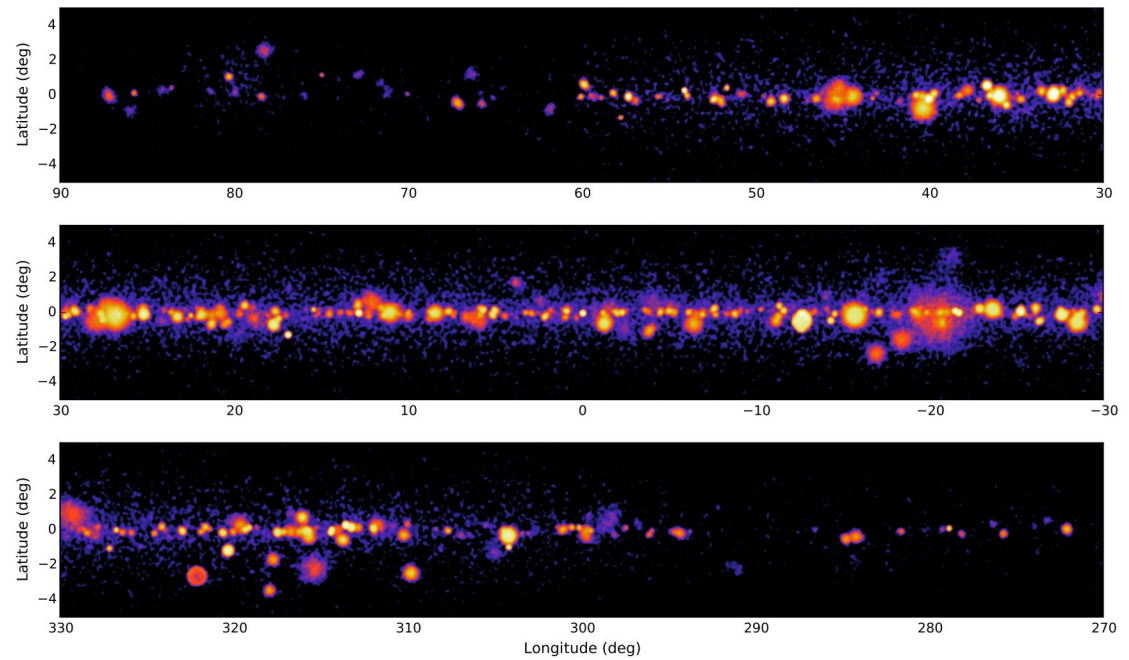




CTA data hands-on
workshop
2-3 October 2017

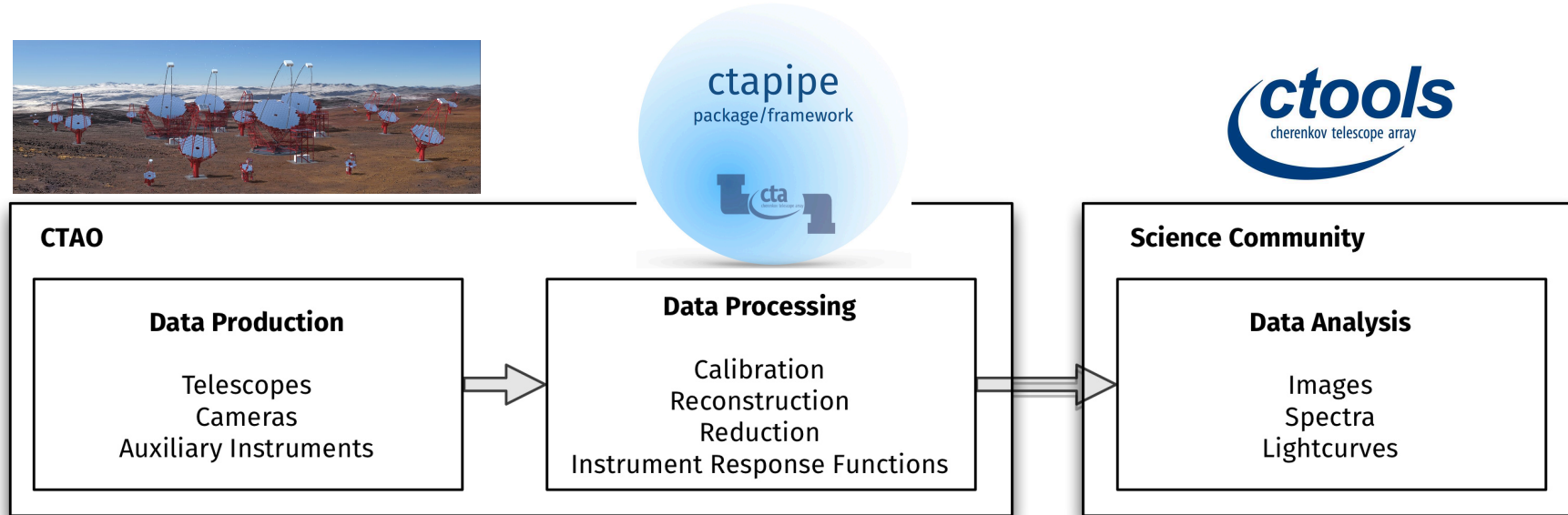
Jürgen Knödlseeder



Topics covered

- A few ctools basics
- Using ctools
- How to get help

The CTA data model

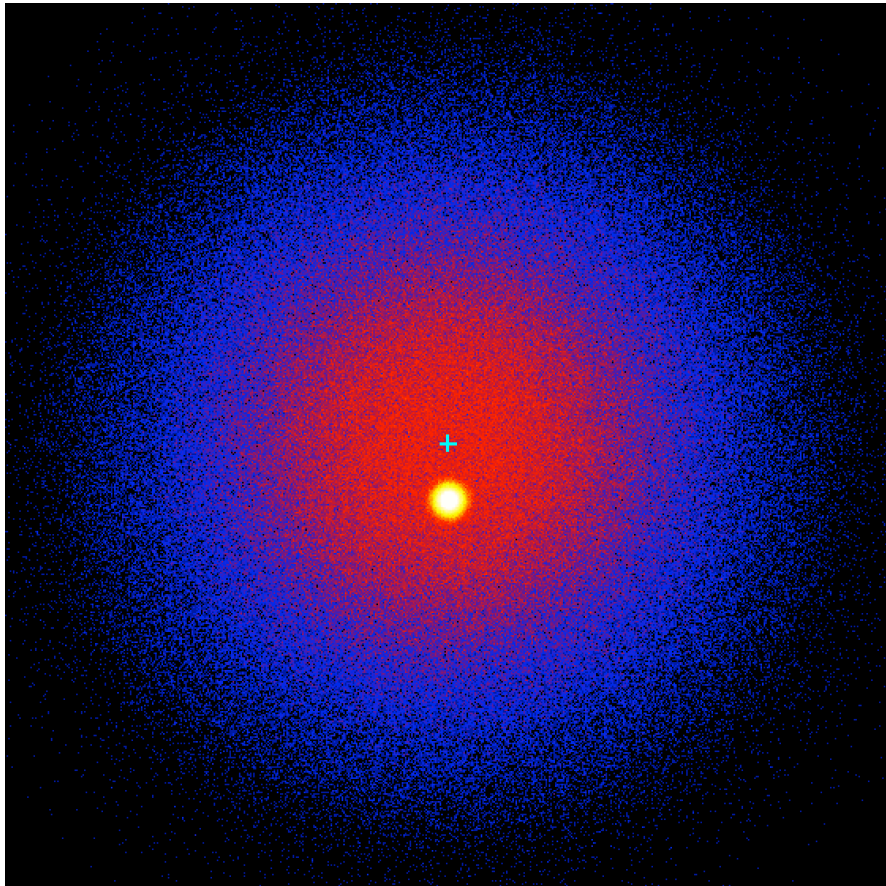


- The Science Community will get from CTAO a **predefined*** data product
 - Science Community can **not** run own calibration, reconstruction or reduction
 - A **number of different data cuts** will be provided to the science community
 - Science Community will get from CTAO the **software for data analysis**
 - CTAO will provide User Support to Science Community
- Data processing runs on CTAO infrastructure
- Data analysis runs on scientist's infrastructure (laptop, institute cluster, etc.)

*by CTAO

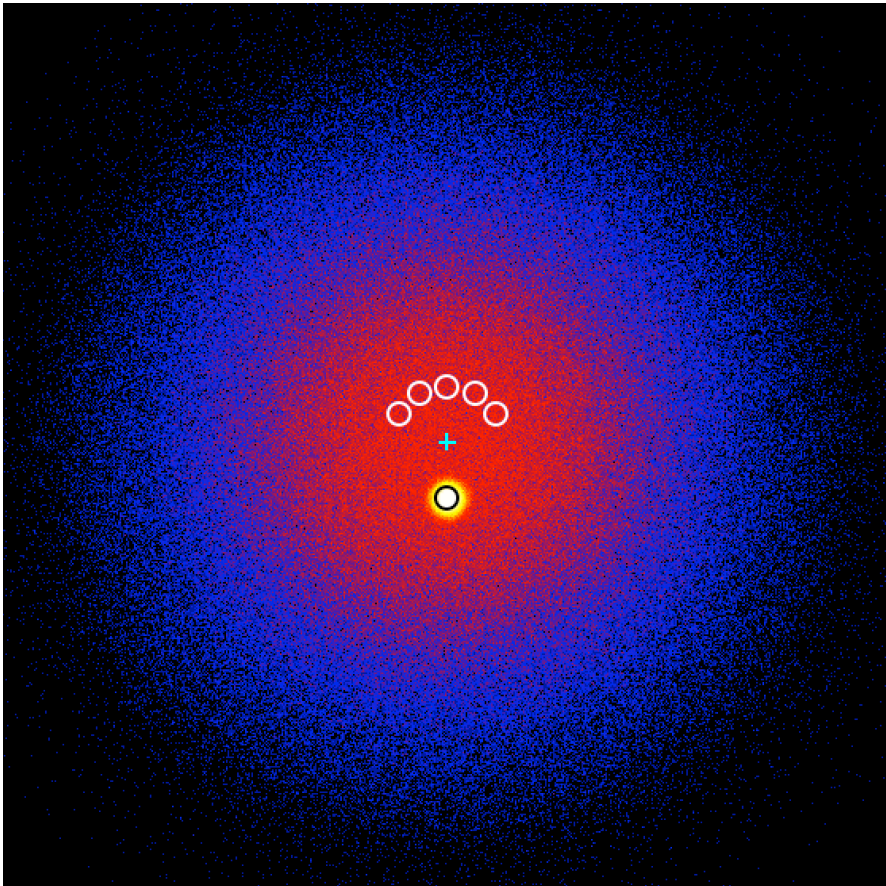
The ctools analysis model

50 h Crab simulation (0.5° off-axis)



The ctools analysis model

50 h Crab simulation (0.5° off-axis)

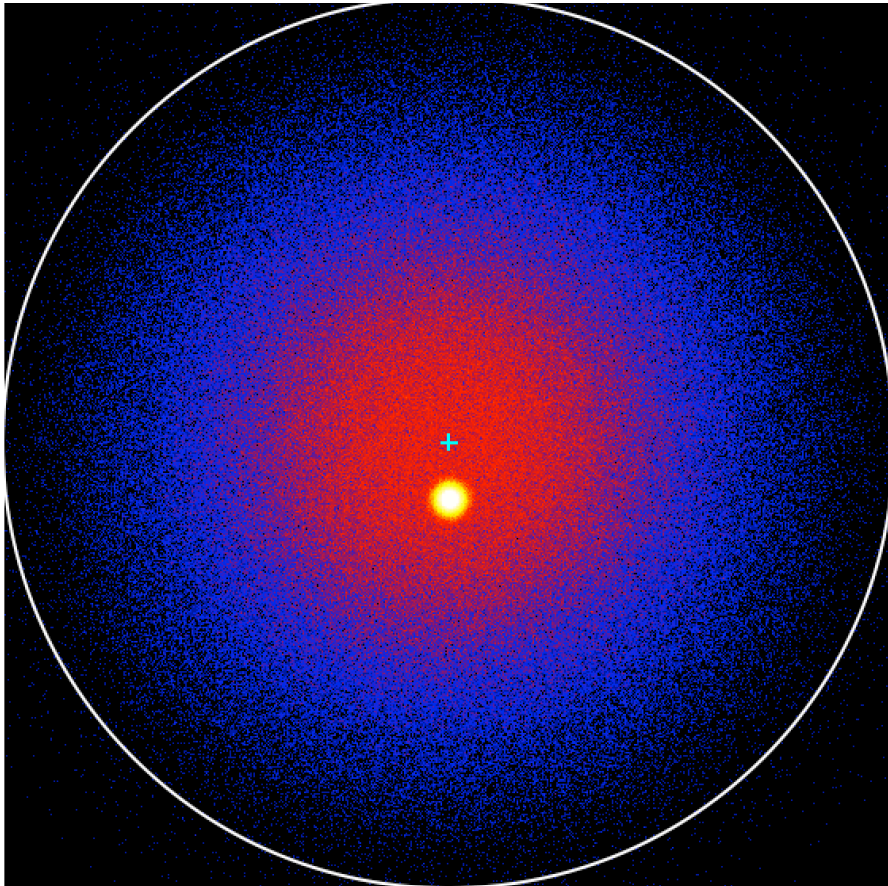


Classical VHE analysis

- Define reflected regions for background determination (white circles, 5 is standard for CTA)
- Assume that the background in these regions is the same as in the source region (axisymmetric background acceptance model)
- Determine source significance by maximum likelihood fitting in on and off regions (i.e. Li & Ma)

The ctools analysis model

50 h Crab simulation (0.5° off-axis)



ctools analysis

- Define reflected regions for background determination (white circles, 5 is standard for CTA)
- Assume that the background shape over a Region of Interest (RoI) is known (template fitting) in these regions is the same as in the source region (flat background acceptance model)
- Determine source significance by maximum likelihood fitting in on and off regions over the entire RoI (i.e. Li & Ma)

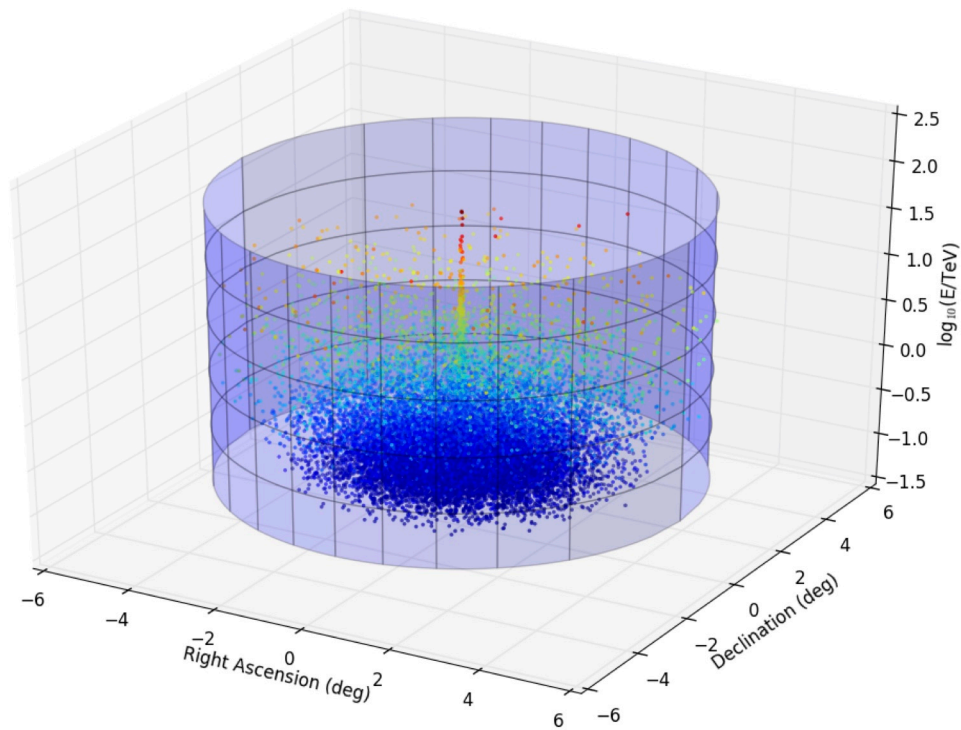
=>

- Main difference expected from different handling of background fitting
- Difference of PSF fitting expected to be small

How does the ctools analysis work?

- CTA event data live in a 4 dimensional world
 - Reconstructed arrival direction (2d)
 - Reconstructed energy (1d)
 - Time (1d)
- **Event lists** can be fitted with a **parametric model** using an **unbinned maximum likelihood algorithm**

fixed pointing



$$-\ln L_i(M) = e_i(M) - \sum_k \ln P_i(\mathbf{p}'_k, E'_k, t'_k | M)$$

$$e_i(M) = \int_{GTI} \int_{Ebounds} \int_{ROI} P_i(\mathbf{p}', E', t' | M) d\mathbf{p}' dE' dt'$$

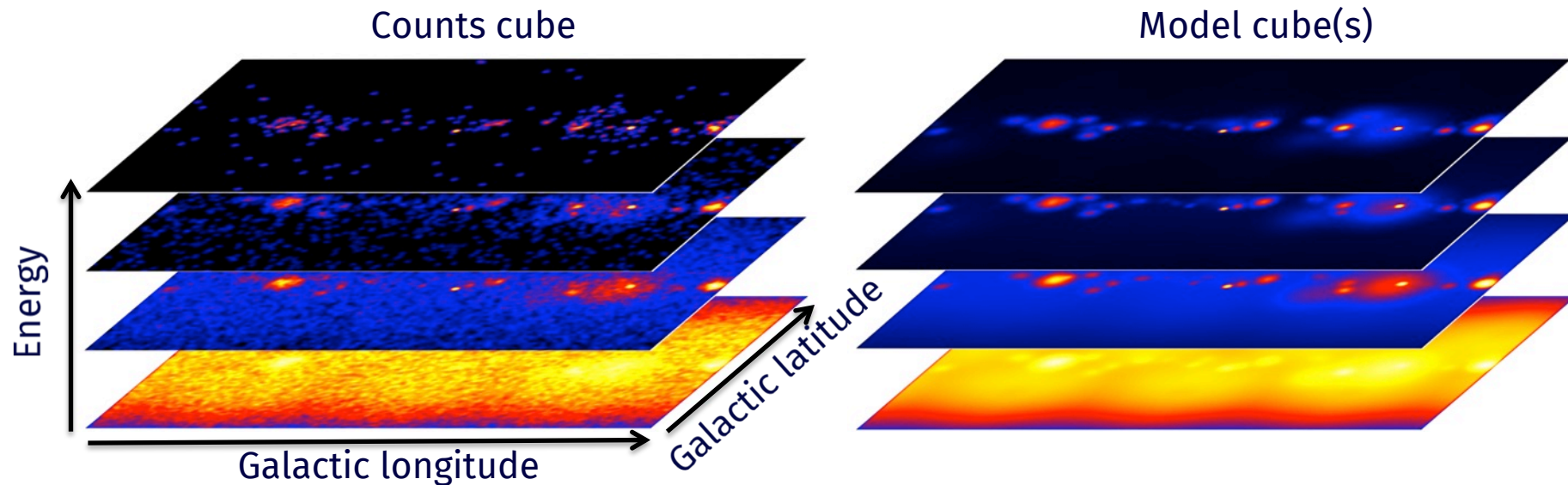


Probability density that given the model M an event with reconstructed arrival direction \mathbf{p}' , reconstructed energy E' and trigger time t' occurs.

How does the ctools analysis work?

