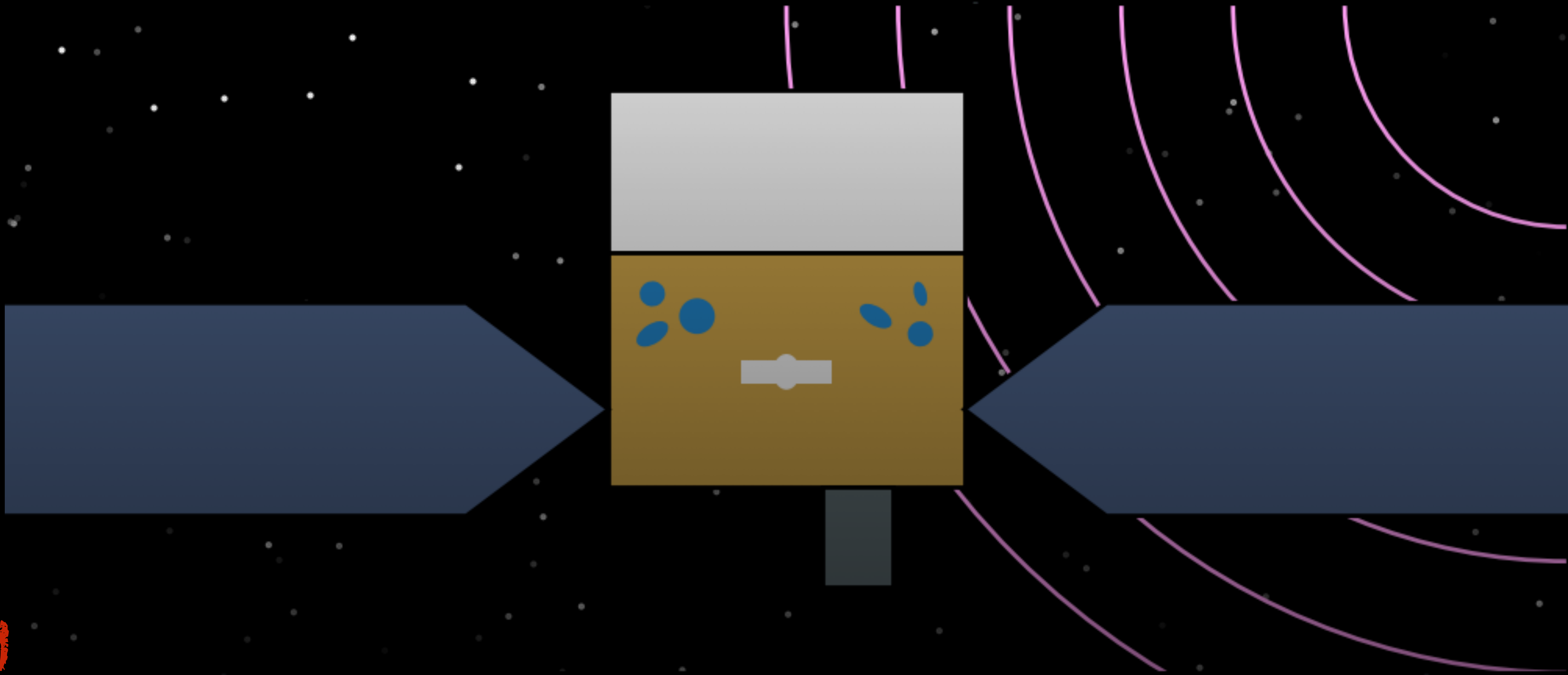

Gamma-ray

The ~~Fermi GBM~~ Data Tools

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The GBM Data Tools

A Python API for GBM Data

https://fermi.gsfc.nasa.gov/ssc/data/analysis/gbm/

- Interface to GBM data (both trigger **and** continuous)
- Sufficiently **high-level** part of the API so that it is easily accessible to many, but also **lower-level** part of the API for expert users
- Reduce and Analyze data (binning, background estimation)
- Export/conversion of data
- Observing conditions — Source visibility, GTIs, detector angles, etc
- Spectral analysis
- Simulations
- Wide range of visualizations
- Interface to HEASARC FTP archive and Browse Catalogs