- For a given time interval, events can be binned in a 3d data space
- **Counts cubes** can be fitted with a **parametric model** using a **binned maximum likelihood algorithm**

fixed pointing



$$-\ln L_i(M) = \sum_k e_{k,i}(M) - n_{k,i} \ln e_{k,i}(M)$$

Sky model factorisation

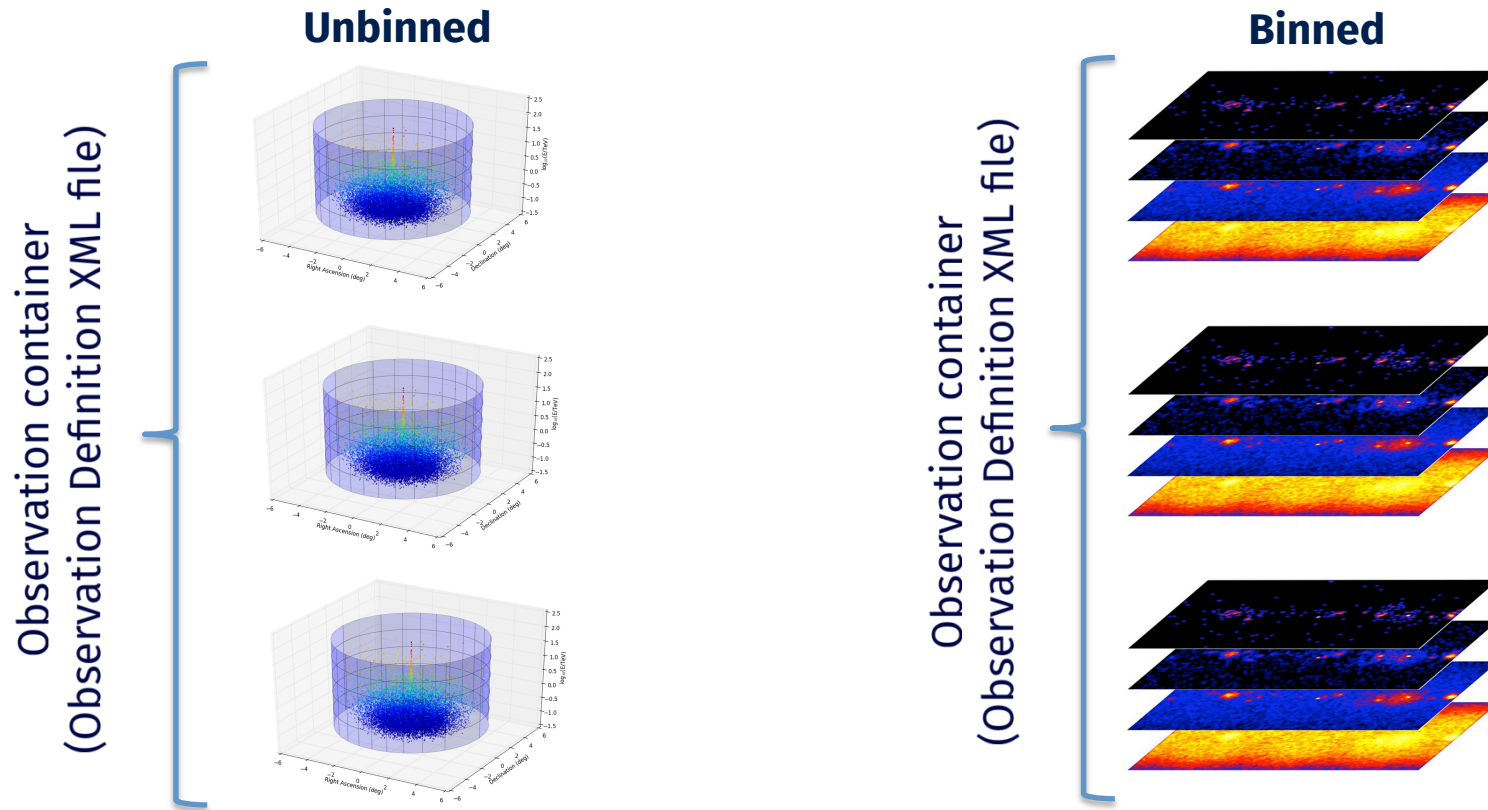
$$M^S(\mathbf{p}, E, t) = \underbrace{M_S(\mathbf{p}|E, t)}_{\text{spatial}} \times \underbrace{M_E(E|t)}_{\text{spectral}} \times \underbrace{M_T(t)}_{\text{temporal}}$$

- | spatial | spectral | temporal |
|--|--|--|
| <ul style="list-style-type: none"> • Point source • Radial symmetric models <ul style="list-style-type: none"> – Gaussian – Disk – Shell – Profiles (including DM halos) • Elliptical models <ul style="list-style-type: none"> – Gaussian – Disk • “Diffuse” models <ul style="list-style-type: none"> – Map – Map cubes (energy dependent maps) – Isotropic • Composite | <ul style="list-style-type: none"> • Power law • Broken power law • Smoothly 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) | <ul style="list-style-type: none"> • Constant • Light curve • Phase curve |

Model definition XML file

```
<?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="PivotEnergy" scale="1e6" value="0.3" min="0.01" max="1000.0" free="0"/>
    </spectrum>
    <spatialModel type="PointSource">
      <parameter name="RA" scale="1" value="83.6331" min="-360" max="360" free="0"/>
      <parameter name="DEC" scale="1" value="22.0145" min="-90" max="90" free="0"/>
    </spatialModel>
    <temporal type="LightCurve" file="model_temporal_lightcurve.fits">
      <parameter name="Normalization" scale="1" value="1.0" min="0.0" max="1000.0" free="0"/>
    </temporal>
  </source>
  <source name="Background" type="CTAIrfBackground" instrument="CTA">
    <spectrum type="PowerLaw">
      <parameter name="Prefactor" scale="1.0" value="1.0" min="1e-3" max="1e3" free="1"/>
      <parameter name="Index" scale="1.0" value="0.0" min="-5.0" max="+5.0" free="1"/>
      <parameter name="PivotEnergy" scale="1e6" value="1.0" min="0.01" max="1000.0" free="0"/>
    </spectrum>
  </source>
</source_library>
```

Combination of pointings



$$-\ln L(M) = -\sum_i \ln L_i(M)$$

Observation definition XML files

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<observation_list title="observation list">
  <observation name="GPS" id="110000" instrument="CTA">
    <parameter name="Calibration" database="1dc" response="South_z40_50h" />
    <parameter name="EventList" file="$CTADATA/data/baseline/gps/gps_baseline_110000.fits" />
  </observation>
  <observation name="GPS" id="110001" instrument="CTA">
    <parameter name="Calibration" database="1dc" response="South_z40_50h" />
    <parameter name="EventList" file="$CTADATA/data/baseline/gps/gps_baseline_110001.fits" />
  </observation>
  <observation name="GPS" id="110002" instrument="CTA">
    <parameter name="Calibration" database="1dc" response="South_z40_50h" />
    <parameter name="EventList" file="$CTADATA/data/baseline/gps/gps_baseline_110002.fits" />
  </observation>
  <observation name="GPS" id="110003" instrument="CTA">
    <parameter name="Calibration" database="1dc" response="South_z40_50h" />
    <parameter name="EventList" file="$CTADATA/data/baseline/gps/gps_baseline_110003.fits" />
  </observation>
</observation_list>
```

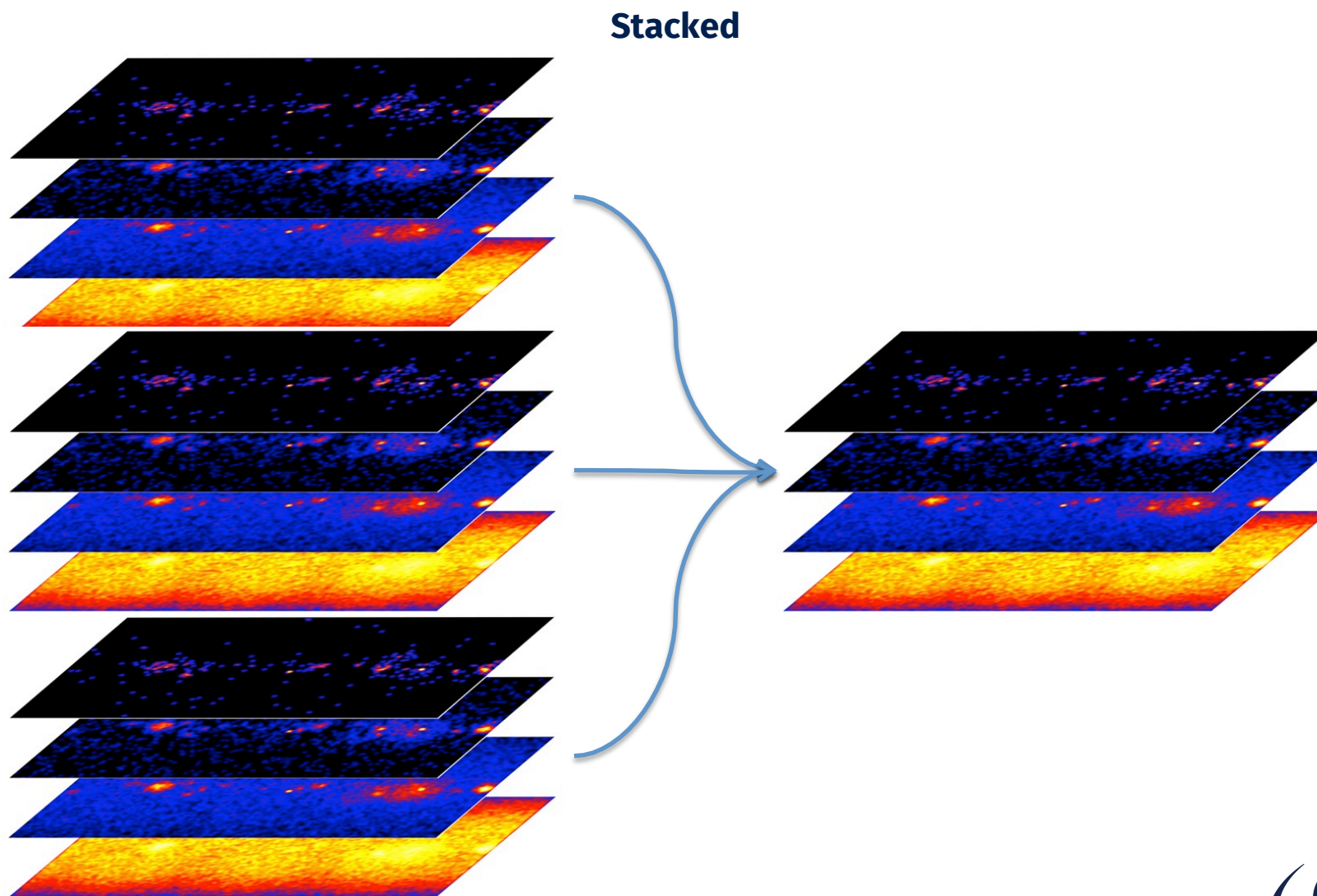
Unbinned

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<observation_list title="observation list">
  <observation name="GPS" id="110000" instrument="CTA">
    <parameter name="Calibration" database="1dc" response="South_z40_50h" />
    <parameter name="CountsCube" file="gps_cntcube_110000.fits" />
  </observation>
  <observation name="GPS" id="110001" instrument="CTA">
    <parameter name="Calibration" database="1dc" response="South_z40_50h" />
    <parameter name="CountsCube" file="gps_cntcube_110001.fits" />
  </observation>
  <observation name="GPS" id="110002" instrument="CTA">
    <parameter name="Calibration" database="1dc" response="South_z40_50h" />
    <parameter name="CountsCube" file="gps_cntcube_110002.fits" />
  </observation>
  <observation name="GPS" id="110003" instrument="CTA">
    <parameter name="Calibration" database="1dc" response="South_z40_50h" />
    <parameter name="CountsCube" file="gps_cntcube_110003.fits" />
  </observation>
</observation_list>
```

Binned



Combination of counts cubes



Observation definition XML files

```
<?xml version="1.0" standalone="no"?>
<observation_list title="observation library">
  <observation name="Crab" id="00001" instrument="CTA">
    <parameter name="CountsCube" file="cntcube.fits"/>
    <parameter name="ExposureCube" file="expcube.fits"/>
    <parameter name="PsfCube" file="psfcube.fits"/>
    <parameter name="BkgCube" file="bkgcube.fits"/>
  </observation>
</observation_list>
```

Stacked

Stacked analysis is the recommended standard ctools analysis method

- Events of multiple observations are binned in a single counts cube
- Computation of livetime weighted exposure cube, PSF cube and background cube

Event file format

Index	Extension	Type	Dimension	View
0	Primary	Image	0	Header Image Table
1	EVENTS	Binary	8 cols X 107290 rows	Header Hist Plot All Select
2	GTI	Binary	2 cols X 1 rows	Header Hist Plot All Select

Event file characteristics

- One event file per (fixed) pointing
- Covers period of 30 min
- Covers energies from 30 GeV to 160 TeV
- Include energy dispersion
- EVENTS extension contains event list (one event per row)
- GTI extension contains Good Time Intervals (single interval)

Event file format

Event list table

fv: Binary Table of gps_baseline_110000.fits[1] in /Users/jurgen/analysis/cta/dc/1dc/1dc/gps.20170720/1dc/data/baseline/gps/

File Edit Tools Help

Select	EVENT_ID	TIME	RA	DEC	ENERGY	DETX	DETY	MC_ID
<input type="checkbox"/> All	1J	1D	1E	1E	1E	1E	1E	1J
	s	s	deg	deg	TeV	deg	deg	
<input type="checkbox"/> Invert	<input type="checkbox"/> Modify	<input type="checkbox"/> Modify	<input type="checkbox"/> Modify	<input type="checkbox"/> Modify	<input type="checkbox"/> Modify	<input type="checkbox"/> Modify	<input type="checkbox"/> Modify	<input type="checkbox"/> Modify
1	1	6.627744032550E+08	-1.732869E+02	-6.240993E+01	4.861494E-02	1.607946E+00	2.580158E-01	2
2	2	6.627744591838E+08	-1.726196E+02	-6.303463E+01	6.110354E-02	9.790584E-01	5.551662E-01	2
3	3	6.627744793092E+08	-1.705929E+02	-6.347148E+01	4.614199E-02	5.105490E-01	1.451438E+00	2
4	4	6.627744907238E+08	-1.756367E+02	-6.364094E+01	4.935673E-02	3.668797E-01	-7.959080E-01	2
5	5	6.627745068648E+08	-1.721235E+02	-6.340126E+01	5.054006E-02	6.073638E-01	7.701997E-01	2
6	6	6.627745188484E+08	-1.719797E+02	-6.314213E+01	6.685498E-02	8.645879E-01	8.421167E-01	2
7	7	6.627745253335E+08	-1.748123E+02	-6.409695E+01	5.897600E-02	-8.116303E-02	-4.230072E-01	2
8	8	6.627745305569E+08	-1.746414E+02	-6.304284E+01	5.658822E-02	9.739035E-01	-3.615367E-01	2
9	9	6.627745571515E+08	-1.715107E+02	-6.220671E+01	5.724507E-02	1.792477E+00	1.087869E+00	2
10	10	6.627745692051E+08	-1.710337E+02	-6.171667E+01	5.577112E-02	2.273161E+00	1.331486E+00	2
11	11	6.627745874472E+08	-1.730401E+02	-6.253468E+01	7.003513E-02	1.481997E+00	3.707363E-01	2
12	12	6.627746088038E+08	-1.742967E+02	-6.370272E+01	3.768072E-02	3.155670E-01	-2.005937E-01	2
13	13	6.627746315176E+08	-1.752712E+02	-6.583829E+01	4.306062E-02	-1.825866E+00	-5.842795E-01	2
14	14	6.627746368873E+08	-1.688460E+02	-6.380654E+01	5.558641E-02	1.260536E-01	2.203822E+00	2
15	15	6.627746500328E+08	-1.735892E+02	-6.547857E+01	6.137832E-02	-1.459779E+00	1.056988E-01	2
16	16	6.627746642211E+08	-1.767322E+02	-6.260846E+01	5.654409E-02	1.380554E+00	-1.328510E+00	2
17	17	6.627746702556E+08	-1.742908E+02	-6.426160E+01	5.121857E-02	-2.432814E-01	-1.940633E-01	2
18	18	6.627746789837E+08	-1.712142E+02	-6.232095E+01	6.666495E-02	1.672971E+00	1.221390E+00	2
19	19	6.627747002520E+08	-1.746416E+02	-6.311734E+01	3.215407E-02	8.994074E-01	-3.607161E-01	2
20	20	6.627747280266E+08	-1.722550E+02	-6.524733E+01	4.411121E-02	-1.236651E+00	6.652415E-01	2

Go to: Edit cell:



Event file format

Event list header

```
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 = '0.03:160' / Data sub-space value
DSTYP3 = 'POS(RA,DEC)' / Data sub-space type
DSUNI3 = 'deg' / Data sub-space unit
DSVAL3 = 'CIRCLE(186.1561,-64.019,5)' / Data sub-space value
NDSKEYS = 3 / Number of data sub-space keys
NMCIDS = 43 / Number of Monte Carlo identifiers
MID00001= 2 / Monte Carlo identifier for model 1
MMN00001= 'IEM' / Name of model 1
MID00002= 213 / Monte Carlo identifier for model 2
MMN00002= 'pwn_128' / Name of model 2
MID00003= 686 / Monte Carlo identifier for model 3
MMN00003= 'composite_90' / Name of model 3
MID00004= 1071 / Monte Carlo identifier for model 4

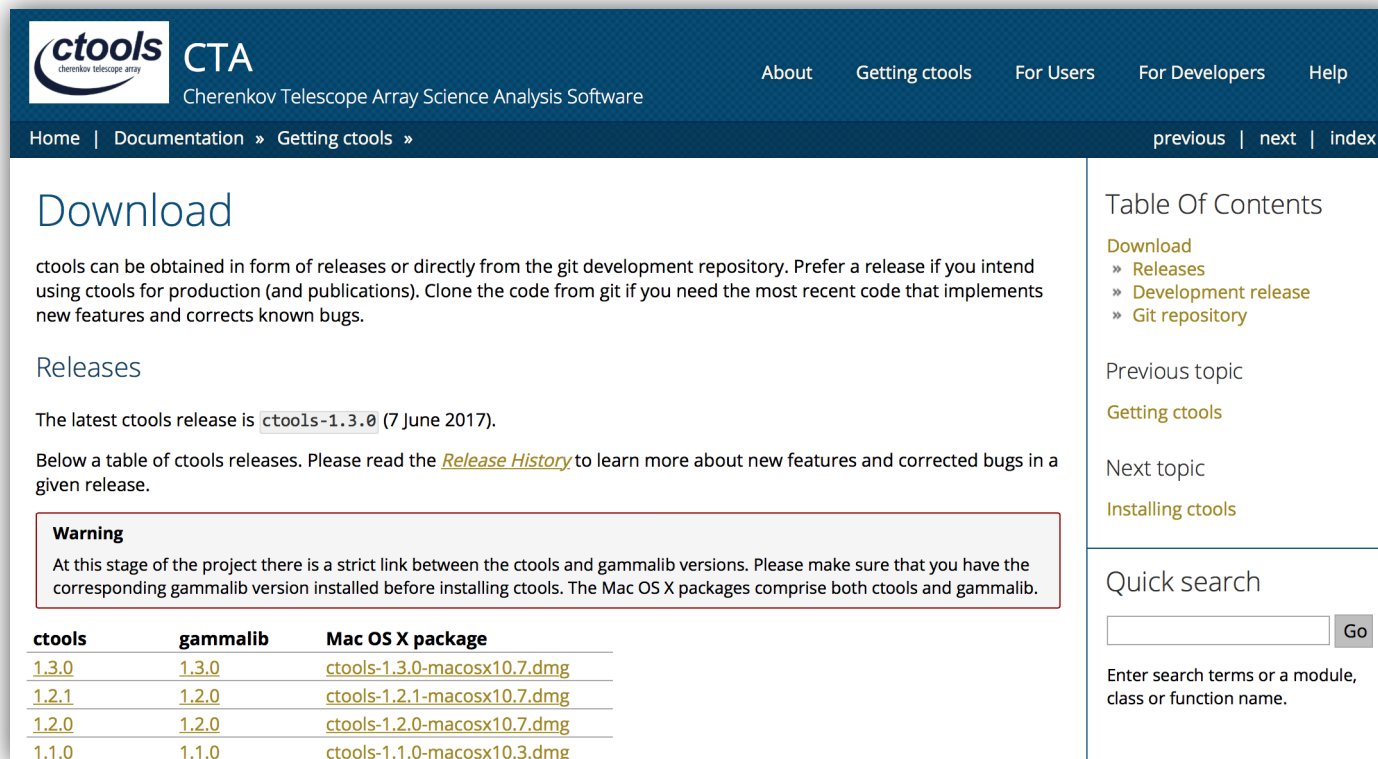
MID00040= 610 / Monte Carlo identifier for model 40
MMN00040= 'composite_14' / Name of model 40
MID00041= 620 / Monte Carlo identifier for model 41
MMN00041= 'composite_24' / Name of model 41
MID00042= 704 / Monte Carlo identifier for model 42
MMN00042= 'composite_109' / Name of model 42
MID00043= 1 / Monte Carlo identifier for model 43
MMN00043= 'Background model' / Name of model 43
CREATOR = 'ctobssim (1.4.0)' / Program which created the file
TELESCOP= 'CTA' / Telescope
```

```
OBS_ID = 110000 / 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= 1.7640000000E+03 / [s] Total livetime
DEADC = 9.8000001907E-01 / Deadtime correction factor
TIMEDEL = 1 / Time resolution
OBJECT = 'Galactic Plane Survey' / Observed object
RA_OBJ = 0 / [deg] Target Right Ascension
DEC_OBJ = 0 / [deg] Target Declination
RA_PNT = 1.8615609741E+02 / [deg] Pointing Right Ascension
DEC_PNT = -6.4019000000E+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
ALTITUDE= 2.1500000000E+00 / [km] Altitude of array centre
EUNIT = 'TeV' / Energy unit
EVTVER = 'draft1' / Event list version number
CALDB = 'ldc' / Calibration database
IRF = 'South_z40_50h' / Instrument Response Function
END
```

How to install ctools

Download the code

- <http://cta.irap.omp.eu/ctools/admin/download.html>
- Release tarballs for source installation
- Binary package for Mac OS X (more OS to come soon)
- Clone the development version using Git



The screenshot shows the 'Download' page of the ctools website. The page header includes the ctools logo and navigation links: About, Getting ctools, For Users, For Developers, and Help. The breadcrumb trail is Home | Documentation » Getting ctools ». The main content area is titled 'Download' and contains the following text: '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.' Below this is a 'Releases' section stating 'The latest ctools release is `ctools-1.3.0` (7 June 2017).' and 'Below a table of ctools releases. Please read the [Release History](#) to learn more about new features and corrected bugs in a given release.' A 'Warning' box states: '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.' A table follows with columns for 'ctools', 'gammalib', and 'Mac OS X package'. The right sidebar contains a 'Table Of Contents' with links to 'Download', 'Releases', 'Development release', and 'Git repository', as well as 'Previous topic' (Getting ctools) and 'Next topic' (Installing ctools). At the bottom of the sidebar is a 'Quick search' box with a 'Go' button and instructions: 'Enter search terms or a module, class or function name.'

ctools	gammalib	Mac OS X package
1.3.0	1.3.0	ctools-1.3.0-macosx10.7.dmg
1.2.1	1.2.0	ctools-1.2.1-macosx10.7.dmg
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

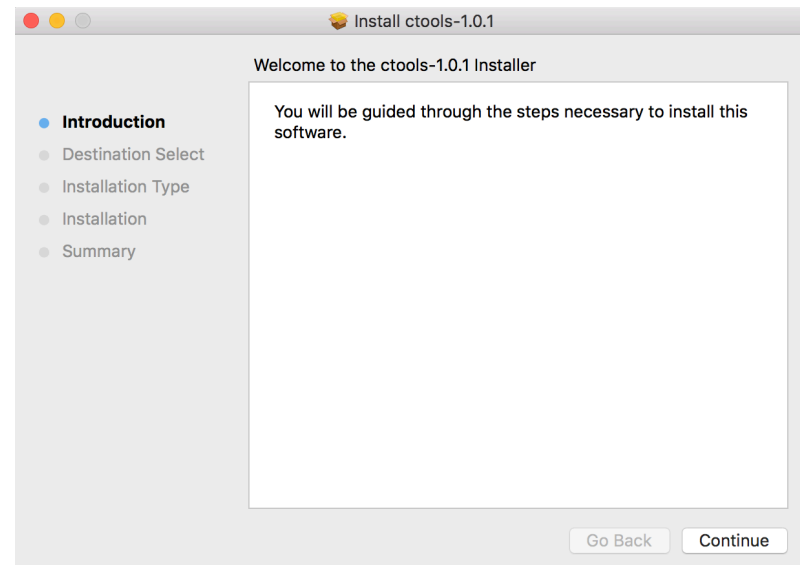


How to install ctools

Building from source
(first GammaLib, then ctools)

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

Using the Mac OS X binary package
(includes GammaLib & ctools)

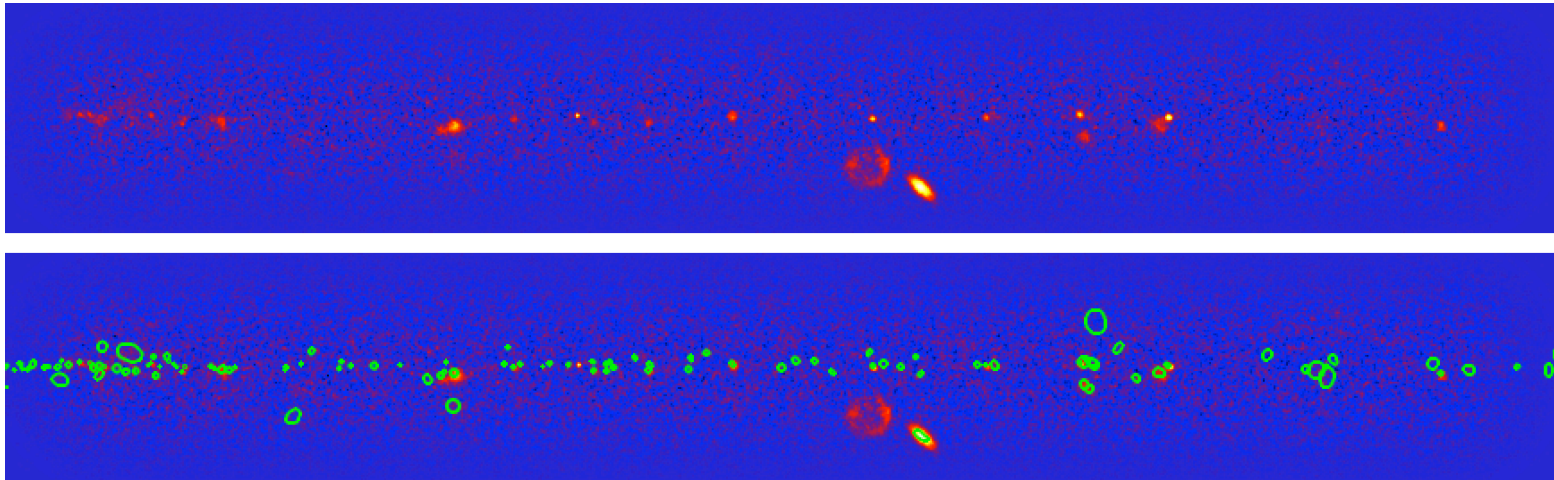
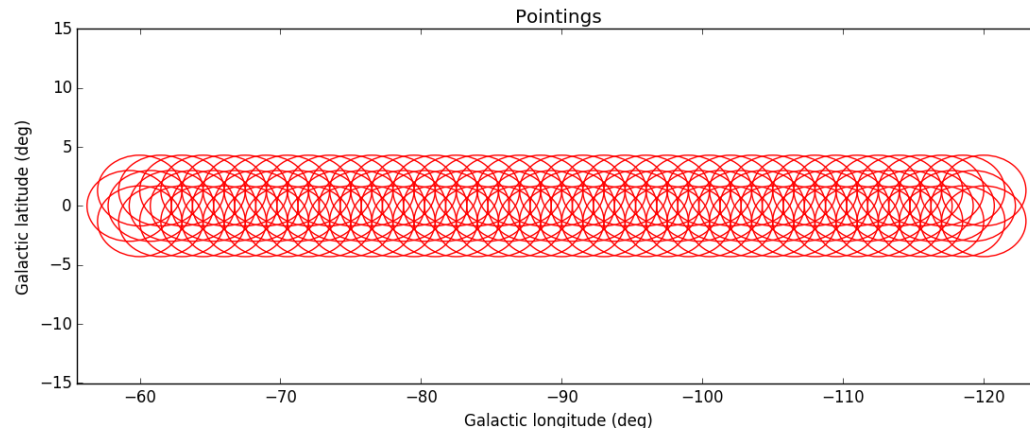


Configuring GammaLib & ctools
(put this into your .profile or .bashrc script)

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

The hands-on dataset

Dedicated hands-on dataset prepared for this workshop



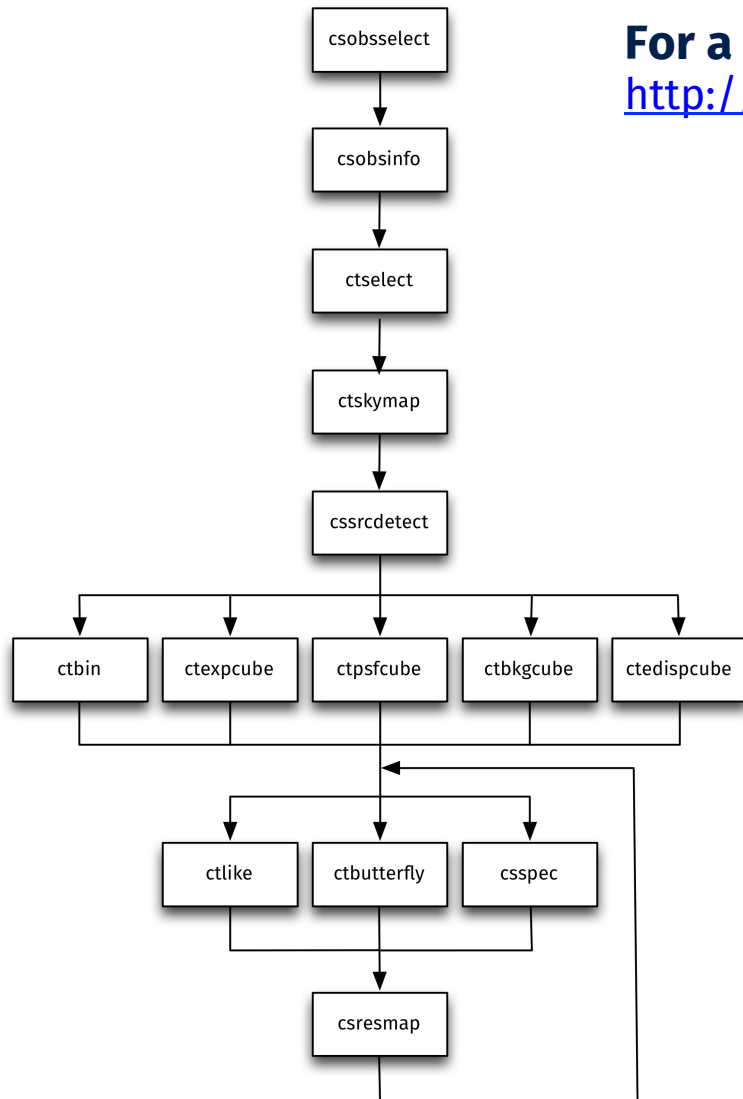
The hands-on dataset

```
$ export CTADATA=/Users/jurgen/analysis/cta/handson/handson
$ export CALDB=$CTADATA/caldb

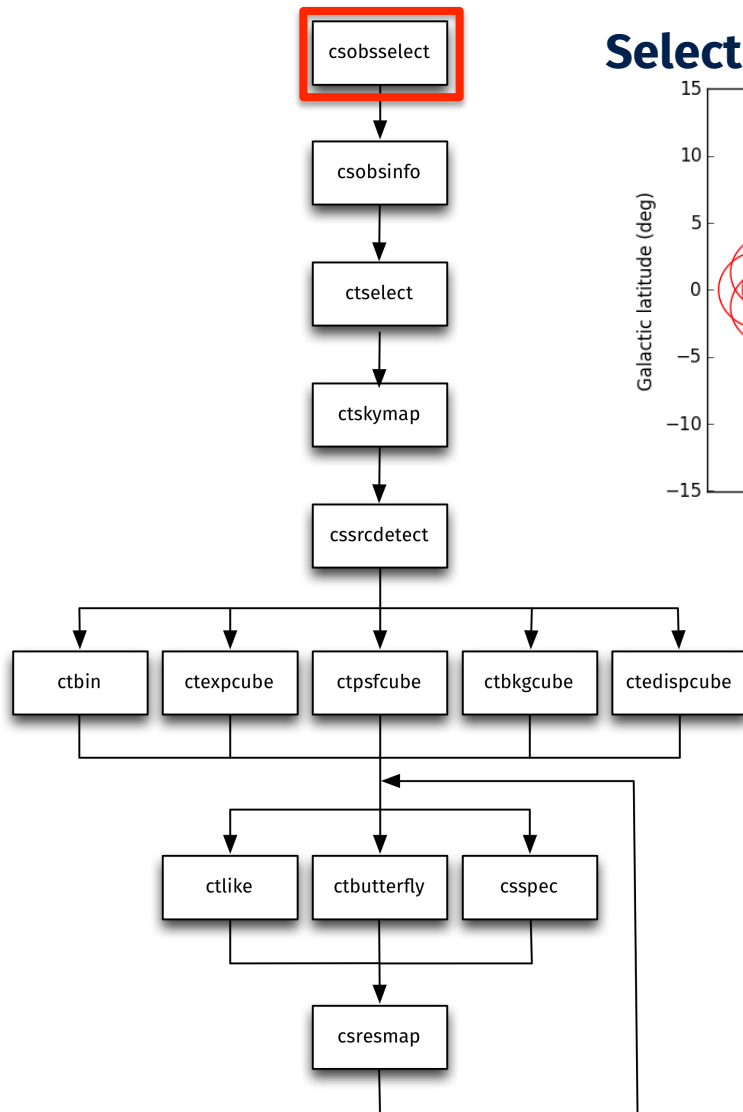
$ csobsinfo debug=yes
Input event list, ... XML file [obs_selected.xml] $CTADATA/obs/obs_handson.xml
Output DS9 region file [ds9.reg]
2017-09-28T10:42:08: === Observations ===
2017-09-28T10:42:08:   Unbinned observations .....: 123
2017-09-28T10:42:08:   Binned observations .....: 0
2017-09-28T10:42:08: === Events ===
2017-09-28T10:42:08:   Number of events .....: 6062856
2017-09-28T10:42:08:   Number of bins .....: 0
2017-09-28T10:42:08: === Pointings ===
2017-09-28T10:42:08:   Mean offset angle .....: Unknown
2017-09-28T10:42:08:   Mean zenith angle .....: 0.00 deg
2017-09-28T10:42:08:   Mean azimuth angle .....: 0.00 deg
2017-09-28T10:42:08: === Energy range ===
2017-09-28T10:42:08:   Minimum energy .....: 30 GeV
2017-09-28T10:42:08:   Maximum energy .....: 160 TeV
2017-09-28T10:42:08: === Time range ===
2017-09-28T10:42:08:   MJD (days) .....: 59215.500 - 59221.699
2017-09-28T10:42:08:   UTC .....: 2021-01-01T11:58:51 - 2021-01-07T16:44:51
2017-09-28T10:42:08:   MET (seconds) .....: 662774400.000 - 663309960.000
2017-09-28T10:42:08:   Total ontime .....: 221400.00 s = 3690.00 min = 61.50 h
2017-09-28T10:42:08:   Total livetime .....: 216972.00 s = 3616.20 min = 60.27 h
```

Using ctools

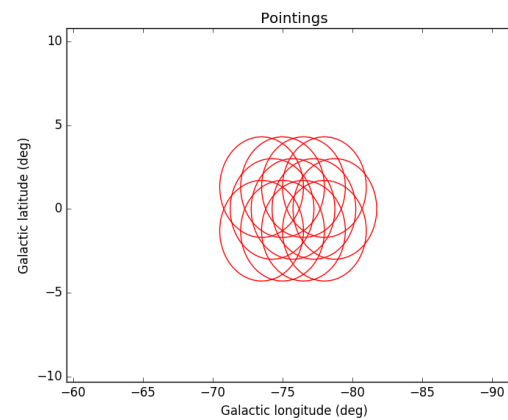
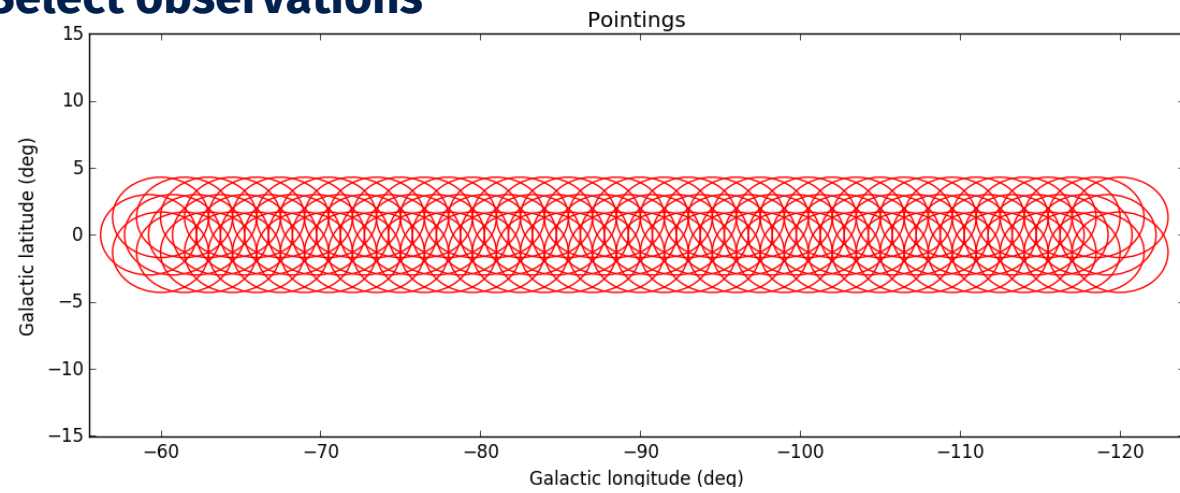
For a detailed description of the workflow see <http://cta.irap.omp.eu/ctools/users/tutorials/1dc/first.html>



Selecting relevant observations



Select observations



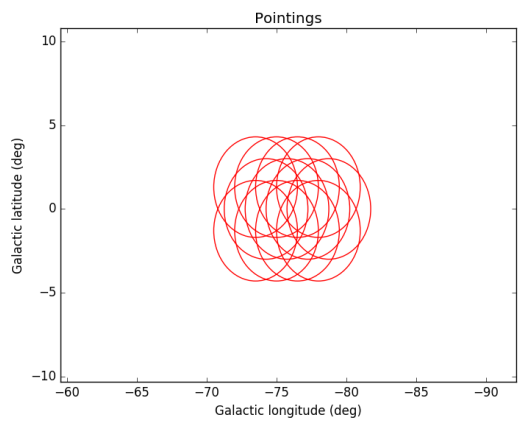
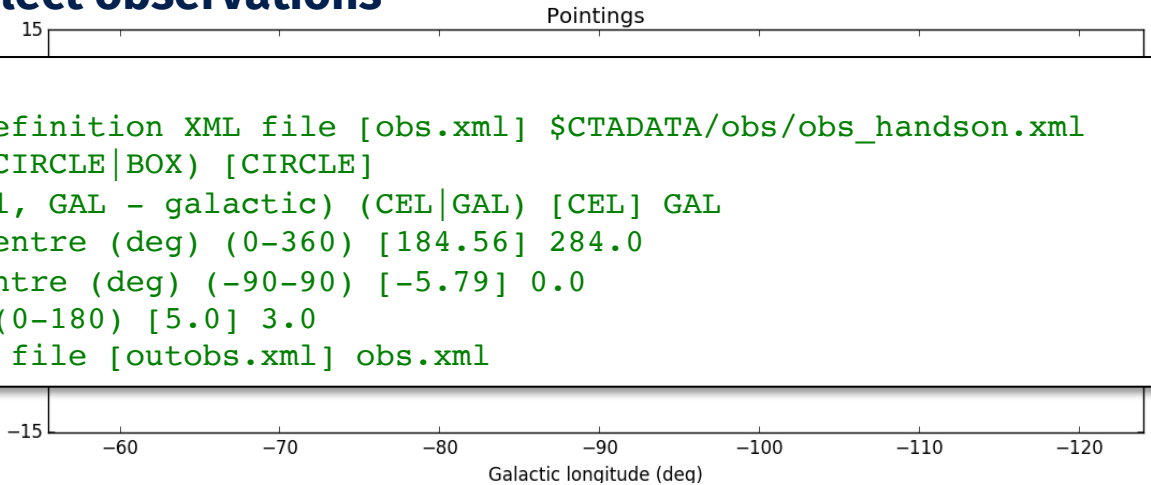
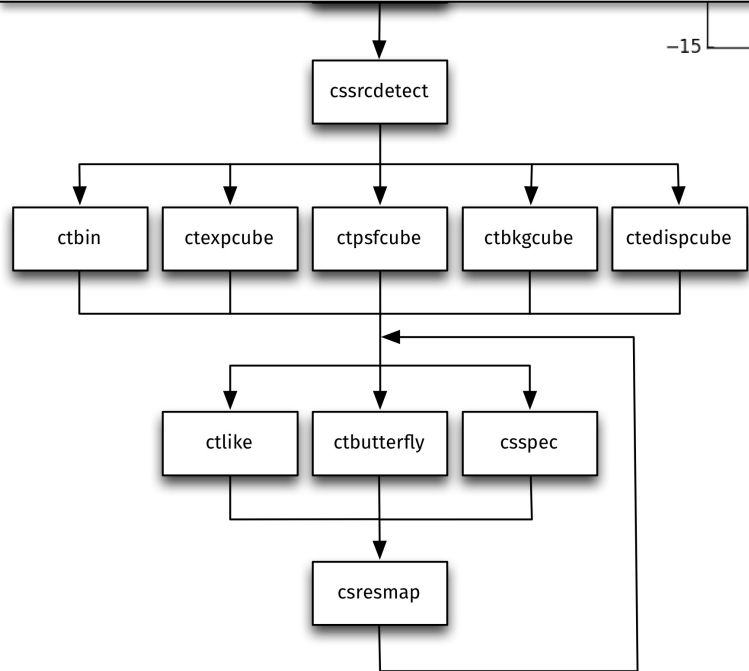
Selecting relevant observations

csobsselect

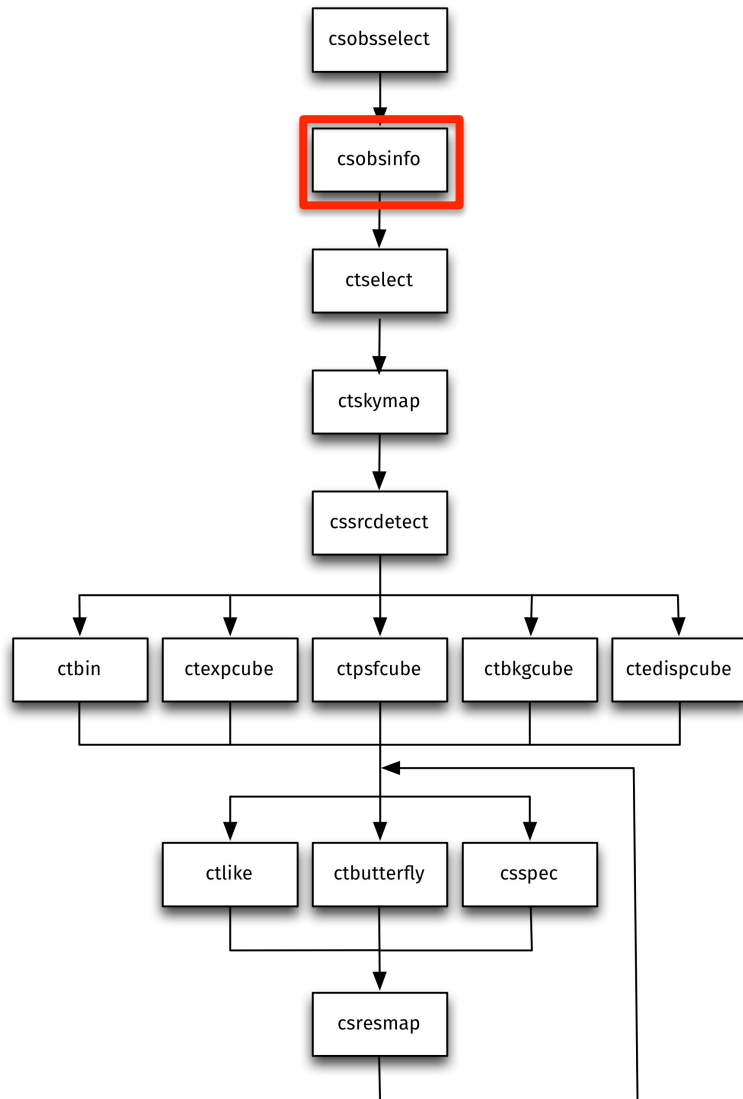
Select observations

```

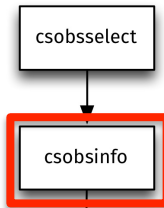
$ csobsselect
Input event list or observation definition XML file [obs.xml] $CTADATA/obs/obs_handson.xml
Pointing selection region shape (CIRCLE|BOX) [CIRCLE]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL] GAL
Galactic longitude of selection centre (deg) (0-360) [184.56] 284.0
Galactic latitude of selection centre (deg) (-90-90) [-5.79] 0.0
Radius of selection circle (deg) (0-180) [5.0] 3.0
Output observation definition XML file [outobs.xml] obs.xml
    
```



Inspect selected observations



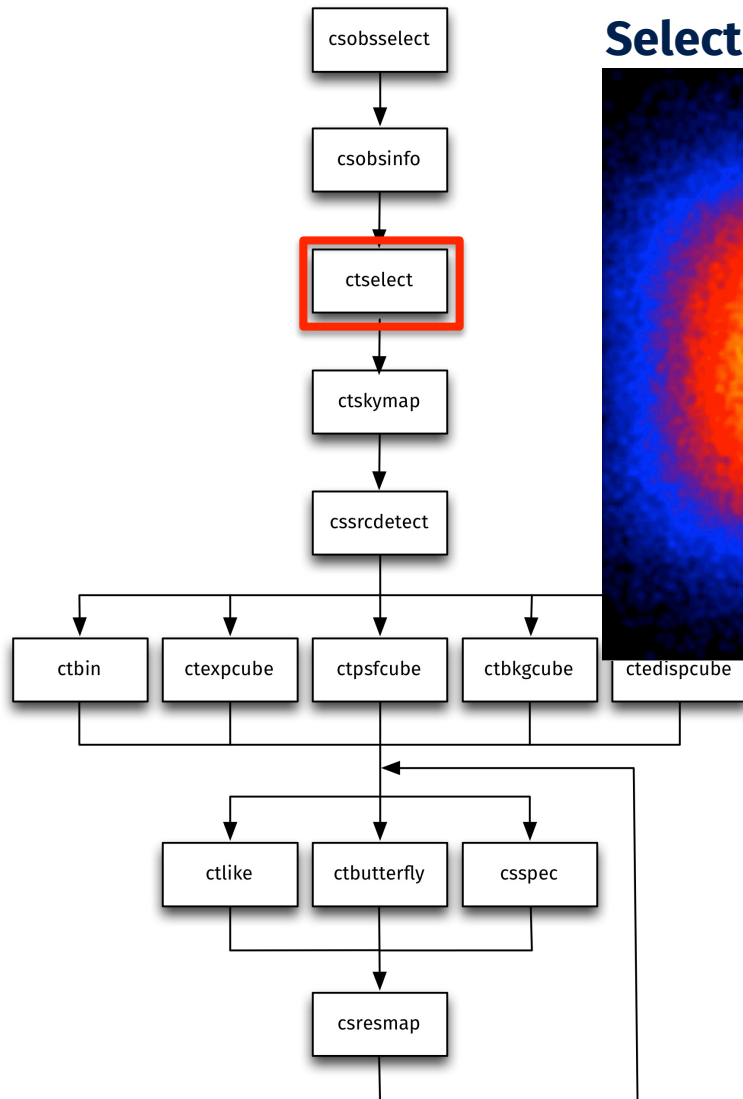
Inspect selected observations



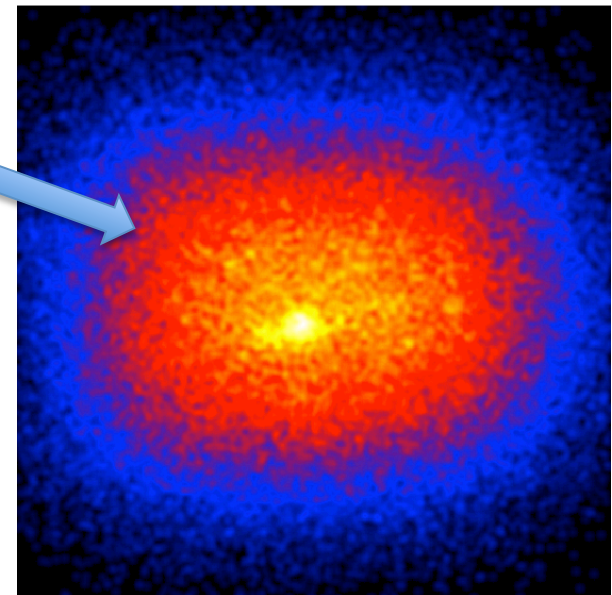
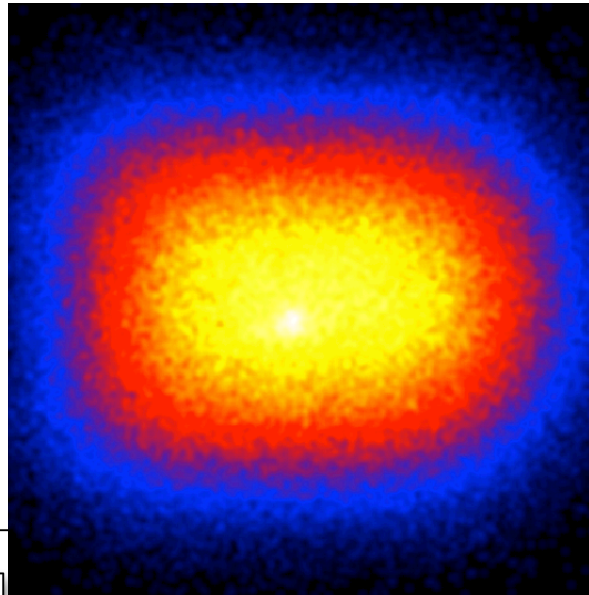
```
$ csobsinfo debug=yes
Input event list, ... XML file [obs_selected.xml] obs.xml
Output DS9 region file [ds9.reg]
2017-09-28T11:04:50: === Observations ===
2017-09-28T11:04:50:  Unbinned observations .....: 12
2017-09-28T11:04:50:  Binned observations .....: 0
2017-09-28T11:04:50: === Events ===
2017-09-28T11:04:50:  Number of events .....: 595899
2017-09-28T11:04:50:  Number of bins .....: 0
2017-09-28T11:04:50: === Pointings ===
2017-09-28T11:04:50:  Mean offset angle .....: Unknown
2017-09-28T11:04:50:  Mean zenith angle .....: 0.00 deg
2017-09-28T11:04:50:  Mean azimuth angle .....: 0.00 deg
2017-09-28T11:04:50: === Energy range ===
2017-09-28T11:04:50:  Minimum energy .....: 30 GeV
2017-09-28T11:04:50:  Maximum energy .....: 160 TeV
2017-09-28T11:04:50: === Time range ===
2017-09-28T11:04:50:  MJD (days) .....: 59216.700 - 59220.921
2017-09-28T11:04:50:  UTC .....: 2021-01-02T16:46:51 - 2021-01-06T22:04:51
2017-09-28T11:04:50:  MET (seconds) .....: 662878080.000 - 663242760.000
2017-09-28T11:04:50:  Total ontime .....: 21600.00 s = 360.00 min = 6.00 h
2017-09-28T11:04:50:  Total livetime .....: 21168.00 s = 352.80 min = 5.88 h
```



Selecting relevant events

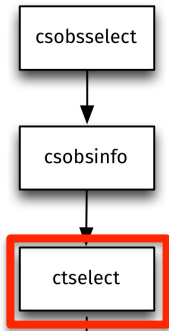


Select events

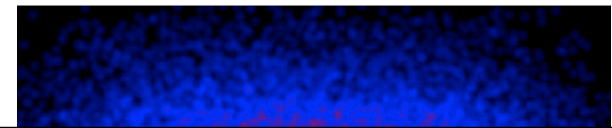
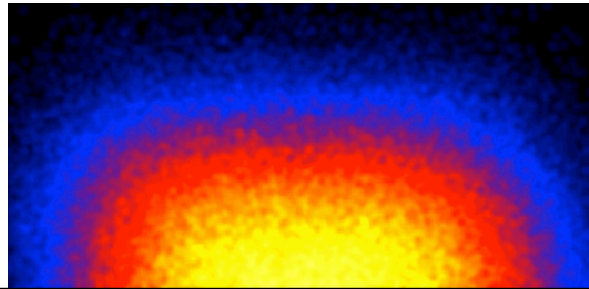


- Here: select events within 0.1 – 100 TeV
- Also possible: spatial and temporal selection

Selecting relevant events

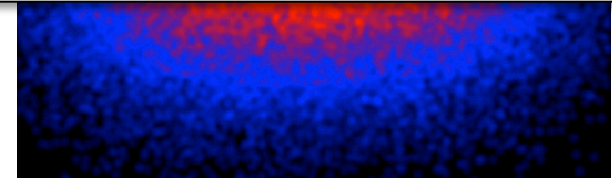
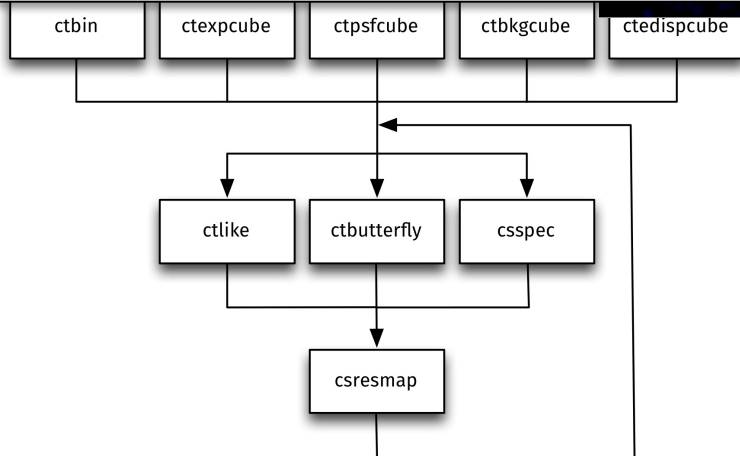


Select events



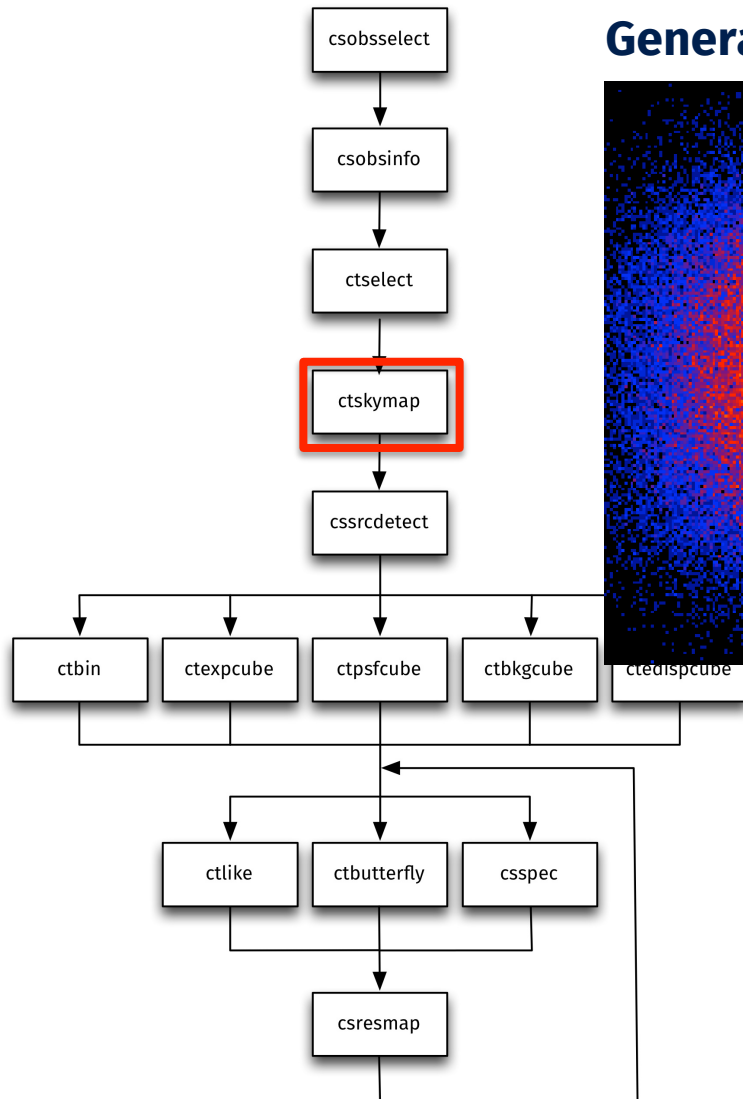
```

$ ctselect
Input event list or observation definition XML file [events.fits] obs.xml
RA for ROI centre (degrees) (0-360) [83.63] UNDEF
Start time (UTC string, JD, MJD or MET in seconds) [NONE]
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
  
```

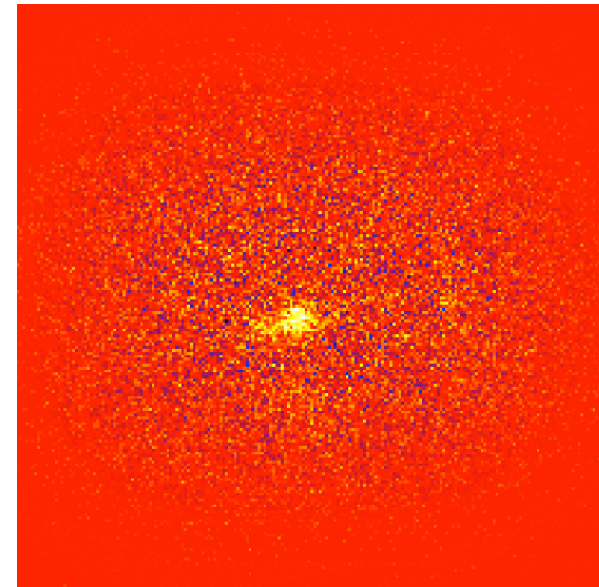
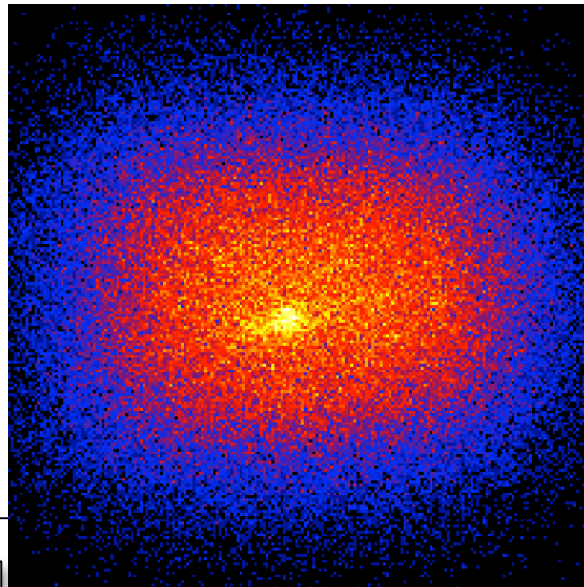


- Here: select events within 0.1 – 100 TeV
- Also possible: spatial and temporal selection

Generating a sky map from the events

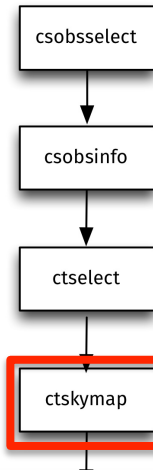


Generate a sky map from events

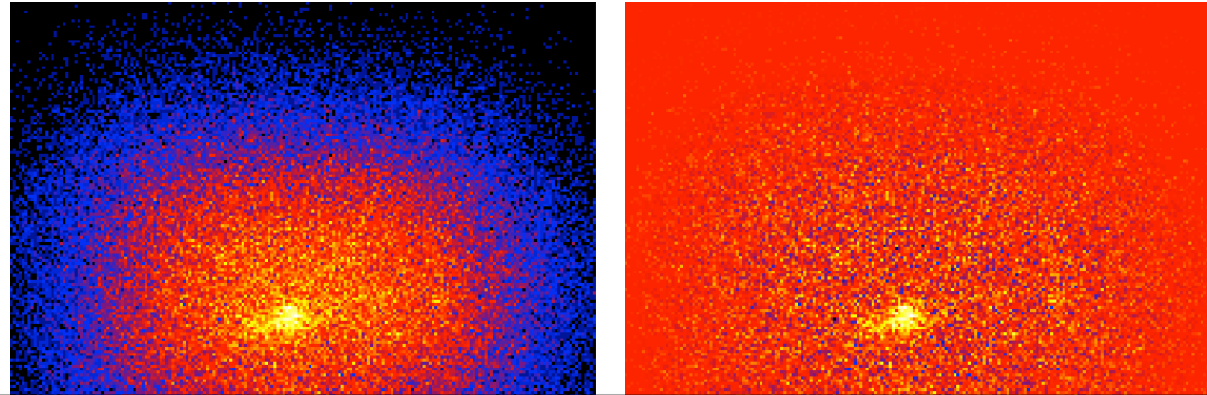


- Left: map of events
- Right: map of events minus background template

Generating a sky map from the events



Generate a sky map from events

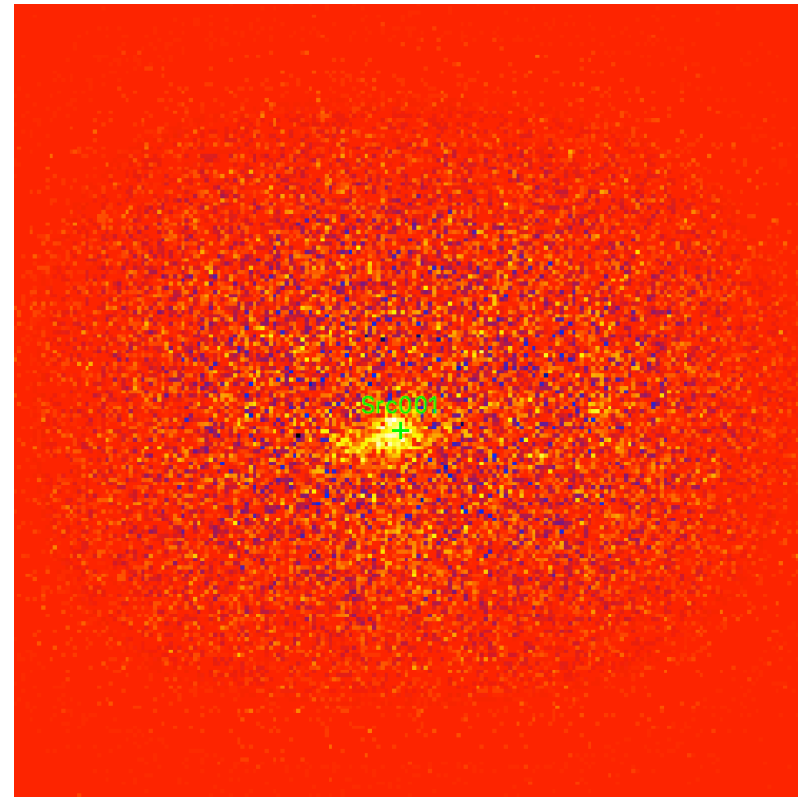
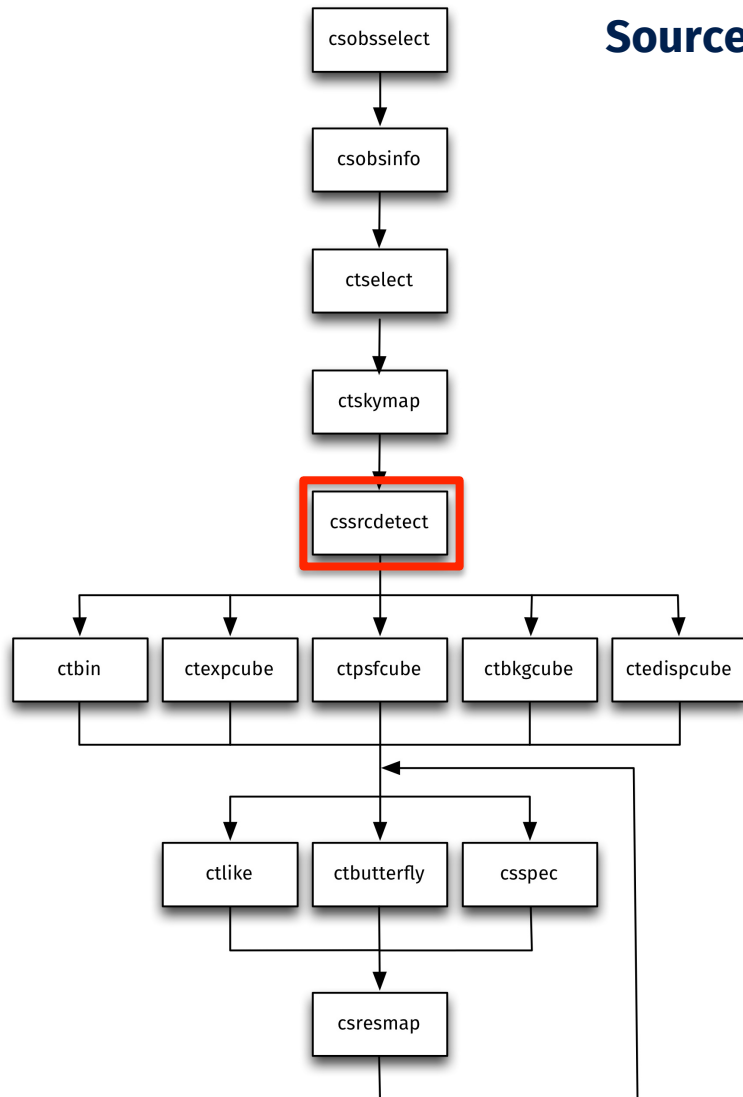


```
$ ctskymap
Input event list or observation definition XML file [events.fits] obs_selected.xml
First coordinate of image center in degrees (RA or galactic l) (0-360) [83.63] 284.0
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0
Projection method (AIT|AZP|CAR|GLS|MER|MOL|SFL|SIN|STG|TAN) [CAR]
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL] GAL
Image scale (in degrees/pixel) [0.02] 0.05
Size of the X axis in pixels [200]
Size of the Y axis in pixels [200]
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Background subtraction method (NONE|IRF) [NONE]
Output skymap file [skymap.fits]
```

csresmap

Finding sources in the sky map

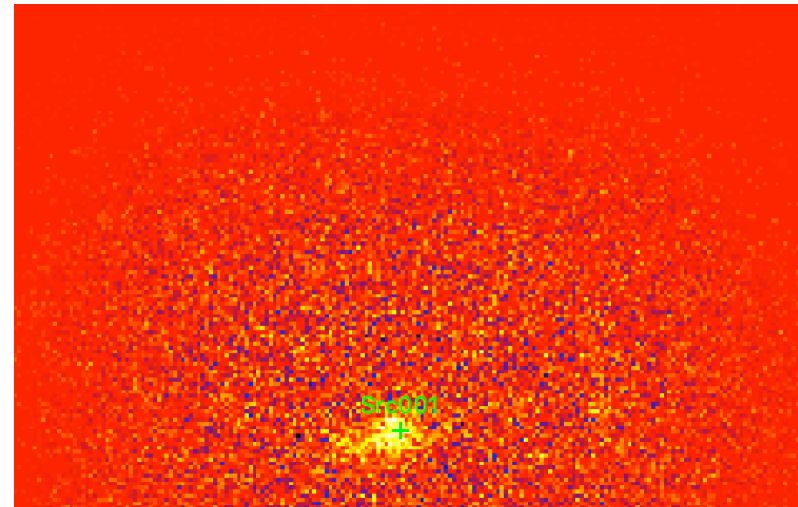
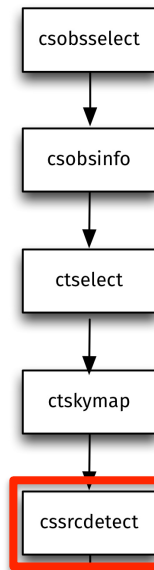
Source detection and model definition XML file creation



- So far implements simple peak above threshold algorithm

Finding sources in the sky map

Source detection and model definition XML file creation

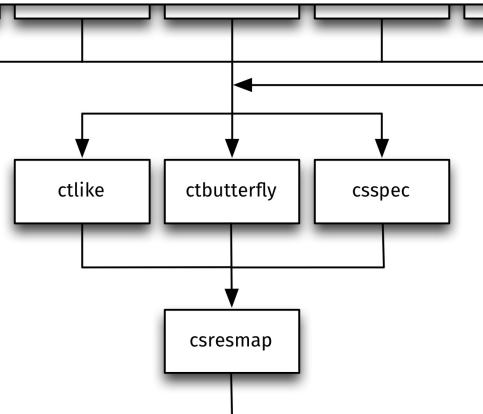


```
$ cssrcdetect maxsracs=1  
Input sky map file [skymap.fits] skymap_irf.fits  
Source model type (POINT) [POINT]  
Background model type (NONE|IRF|AEFF|CUBE) [NONE] IRF  
Detection threshold (Gaussian sigma) [5.0] 10.0  
Output model definition XML file [models.xml]  
Output DS9 region file [ds9.reg] models.reg
```

- So far implements simple peak above threshold algorithm

Finding sources in the sky map

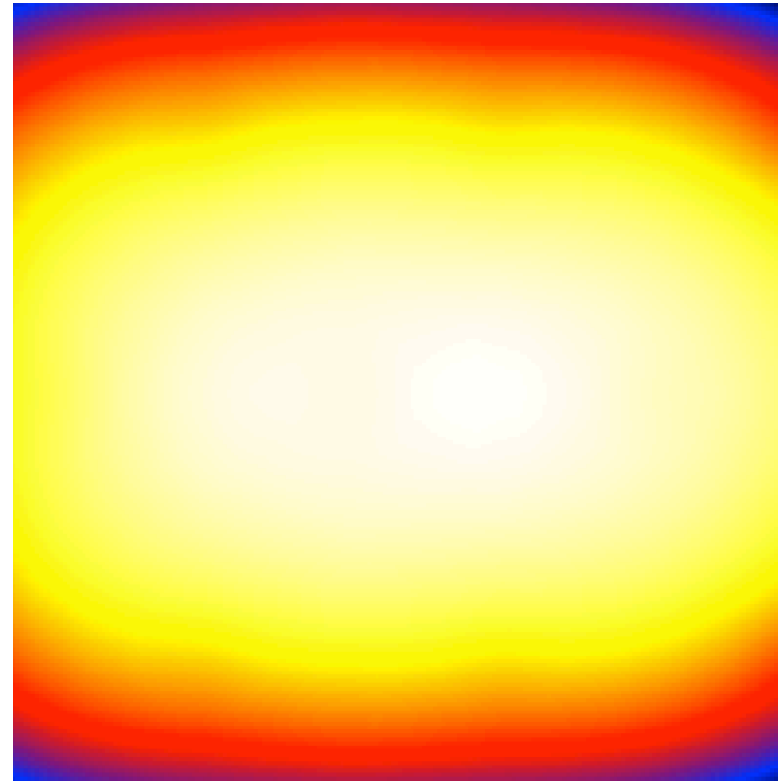
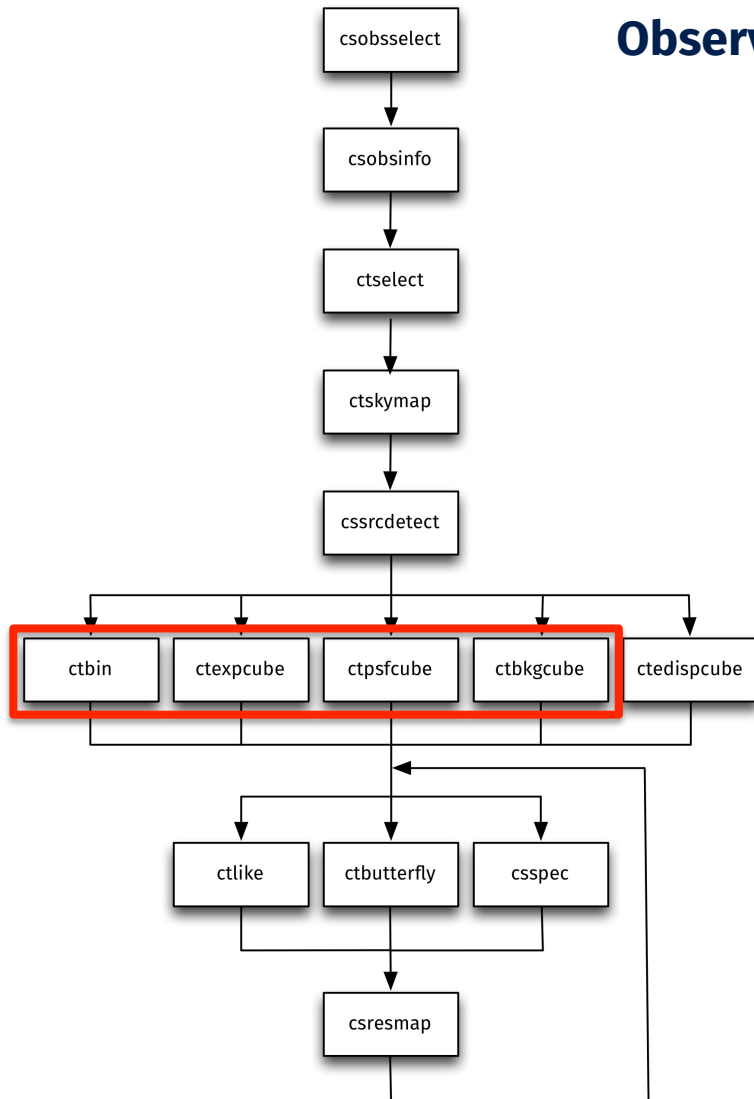
```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<source_library title="source library">
  <source name="Src001" type="PointSource">
    <spectrum type="PowerLaw">
      <parameter name="Prefactor" value="1" error="0" scale="5.7e-18" min="0" free="1" />
      <parameter name="Index" value="1" error="-0" scale="-2.48" min="-4.03225806" max="4.03225806" free="1" />
      <parameter name="PivotEnergy" value="1" scale="300000" free="0" />
    </spectrum>
    <spatialModel type="PointSource">
      <parameter name="RA" value="155.730431674709" error="0" scale="1" free="1" />
      <parameter name="DEC" value="-57.7189221745815" error="0" scale="1" free="1" />
    </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>
```



- So far implements simple peak above threshold algorithm

Stacking the observations

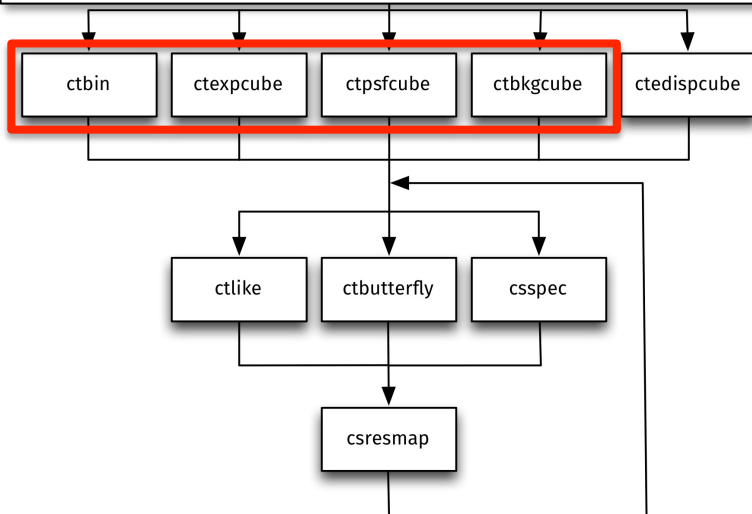
Observation stacking



- Example: exposure at 100 GeV

Stacking the observations

```
$ ctbin
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] 284.0
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0
Projection method (AIT|AZP|CAR|GLS|MER|MOL|SFL|SIN|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]
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 (1-200) [20]
Output counts cube file [cntcube.fits]
```



- Example: exposure at 100 GeV

Stacking the observations

```
$ ctexpcube
```

```
Input event list or observation definition XML file [NONE] obs_selected.xml  
Input counts cube file to extract exposure cube definition [NONE] cntcube.fits  
Output exposure cube file [expcube.fits]
```

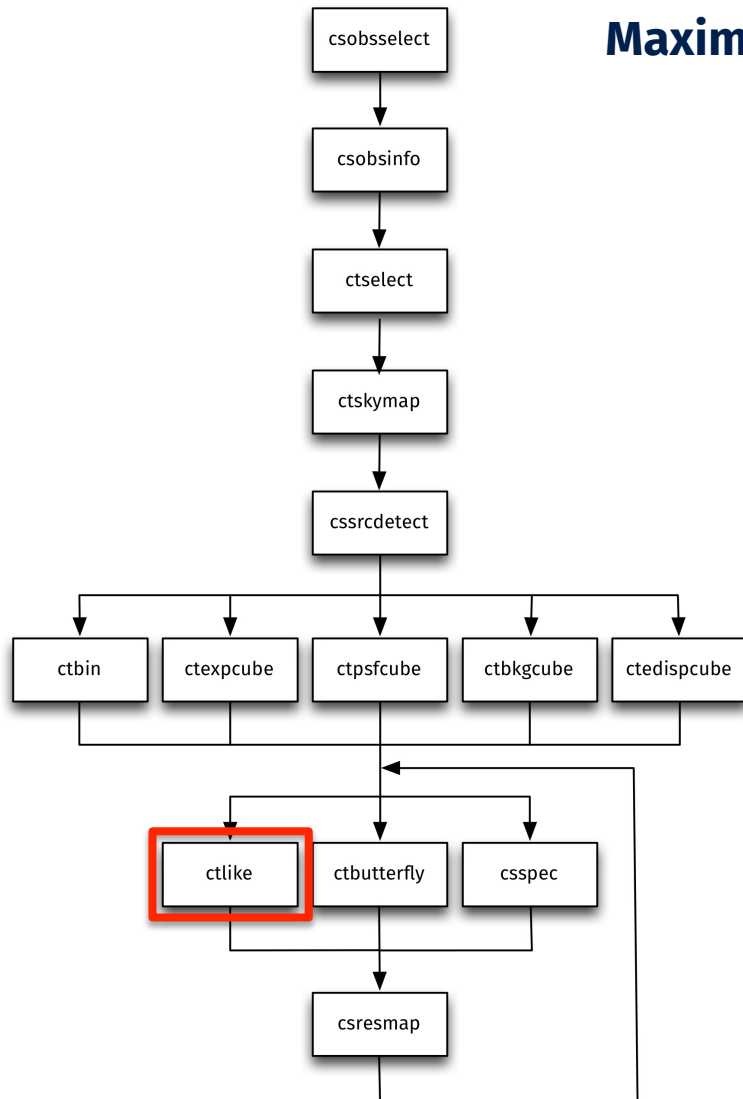
```
$ ctpsfcube
```

```
Input event list or observation definition XML file [NONE] obs_selected.xml  
Input counts cube file to extract PSF cube definition [NONE]  
First coordinate of image center in degrees (RA or galactic l) (0-360) [83.63] 284.0  
Second coordinate of image center in degrees (DEC or galactic b) (-90-90) [22.01] 0.0  
Projection method (AIT|AZP|CAR|GLS|MER|MOL|SFL|SIN|STG|TAN) [CAR]  
Coordinate system (CEL - celestial, GAL - galactic) (CEL|GAL) [CEL] GAL  
Image scale (in degrees/pixel) [1.0]  
Size of the X axis in pixels [10]  
Size of the Y axis in pixels [10]  
Lower energy limit (TeV) [0.1]  
Upper energy limit (TeV) [100.0]  
Number of energy bins [20]  
Output PSF cube file [psfcube.fits]
```

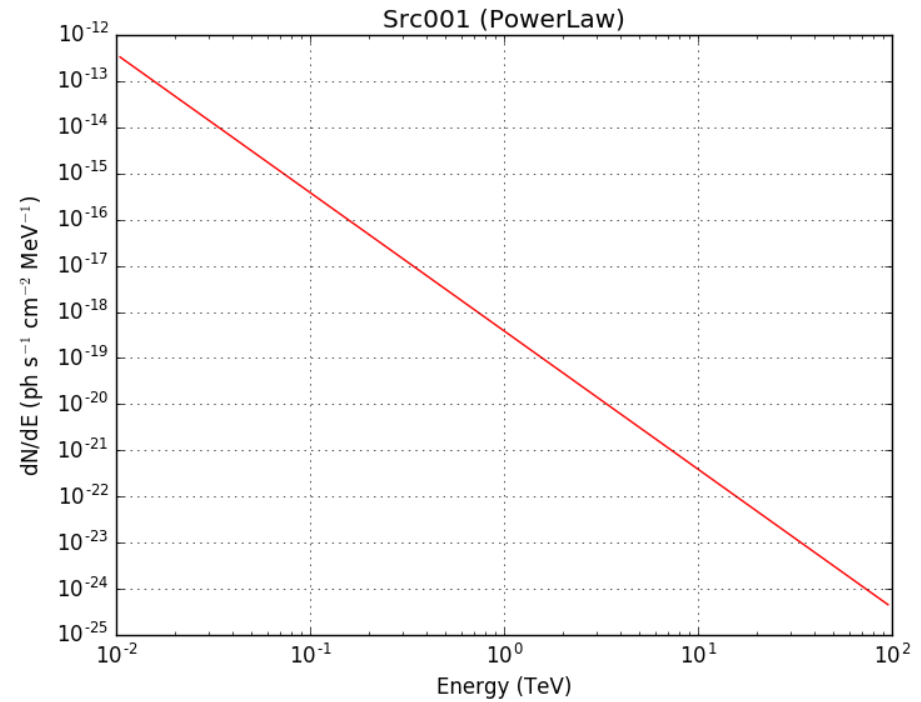
```
$ ctbkgcube
```

```
Input event list or observation definition XML file [NONE] obs_selected.xml  
Input counts cube file to extract background cube definition [NONE] cntcube.fits  
Input model definition XML file [NONE] models.xml  
Output background cube file [bkgcube.fits]  
Output model definition XML file [NONE] models_cube.xml
```

Maximum likelihood fitting



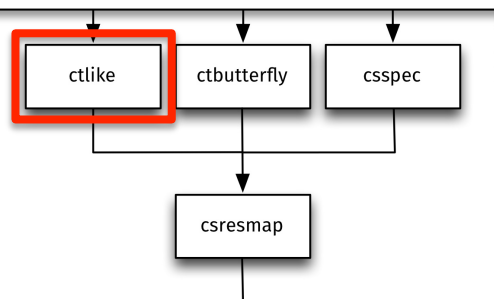
Maximum likelihood fitting



Maximum likelihood fitting

```
$ ctlike debug=yes
Input event list, counts cube or observation definition XML file [events.fits] cntcube.fits
Input exposure cube file [NONE] expcube.fits
Input PSF cube file [NONE] psfcube.fits
Input background cube file [NONE] bkgcube.fits
Input model definition XML file [$CTTOOLS/share/models/crab.xml] models_cube.xml
Output model definition XML file [crab_results.xml] results.xml

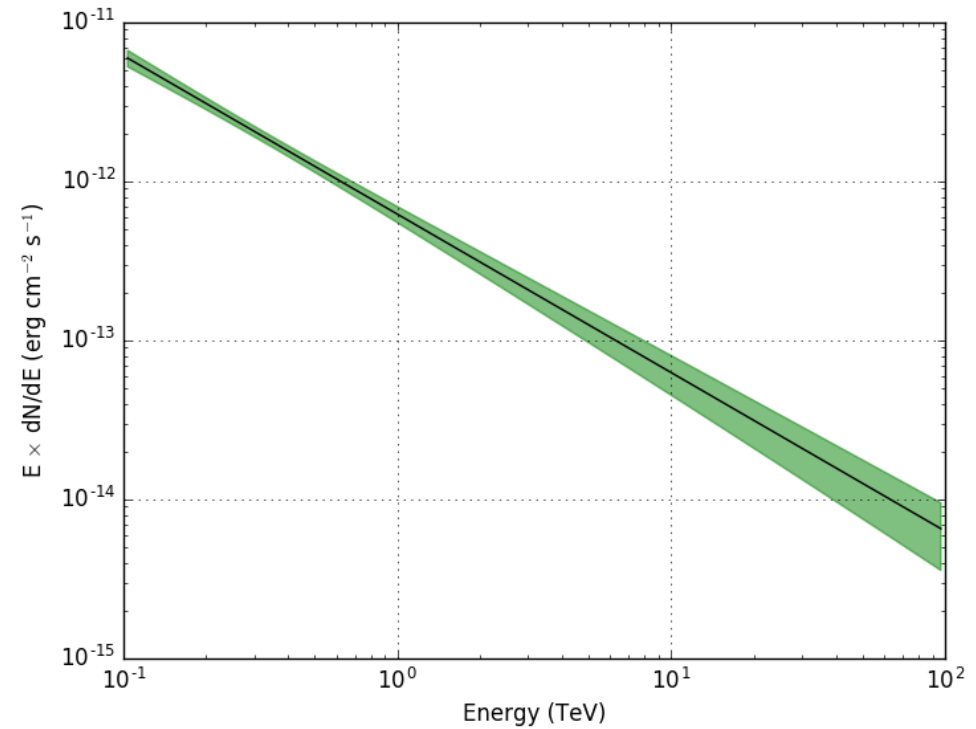
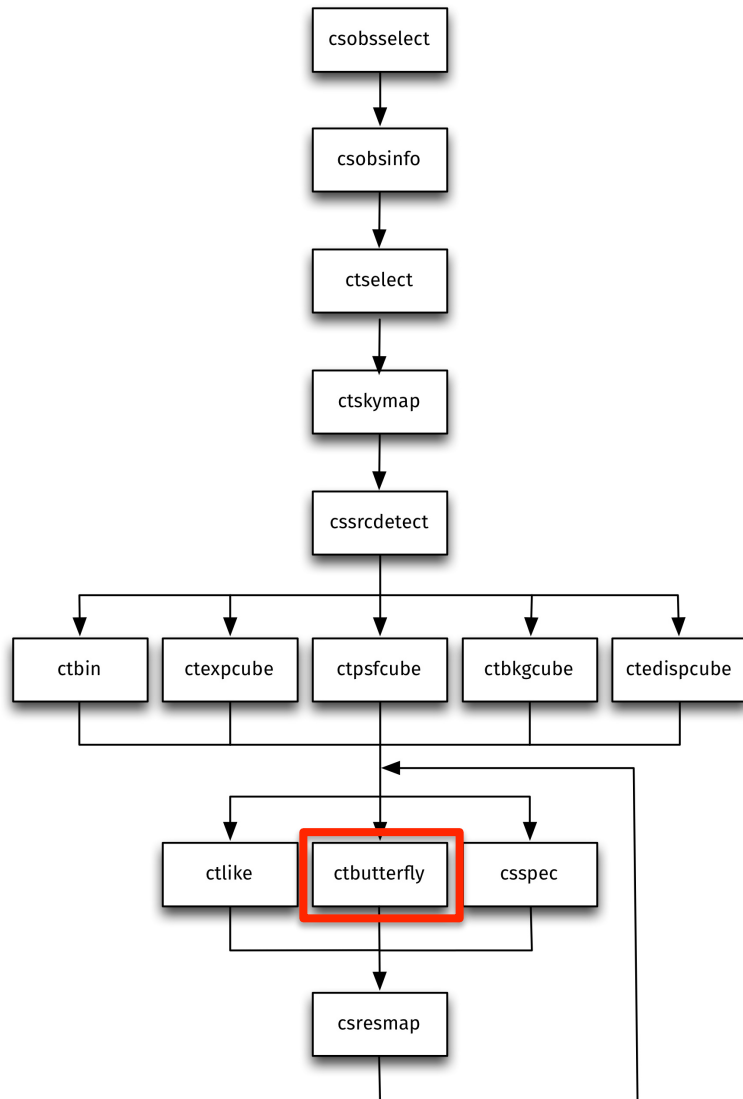
2017-09-29T10:14:03: >Iteration 0: -logL=162916.514, Lambda=1.0e-03
2017-09-29T10:14:04: >Iteration 1: -logL=162674.679, Lambda=1.0e-03, delta=241.834, step=1.0e+00, max(|grad|)=-386.499338 [Prefactor:6]
2017-09-29T10:14:06: >Iteration 2: -logL=162654.758, Lambda=1.0e-04, delta=19.921, step=1.0e+00, max(|grad|)=370.071145 [DEC:1]
2017-09-29T10:14:07: >Iteration 3: -logL=162646.911, Lambda=1.0e-05, delta=7.848, step=1.0e+00, max(|grad|)=363.694688 [DEC:1]
2017-09-29T10:14:09: >Iteration 4: -logL=162641.551, Lambda=1.0e-06, delta=5.360, step=1.0e+00, max(|grad|)=316.982189 [DEC:1]
2017-09-29T10:14:10: >Iteration 5: -logL=162638.318, Lambda=1.0e-07, delta=3.233, step=1.0e+00, max(|grad|)=257.876057 [DEC:1]
2017-09-29T10:14:12: >Iteration 6: -logL=162636.578, Lambda=1.0e-08, delta=1.740, step=1.0e+00, max(|grad|)=194.922043 [DEC:1]
2017-09-29T10:14:13: >Iteration 7: -logL=162635.713, Lambda=1.0e-09, delta=0.865, step=1.0e+00, max(|grad|)=148.734927 [DEC:1]
2017-09-29T10:14:15: >Iteration 8: -logL=162635.311, Lambda=1.0e-10, delta=0.402, step=1.0e+00, max(|grad|)=111.261327 [DEC:1]
2017-09-29T10:14:16: >Iteration 9: -logL=162635.111, Lambda=1.0e-11, delta=0.200, step=1.0e+00, max(|grad|)=83.906156 [DEC:1]
2017-09-29T10:14:18: >Iteration 10: -logL=162635.008, Lambda=1.0e-12, delta=0.103, step=1.0e+00, max(|grad|)=65.175372 [DEC:1]
2017-09-29T10:14:19: >Iteration 11: -logL=162634.951, Lambda=1.0e-13, delta=0.057, step=1.0e+00, max(|grad|)=54.792776 [DEC:1]
2017-09-29T10:14:21: >Iteration 12: -logL=162634.913, Lambda=1.0e-14, delta=0.039, step=1.0e+00, max(|grad|)=46.186164 [DEC:1]
2017-09-29T10:14:22: >Iteration 13: -logL=162634.889, Lambda=1.0e-15, delta=0.024, step=1.0e+00, max(|grad|)=30.334885 [DEC:1]
2017-09-29T10:14:24: >Iteration 14: -logL=162634.876, Lambda=1.0e-16, delta=0.012, step=1.0e+00, max(|grad|)=30.327022 [DEC:1]
2017-09-29T10:14:25: >Iteration 15: -logL=162634.862, Lambda=1.0e-17, delta=0.014, step=1.0e+00, max(|grad|)=29.326994 [DEC:1]
2017-09-29T10:14:26: >Iteration 16: -logL=162634.853, Lambda=1.0e-18, delta=0.009, step=1.0e+00, max(|grad|)=17.034481 [DEC:1]
2017-09-29T10:14:28: >Iteration 17: -logL=162634.849, Lambda=1.0e-19, delta=0.004, step=1.0e+00, max(|grad|)=14.067471 [DEC:1]
```



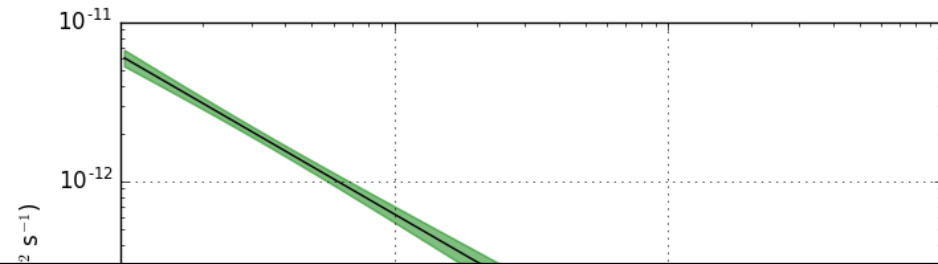
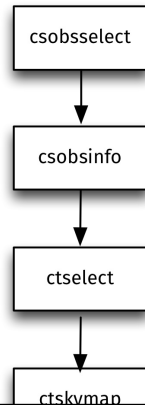
Maximum likelihood fitting

```
2017-09-29T10:14:29: === GOptimizerLM ===
2017-09-29T10:14:29: Optimized function value ... 162634.849
2017-09-29T10:14:29: Absolute precision ..... 0.005
2017-09-29T10:14:29: Acceptable value decrease .. 2
2017-09-29T10:14:29: Optimization status ..... converged
2017-09-29T10:14:29: Number of parameters ..... 10
2017-09-29T10:14:29: Number of free parameters .. 6
2017-09-29T10:14:29: Number of iterations ..... 17
2017-09-29T10:14:29: Lambda ..... 1e-20
2017-09-29T10:14:29: Maximum log likelihood .... -162634.849
2017-09-29T10:14:29: Observed events (Nobs) ... 82861.000
2017-09-29T10:14:29: Predicted events (Npred) .. 82860.995 (Nobs - Npred = 0.00502115531708114)
2017-09-29T10:14:29: === GModels ===
2017-09-29T10:14:29: Number of models ..... 2
2017-09-29T10:14:29: Number of parameters ..... 10
2017-09-29T10:14:29: === GModelSky ===
2017-09-29T10:14:29: Name ..... Src001
2017-09-29T10:14:29: Instruments ..... all
2017-09-29T10:14:29: Instrument scale factors .. unity
2017-09-29T10:14:29: Observation identifiers ... all
2017-09-29T10:14:29: Model type ..... PointSource
2017-09-29T10:14:29: Model components ..... "PointSource" * "PowerLaw" * "Constant"
2017-09-29T10:14:29: Number of parameters ..... 6
2017-09-29T10:14:29: Number of spatial par's ... 2
2017-09-29T10:14:29: RA ..... 155.830563187239 +/- 0.00703462449391177 deg (free,scale=1)
2017-09-29T10:14:29: DEC ..... -57.7562830556977 +/- 0.00367619623578647 deg (free,scale=1)
2017-09-29T10:14:29: Number of spectral par's ... 3
2017-09-29T10:14:29: Prefactor ..... 1.435495936e-17 +/- 1.116843125e-18 [0,infty[ ph/cm2/s/MeV (free,scale=5.7e-18,gradient)
2017-09-29T10:14:29: Index ..... -2.99659451192301 +/- 0.0791118536010512 [10,-10] (free,scale=-2.48,gradient)
2017-09-29T10:14:29: PivotEnergy ..... 300000 MeV (fixed,scale=300000,gradient)
2017-09-29T10:14:29: Number of temporal par's ... 1
2017-09-29T10:14:29: Normalization ..... 1 (relative value) (fixed,scale=1,gradient)
2017-09-29T10:14:29: === GCTAModelCubeBackground ===
2017-09-29T10:14:29: Name ..... BackgroundModel
2017-09-29T10:14:29: Instruments ..... CTA, HESS, MAGIC, VERITAS
2017-09-29T10:14:29: Instrument scale factors .. unity
2017-09-29T10:14:29: Observation identifiers ... all
2017-09-29T10:14:29: Model type ..... "PowerLaw" * "Constant"
2017-09-29T10:14:29: Number of parameters ..... 4
2017-09-29T10:14:29: Number of spectral par's ... 3
2017-09-29T10:14:29: Prefactor ..... 1.09431953979467 +/- 0.00933498203600886 [0.01,100] ph/cm2/s/MeV (free,scale=1,gradient)
2017-09-29T10:14:29: Index ..... 0.0839727564602386 +/- 0.00489569197634214 [-5,5] (free,scale=1,gradient)
2017-09-29T10:14:29: PivotEnergy ..... 1000000 MeV (fixed,scale=1000000,gradient)
2017-09-29T10:14:29: Number of temporal par's ... 1
2017-09-29T10:14:29: Normalization ..... 1 (relative value) (fixed,scale=1,gradient)
```

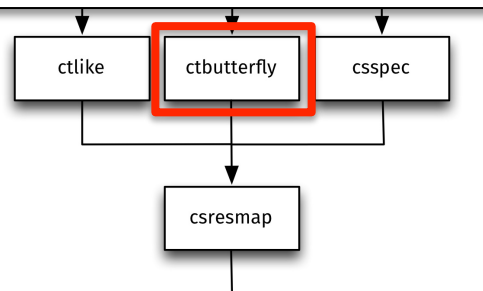
Generating a butterfly diagram



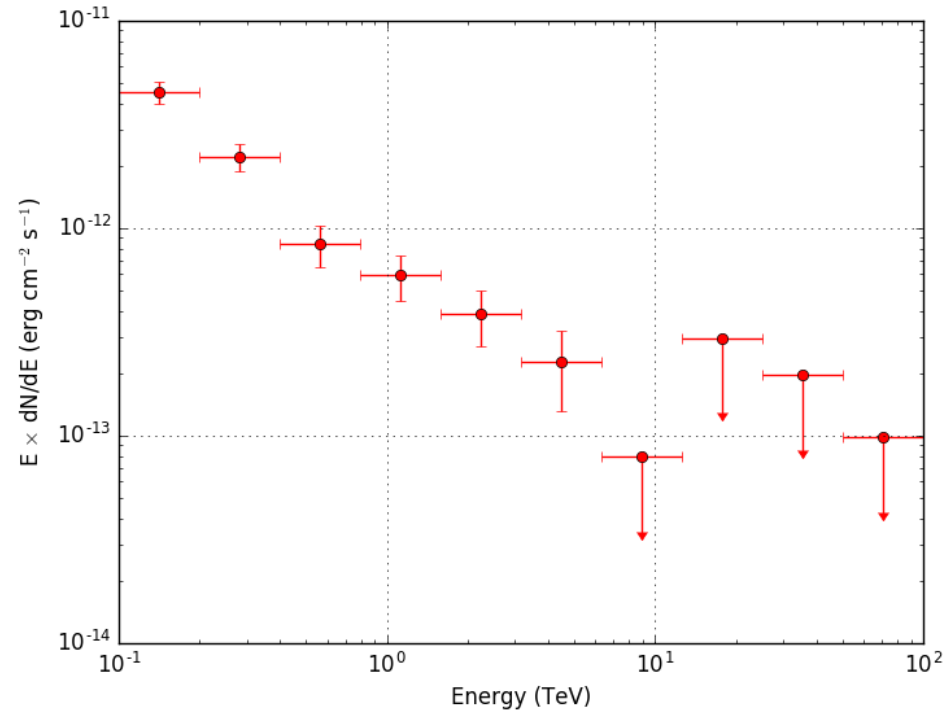
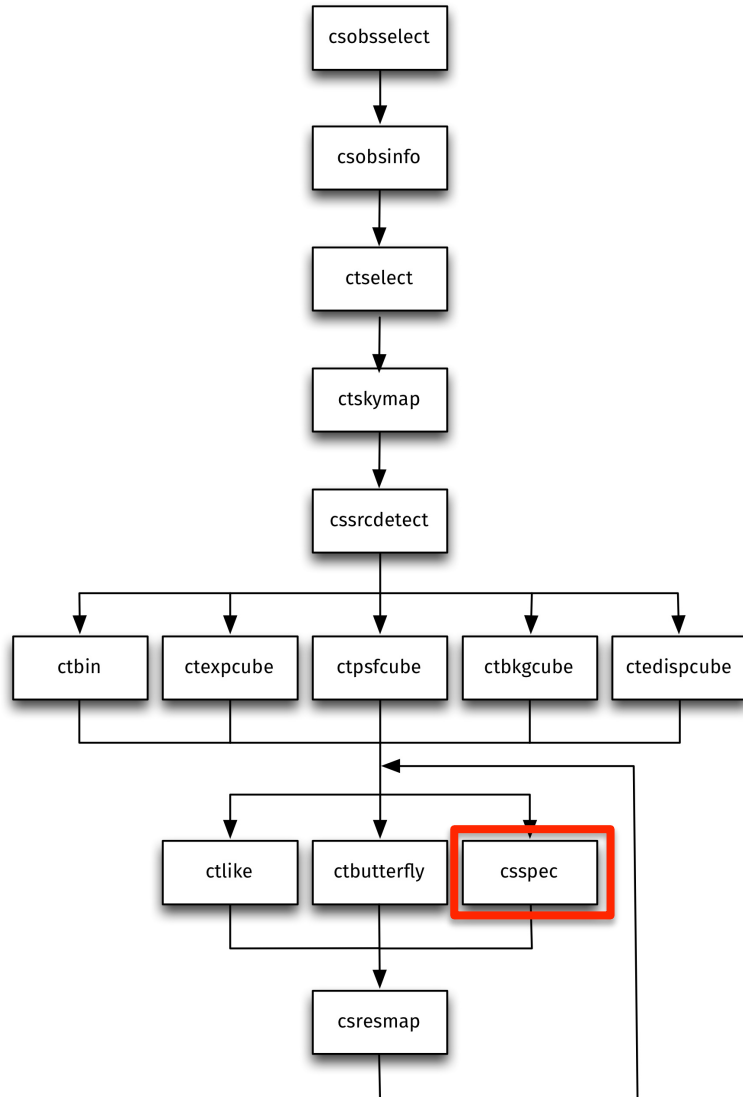
Generating a butterfly diagram



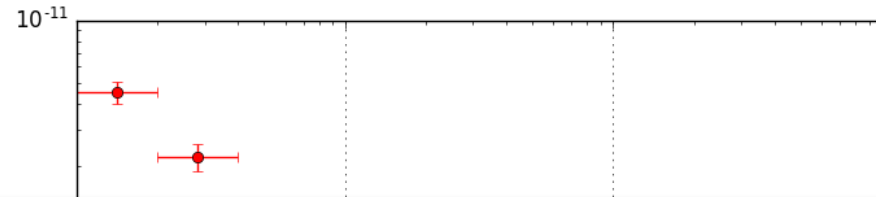
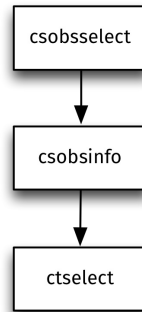
```
$ ctbutterfly
Input event list, counts cube or observation definition XML file [events.fits] cntcube.fits
Input exposure cube file [NONE] expcube.fits
Input PSF cube file [NONE] psfcube.fits
Input background cube file [NONE] bkgcube.fits
Source of interest [Crab] Src001
Input model definition XML file [$CTTOOLS/share/models/crab.xml] results.xml
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Output ASCII file [butterfly.txt]
```



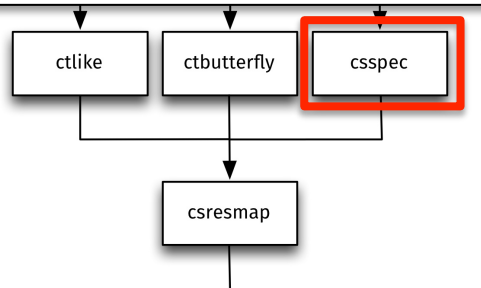
Generating a SED



Generating a SED

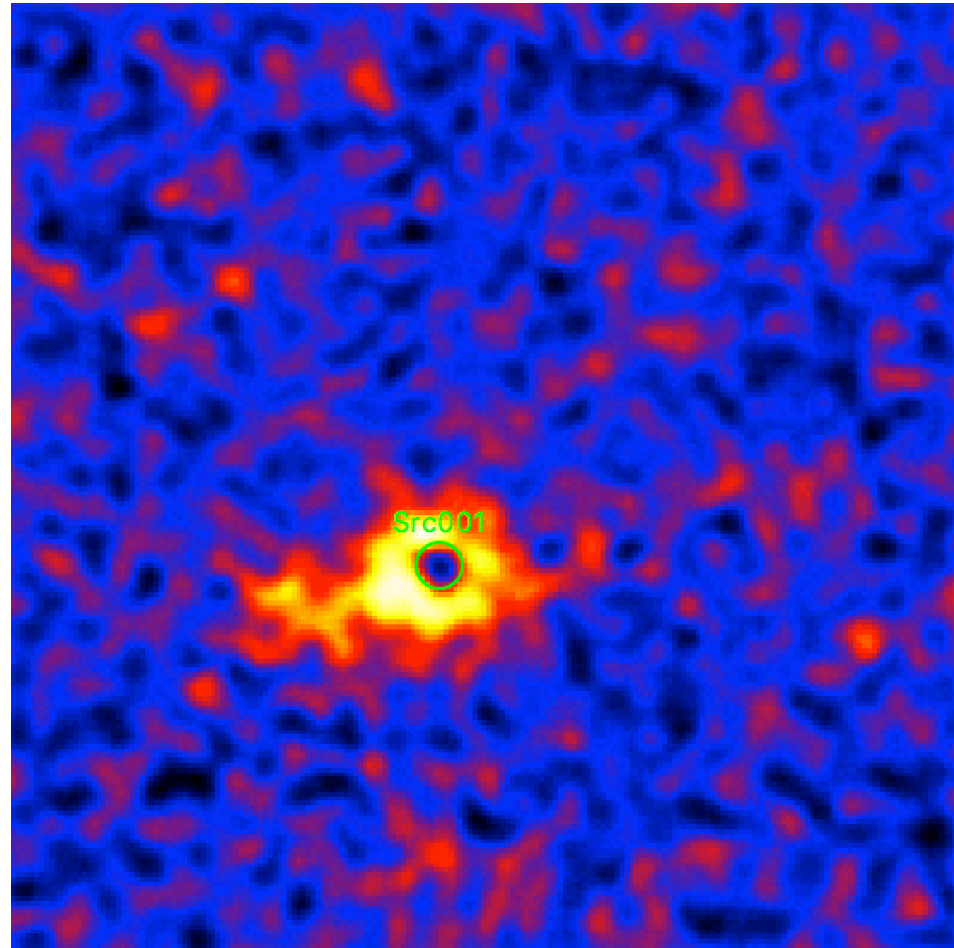
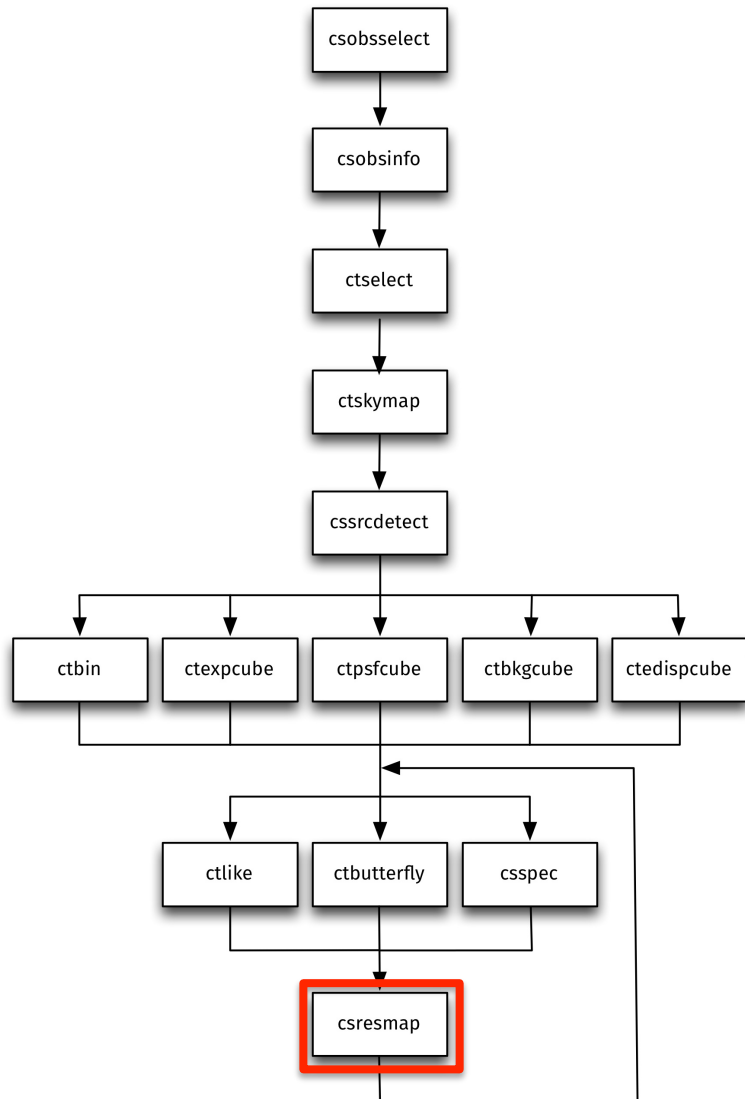


```
$ csspec
Input event list, counts cube, or observation definition XML file [events.fits] cntcube.fits
Input exposure cube file [NONE] expcube.fits
Input PSF cube file [NONE] psfcube.fits
Input background cube file [NONE] bkgcube.fits
Input model definition XML file [$CTTOOLS/share/models/crab.xml] results.xml
Source name [Crab] Src001
Binning algorithm (LIN|LOG|FILE) [LOG]
Lower energy limit (TeV) [0.1]
Upper energy limit (TeV) [100.0]
Number of energy bins [20] 10
Output spectrum file [spectrum.fits]
```

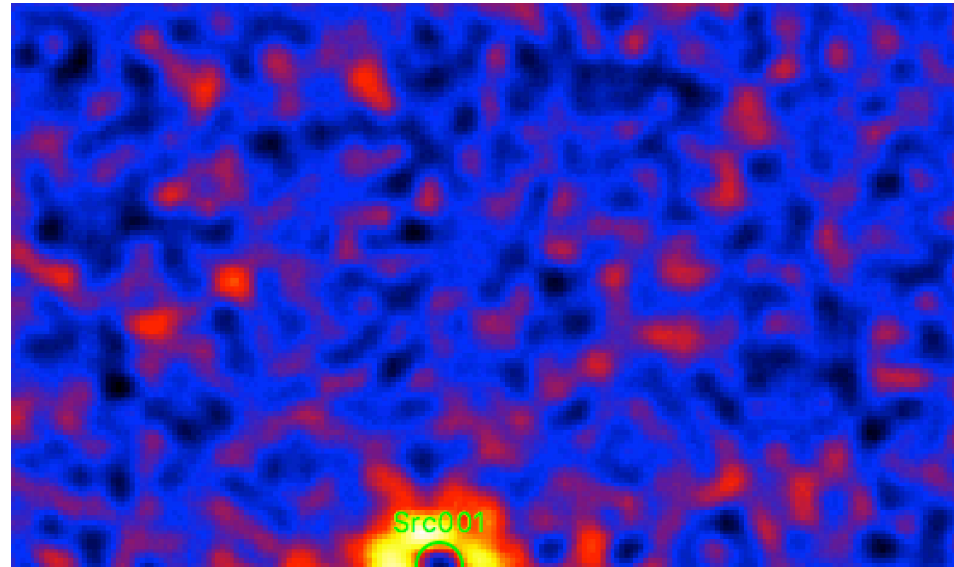
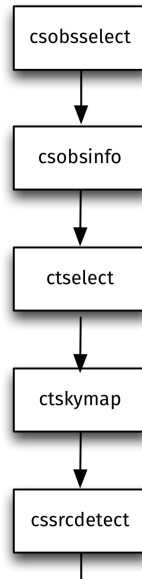


Energy (TeV)

Inspecting the residuals



Inspecting the residuals

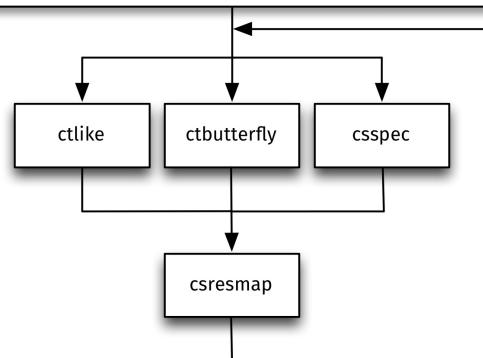


```
$ csresmap
Input event list, counts cube, or observation definition XML file [events.fits] cntcube.fits
Input model cube file (generated with ctmodel) [NONE]
Input exposure cube file [NONE] expcube.fits
Input PSF cube file [NONE] psfcube.fits
Input background cube file [NONE] bkgcube.fits
Input model definition XML file [$CTOOLS/share/models/crab.xml] results.xml
Residual map computation algorithm (SUB|SUBDIV|SUBDIVSQRT|SIGNIFICANCE) [SIGNIFICANCE]
Output residual map file [resmap.fits]
```

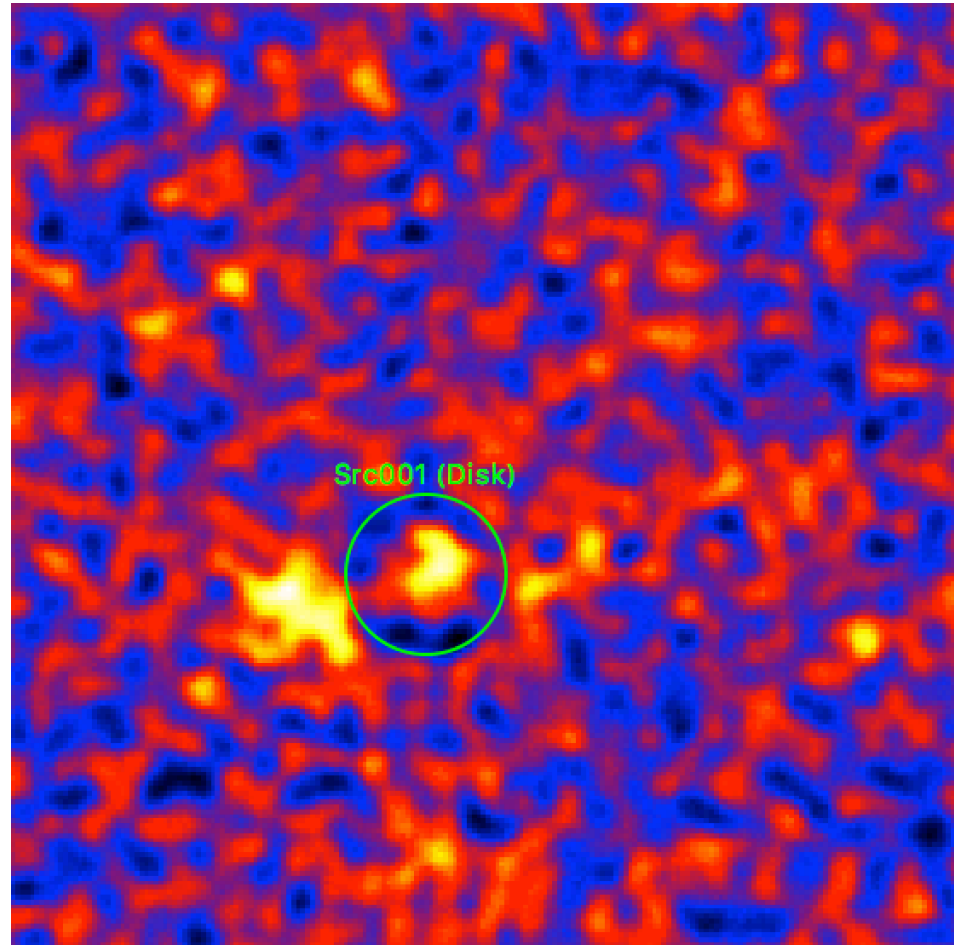
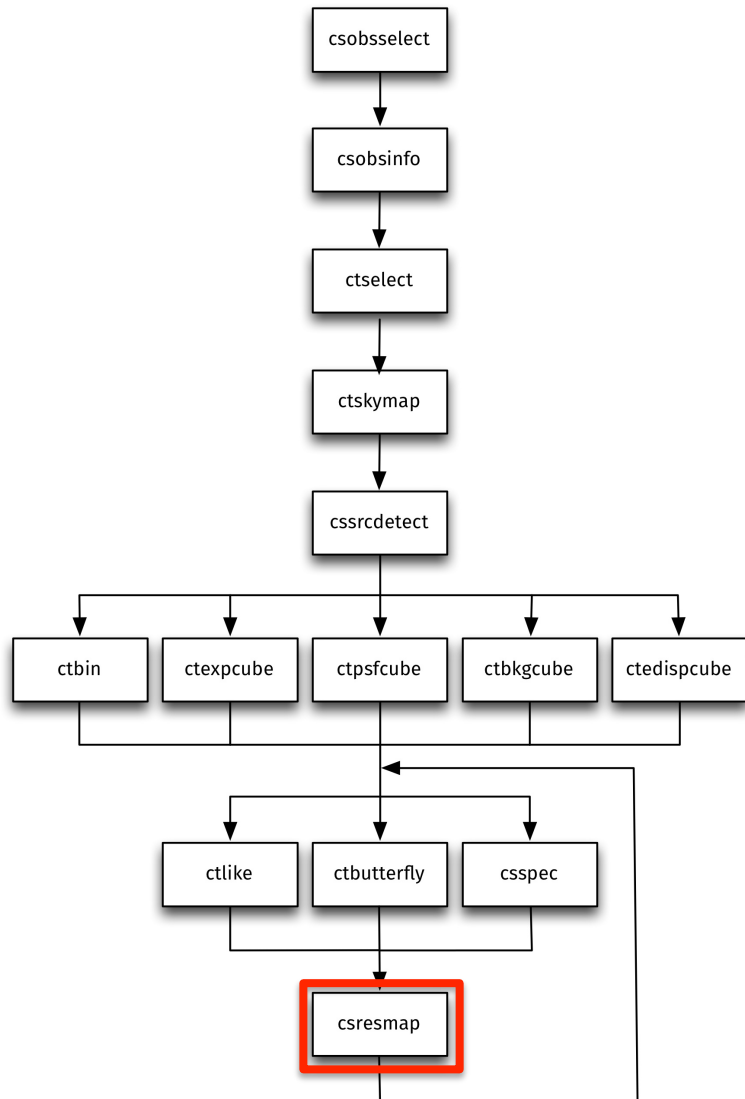


Improving the source model

```
<?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="-4.03225806" max="4.03225806" free="1" />
      <parameter name="PivotEnergy" value="1" scale="300000" free="0" />
    </spectrum>
    <spatialModel type="RadialDisk">
      <parameter name="RA" value="155.730" scale="1" free="1" />
      <parameter name="DEC" value="-57.719" scale="1" free="1" />
      <parameter name="Radius" value="0.1" scale="1" min="0.0001" max="1.0" free="1" />
    </spatialModel>
  </source>
  <source name="BackgroundModel" type="CTACubeBackground" instrument="CTA,HESS,MAGIC,VERITAS">
    <spectrum type="PowerLaw">
      <parameter name="Prefactor" value="1" error="0" scale="1" min="0.01" max="100" free="1" />
      <parameter name="Index" value="0" error="0" scale="1" min="-5" max="5" free="1" />
      <parameter name="PivotEnergy" value="1" scale="1000000" free="0" />
    </spectrum>
  </source>
</source_library>
```

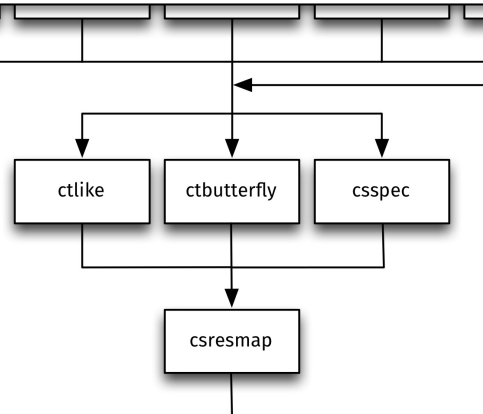


Inspecting the residuals

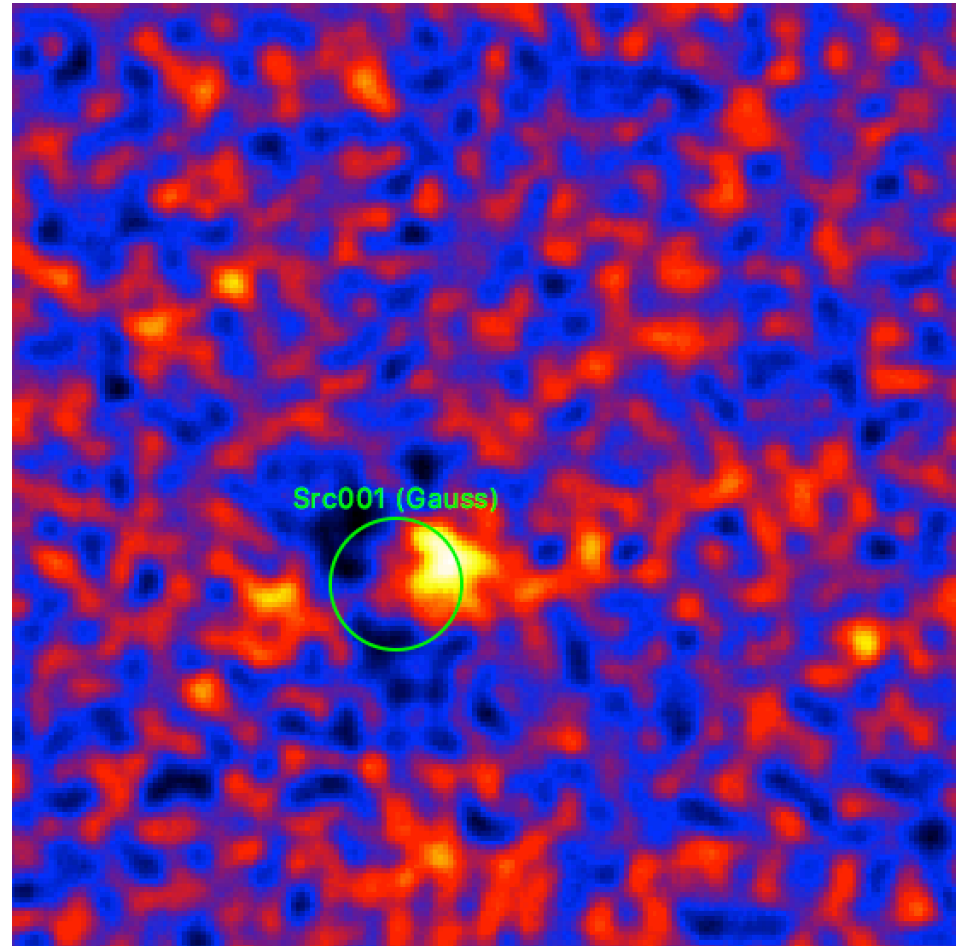
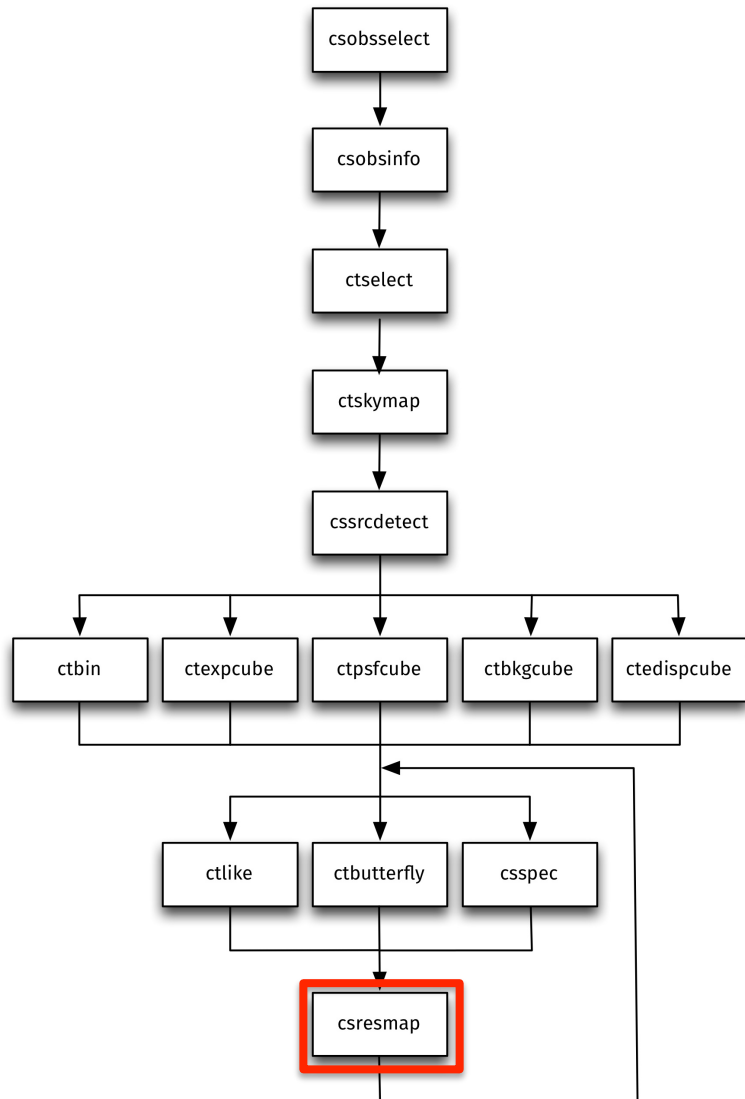


Improving the source model

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<source_library title="source library">
  <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="-4.03225806" max="4.03225806" free="1" />
    <parameter name="PivotEnergy" value="1" scale="300000" free="0" />
  </spectrum>
  <spatialModel type="RadialGaussian">
    <parameter name="RA" value="155.730" scale="1" free="1" />
    <parameter name="DEC" value="-57.719" scale="1" free="1" />
    <parameter name="Sigma" value="0.1" scale="1" min="0.0001" max="1.0" free="1" />
  </spatialModel>
</source>
<source name="BackgroundModel" type="CTACubeBackground" instrument="CTA,HESS,MAGIC,VERITAS">
  <spectrum type="PowerLaw">
    <parameter name="Prefactor" value="1" error="0" scale="1" min="0.01" max="100" free="1" />
    <parameter name="Index" value="0" error="0" scale="1" min="-5" max="5" free="1" />
    <parameter name="PivotEnergy" value="1" scale="1000000" free="0" />
  </spectrum>
</source>
</source_library>
```

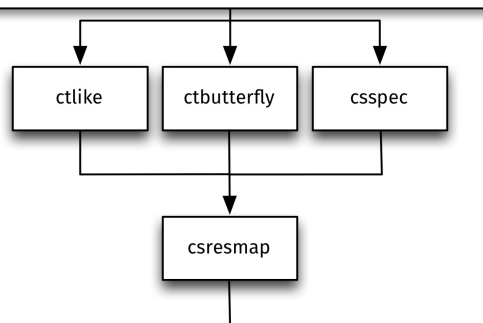


Inspecting the residuals

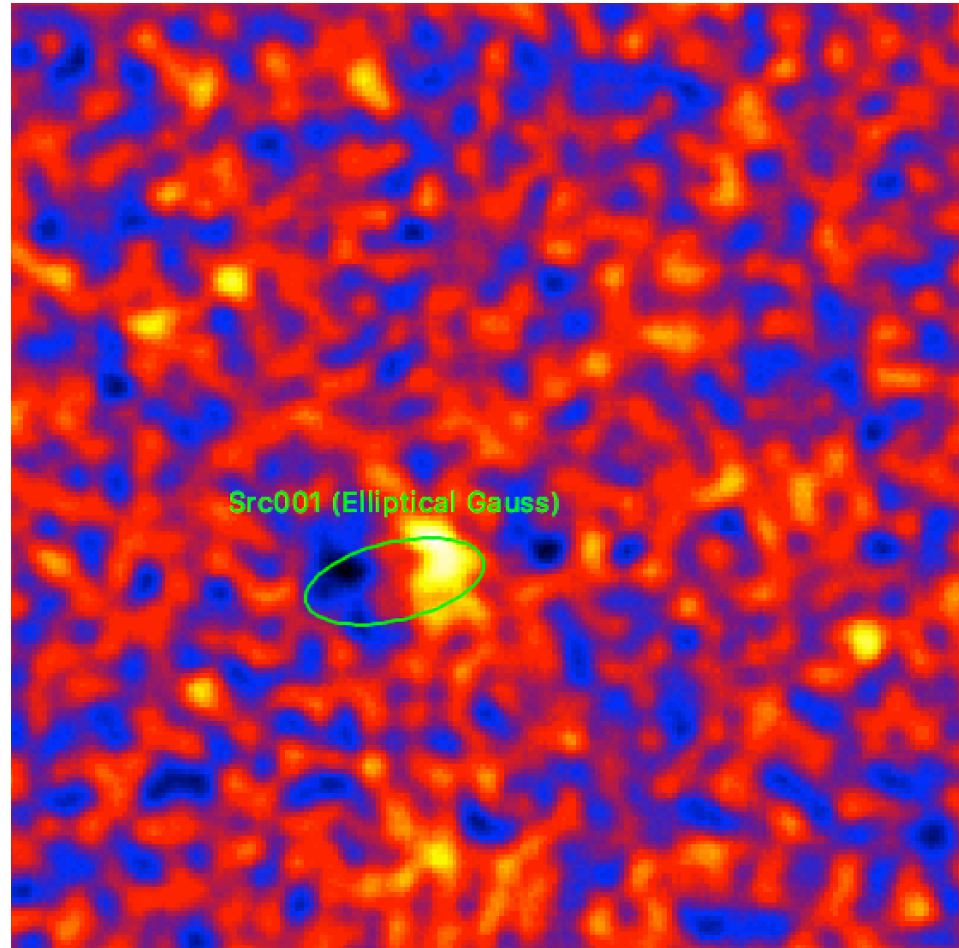
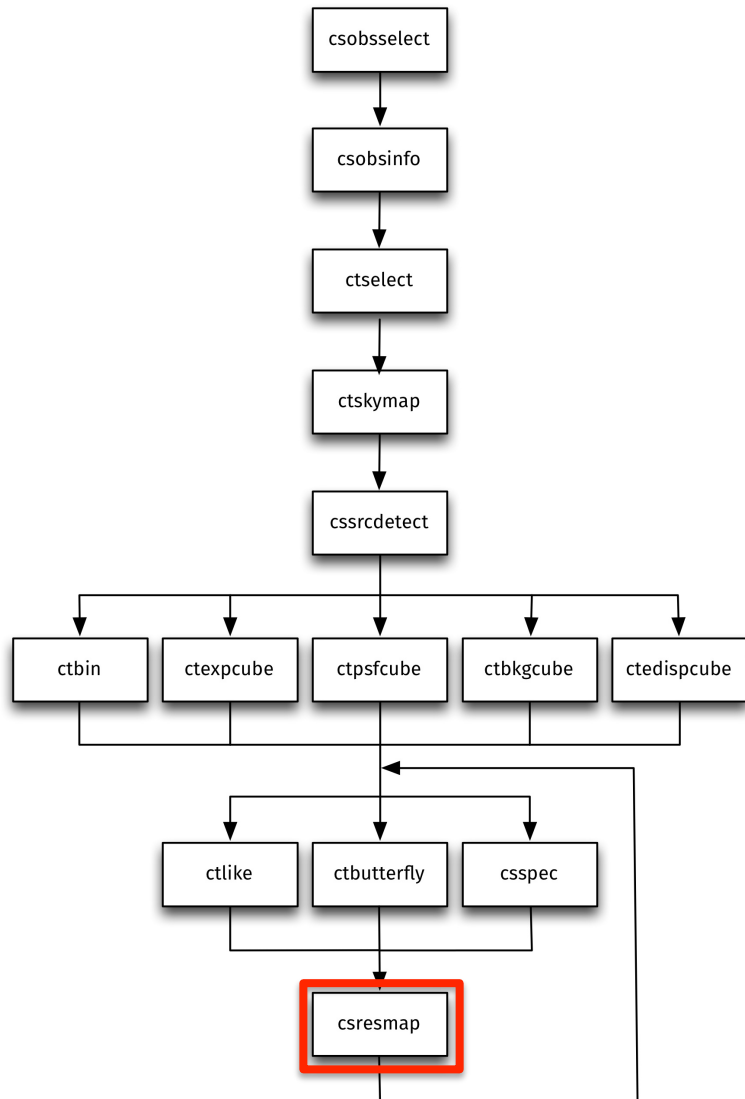


Improving the source model

```
<?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="-4.03225806" max="4.03225806" free="1" />
      <parameter name="PivotEnergy" value="1" scale="300000" free="0" />
    </spectrum>
    <spatialModel type="EllipticalGauss">
      <parameter name="RA" value="155.730" scale="1" free="1" />
      <parameter name="DEC" value="-57.719" scale="1" free="1" />
      <parameter name="PA" value="45.0" scale="1" min="-360.0" max="+360.0" free="1" />
      <parameter name="MinorRadius" value="0.2" scale="1" min="0.05" max="1.0" free="1" />
      <parameter name="MajorRadius" value="0.4" scale="1" min="0.1" max="1.0" free="1" />
    </spatialModel>
  </source>
  <source name="BackgroundModel" type="CTACubeBackground" instrument="CTA,HESS,MAGIC,VERITAS">
    <spectrum type="PowerLaw">
      <parameter name="Prefactor" value="1" error="0" scale="1" min="0.01" max="100" free="1" />
      <parameter name="Index" value="0" error="0" scale="1" min="-5" max="5" free="1" />
      <parameter name="PivotEnergy" value="1" scale="1000000" free="0" />
    </spectrum>
  </source>
</source_library>
```

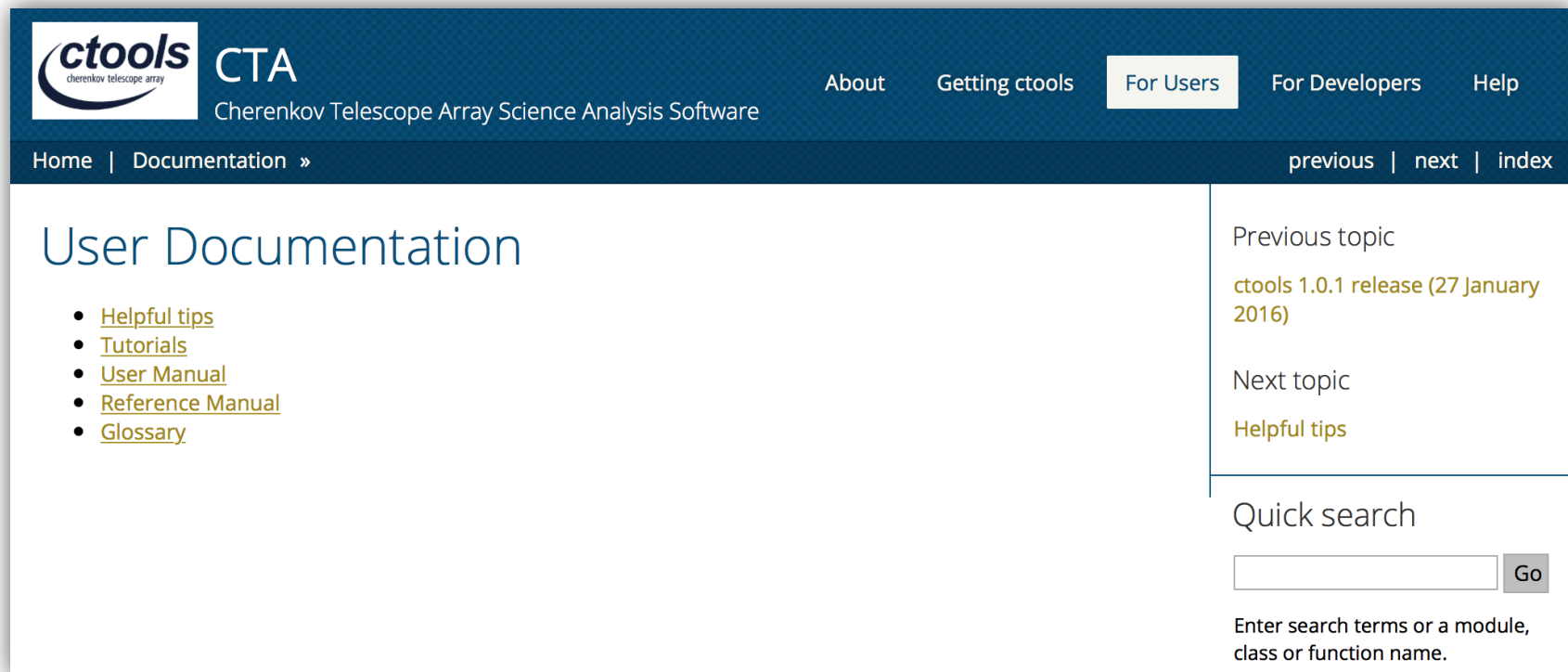


Inspecting the residuals



How do I get help?

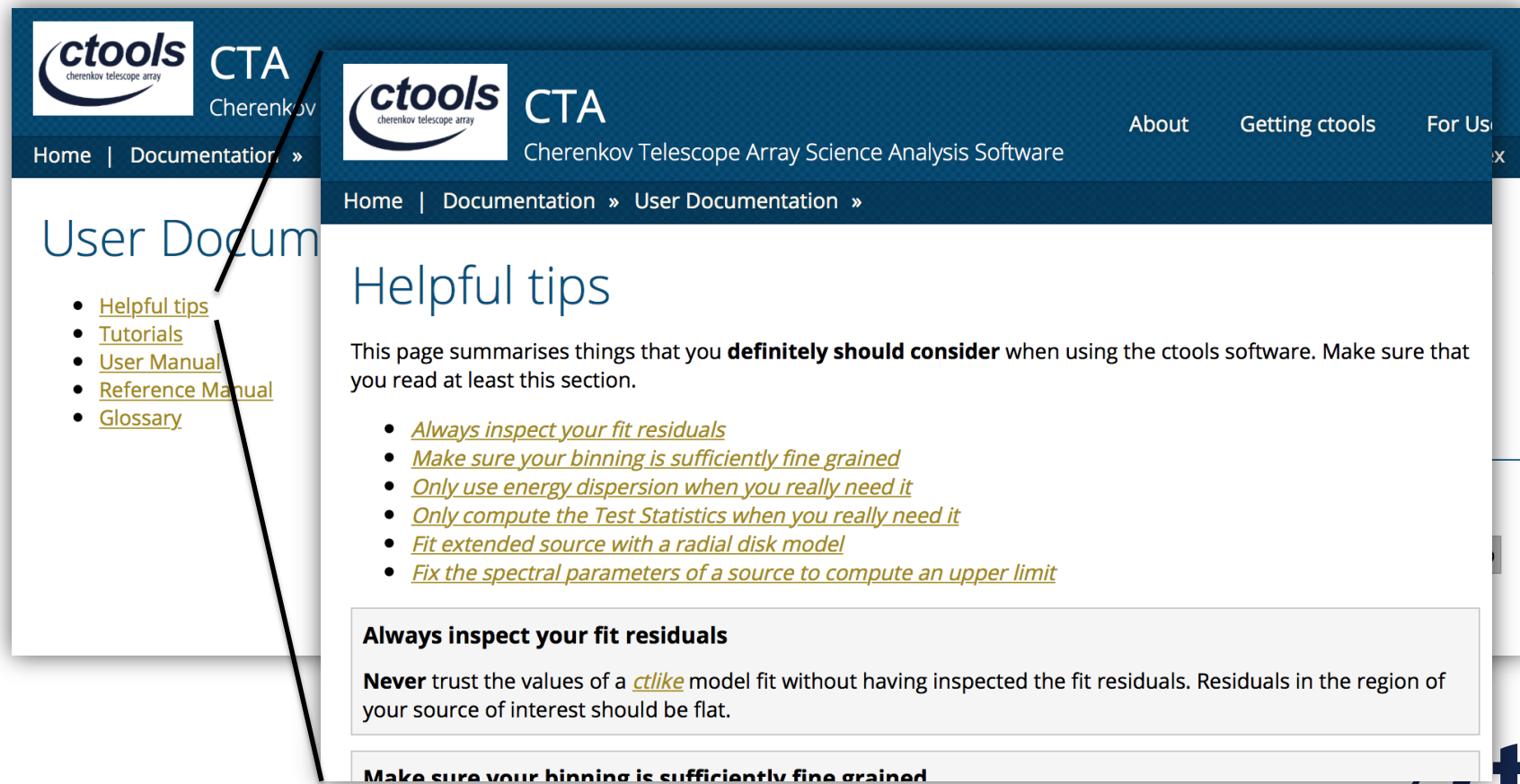
- Read the ctools User Documentation
 - <http://cta.irap.omp.eu/ctools/users/index.html>



The screenshot shows the 'User Documentation' page of the ctools website. The header includes the ctools logo and navigation links: 'About', 'Getting ctools', 'For Users' (highlighted), 'For Developers', and 'Help'. Below the header, there are links for 'Home' and 'Documentation', and navigation for 'previous', 'next', and 'index'. The main content area is titled 'User Documentation' and contains a list of links: 'Helpful tips', 'Tutorials', 'User Manual', 'Reference Manual', and 'Glossary'. The sidebar on the right has sections for 'Previous topic' (ctools 1.0.1 release (27 January 2016)), 'Next topic' (Helpful tips), and a 'Quick search' box with a 'Go' button and a search prompt: 'Enter search terms or a module, class or function name.'

How do I get help?

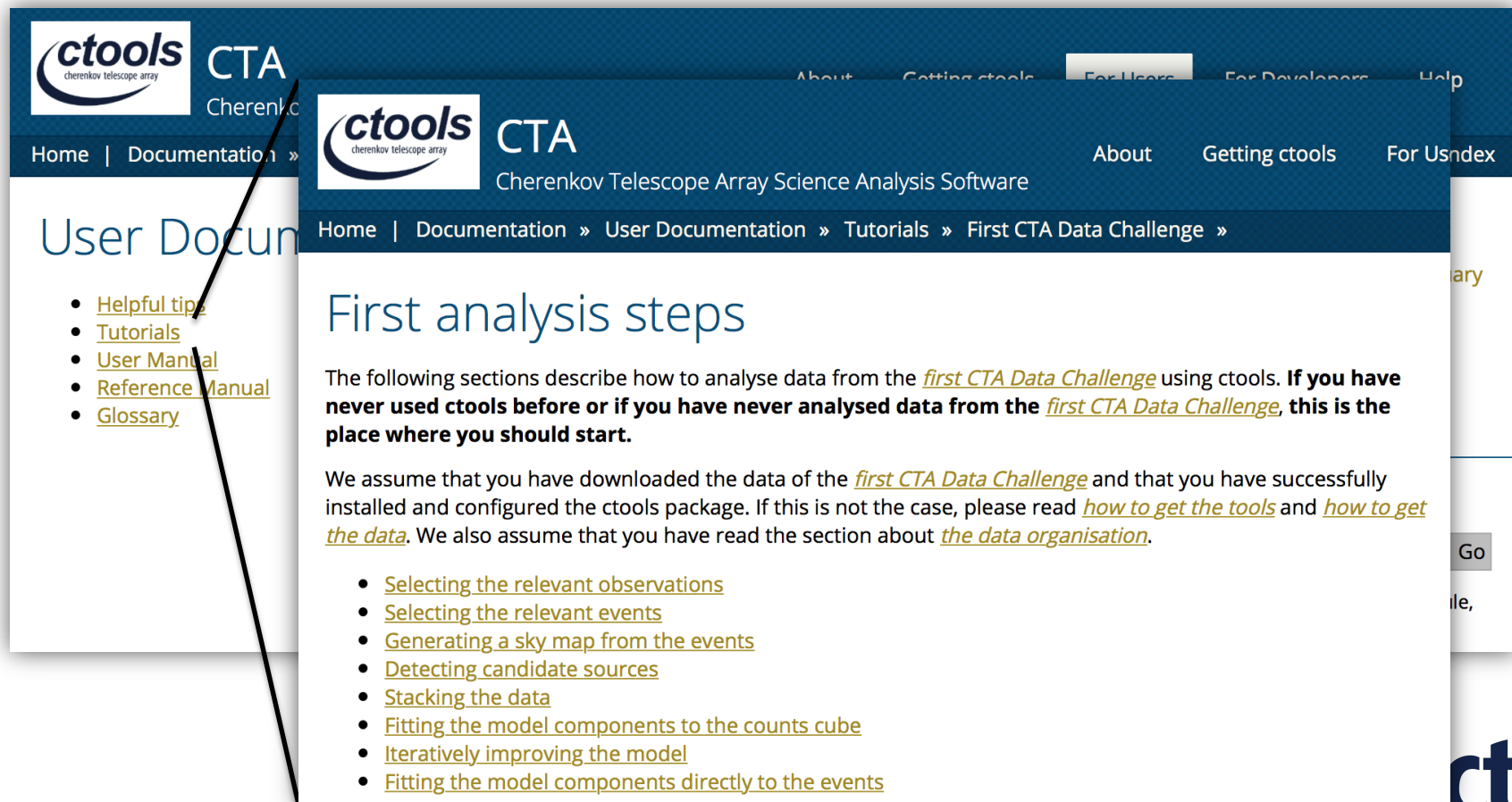
- Read the ctools User Documentation
 - <http://cta.irap.omp.eu/ctools/users/index.html>



The screenshot shows the ctools User Documentation website. The main navigation bar includes 'Home | Documentation »' and 'User Documentation »'. The page title is 'User Documentation'. A sidebar on the left contains a list of links: 'Helpful tips', 'Tutorials', 'User Manual', 'Reference Manual', and 'Glossary'. The main content area is titled 'Helpful tips' and contains the following text: 'This page summarises things that you **definitely should consider** when using the ctools software. Make sure that you read at least this section.' Below this is a list of tips: 'Always inspect your fit residuals', 'Make sure your binning is sufficiently fine grained', 'Only use energy dispersion when you really need it', 'Only compute the Test Statistics when you really need it', 'Fit extended source with a radial disk model', and 'Fix the spectral parameters of a source to compute an upper limit'. A callout box highlights the first tip: 'Always inspect your fit residuals' and provides a warning: 'Never trust the values of a *ctlike* model fit without having inspected the fit residuals. Residuals in the region of your source of interest should be flat.'

How do I get help?

- Read the ctools User Documentation
 - <http://cta.irap.omp.eu/ctools/users/index.html>



The screenshot displays the ctools website interface. The top navigation bar includes the ctools logo and the text 'CTA Cherenkov Telescope Array Science Analysis Software'. Below this, a secondary navigation bar lists 'Home | Documentation » User Documentation » Tutorials » First CTA Data Challenge »'. The main content area is titled 'First analysis steps' and contains the following text:

The following sections describe how to analyse data from the *first CTA Data Challenge* using ctools. **If you have never used ctools before or if you have never analysed data from the *first CTA Data Challenge*, this is the place where you should start.**

We assume that you have downloaded the data of the *first CTA Data Challenge* and that you have successfully installed and configured the ctools package. If this is not the case, please read [how to get the tools](#) and [how to get the data](#). We also assume that you have read the section about [the data organisation](#).

- [Selecting the relevant observations](#)
- [Selecting the relevant events](#)
- [Generating a sky map from the events](#)
- [Detecting candidate sources](#)
- [Stacking the data](#)
- [Fitting the model components to the counts cube](#)
- [Iteratively improving the model](#)
- [Fitting the model components directly to the events](#)

On the left side of the page, a sidebar menu lists the following links: [Helpful tips](#), [Tutorials](#), [User Manual](#), [Reference Manual](#), and [Glossary](#). A black arrow points from the 'User Manual' link in the sidebar to the 'First analysis steps' page content.

How do I get help?

- Read the ctools User Documentation
 - <http://cta.irap.omp.eu/ctools/users/index.html>

The screenshot displays the ctools User Documentation website. The main content area is titled "Analysis cookbook" and includes a sub-header "(27 January)". The text below the title states: "The following sections teach you how to use ctools to address some typical science analysis. The sections provide examples that are based on the data distributed within the CTA Consortium for the *first CTA Data Challenge*. These examples can be easily adapted to any data you have at your disposal."

A list of links is provided, including:

- [Helpful tips](#)
- [Tutorials](#)
- [User Manual](#)
- [Reference Manual](#)
- [Glossary](#)

The "Analysis cookbook" section contains a list of specific topics:

- [How to display the results?](#)
- [How to compute the significance of a source?](#)
- [How to generate a Test Statistic map?](#)
- [How to determine the extension of a source?](#)
- [How to compute upper limits?](#)
- [How to take the energy dispersion into account?](#)
- [How to generate a light curve?](#)
- [How to generate a phase curve of a pulsar?](#)
- [How to exclude bins from a counts cube?](#)
- [How to use Virtual Observatory tools with ctools?](#)
- [How to analyse Fermi-LAT data with ctools?](#)
- [How to analyse COMPTEL data with ctools?](#)
- [How to analyse H.E.S.S. data with ctools?](#)

The website header includes the ctools logo and navigation links: Home | Documentation » User Documentation » Tutorials ». The footer of the page shows the number 55.



How do I get help?

- Read the ctools User Documentation
 - <http://cta.irap.omp.eu/ctools/users/index.html>

The image shows a screenshot of the ctools User Documentation website. The main page is titled "User Document" and has a navigation menu with links for "Helpful tips", "Tutorials", "User Manual", "Reference Manual", and "Glossary". The "Reference Manual" link is highlighted. A zoomed-in view of the "Reference Manual" page is shown, which includes the ctools logo, navigation links, and a list of tools and scripts with their descriptions. The list includes: ctbin, ctbkcube, ctbutterfly, ctubemask, ctediscube, cterror, ctexpcube, ctlike, ctmapcube, ctmodel, ctobssim, ctphase, ctprob, and ctspcube.

ctools
Cherenkov Telescope Array Science Analysis Software

About Getting ctools For Users For Developers Help

Home | Documentation »

User Document

- [Helpful tips](#)
- [Tutorials](#)
- [User Manual](#)
- [Reference Manual](#)
- [Glossary](#)

ctools
Cherenkov Telescope Array Science Analysis Software

About Getting ctools For U

Home | Documentation » User Documentation »

Reference Manual

This manual provides reference information for all ctools and csripts. General information on ctools usage can be found [here](#).

Below you find links to the command line reference for the tools and scripts that are available.

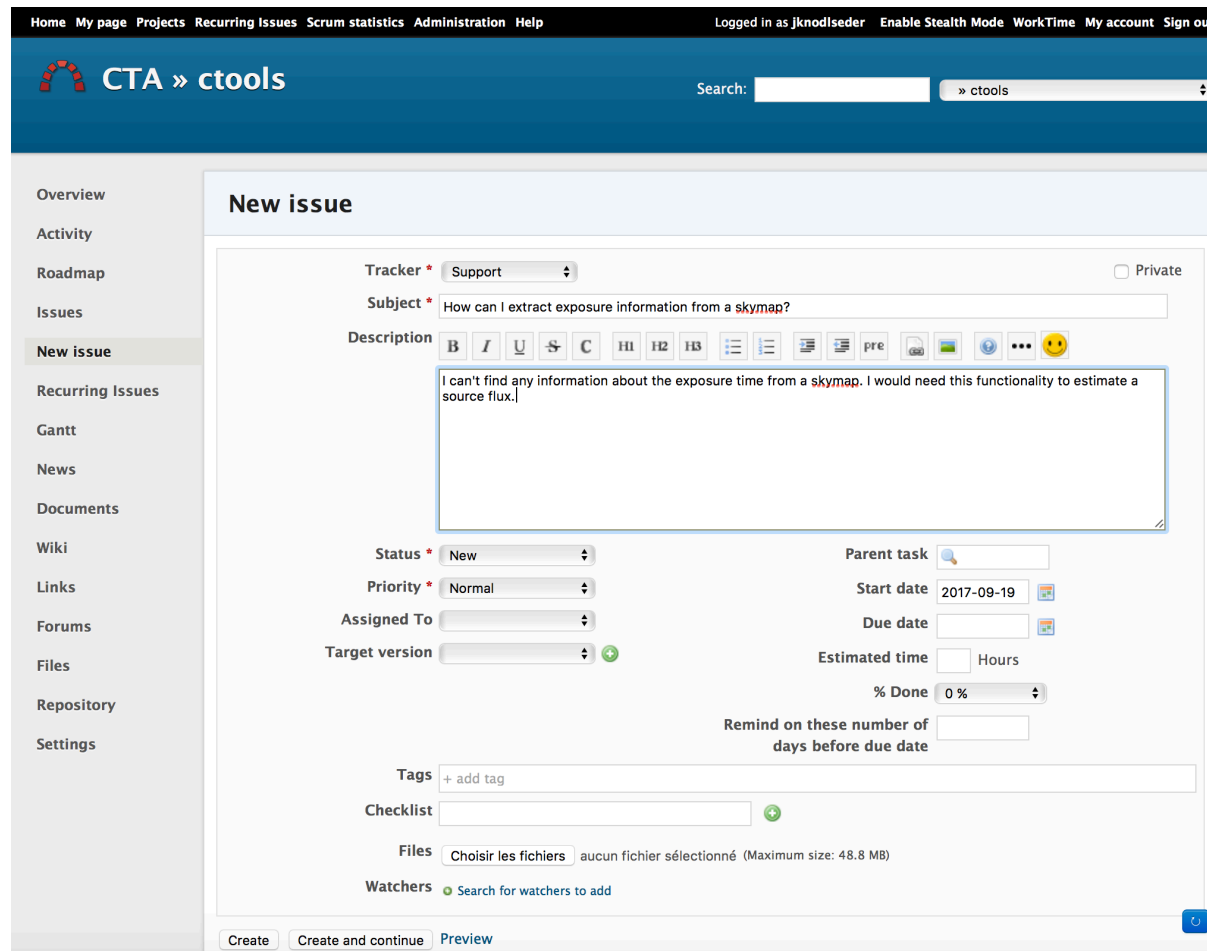
ctools

- [ctbin](#) — Generates counts cube
- [ctbkcube](#) — Generates background cube
- [ctbutterfly](#) — Compute butterfly
- [ctubemask](#) — Filter counts cube
- [ctediscube](#) — Generates energy dispersion cube
- [cterror](#) — Calculates likelihood profile errors
- [ctexpcube](#) — Generates exposure cube
- [ctlike](#) — Performs maximum likelihood fitting
- [ctmapcube](#) — Generates a map cube
- [ctmodel](#) — Computes model counts cube
- [ctobssim](#) — Simulate observations
- [ctphase](#) — Computes the phase of each event
- [ctprob](#) — Computes event probability for a given model
- [ctspcube](#) — Generates point spread function cube

cta

How do I get help?

- Create a “Support” issue on the ctools Redmine
 - <https://cta-redmine.irap.omp.eu/projects/ctools/issues/new>



The screenshot shows the 'New issue' form in the Redmine application. The top navigation bar includes links for Home, My page, Projects, Recurring Issues, Scrum statistics, Administration, and Help. The user is logged in as jknodlseder. The main header shows 'CTA >> ctools' and a search bar. The left sidebar contains navigation options: Overview, Activity, Roadmap, Issues, New issue (selected), Recurring Issues, Gantt, News, Documents, Wiki, Links, Forums, Files, Repository, and Settings. The form fields are as follows:

- Tracker:** Support (dropdown menu)
- Subject:** How can I extract exposure information from a *skymap*? (text input)
- Description:** I can't find any information about the exposure time from a *skymap*. I would need this functionality to estimate a source flux. (rich text editor)
- Status:** New (dropdown menu)
- Priority:** Normal (dropdown menu)
- Assigned To:** (dropdown menu)
- Target version:** (dropdown menu)
- Parent task:** (text input)
- Start date:** 2017-09-19 (calendar icon)
- Due date:** (calendar icon)
- Estimated time:** (text input) Hours
- % Done:** 0% (dropdown menu)
- Remind on these number of days before due date:** (text input)
- Tags:** + add tag (text input)
- Checklist:** (text input)
- Files:** Choisir les fichiers aucun fichier sélectionné (Maximum size: 48.8 MB)
- Watchers:** Search for watchers to add

At the bottom of the form, there are three buttons: Create, Create and continue, and Preview.



How do I get help?

- Send an e-mail to the ctools User list
 - ctools@irap.omp.eu

How do I get help?

- Come to our next coding sprint
 - 9-13 October 2017, IRAP, Toulouse, France
 - Sign-up on ctools Redmine
 - https://cta-redmine.irap.omp.eu/projects/ctools/wiki/Eighth_ctools_coding_sprint