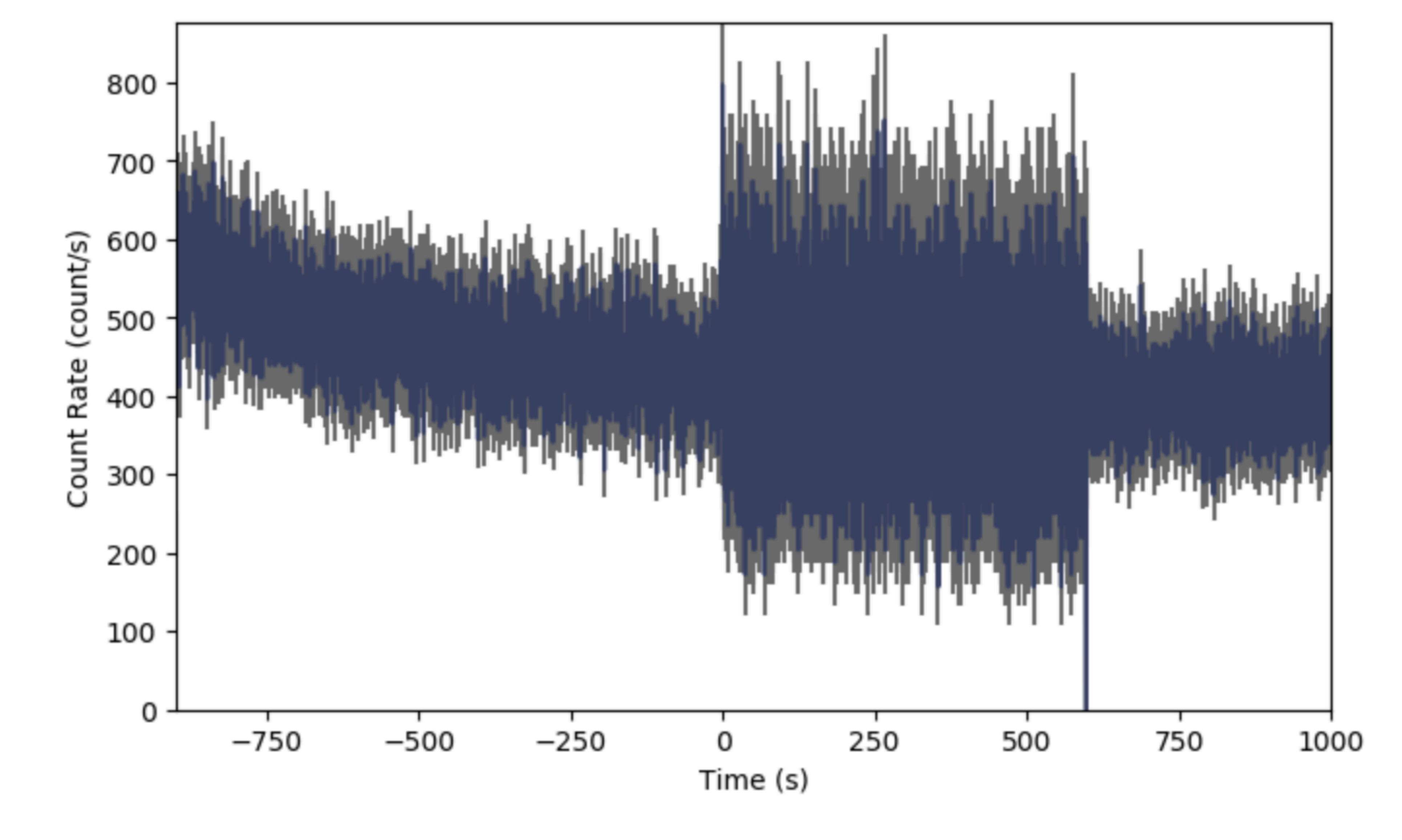
High-Level API — Lightcurves

Read a file and convert to lightcurve

```
# import the CTIME and CSPEC data classes
from gbm.data import Ctime, Cspec

# read a ctime file
ctime = Ctime.open(test_data_dir+'/glg_ctime_nb_bn120415958_v00.pha')
# integrate over 50-300 keV
lightcurve = ctime.to_lightcurve(energy_range=(50.0, 300.0))
```

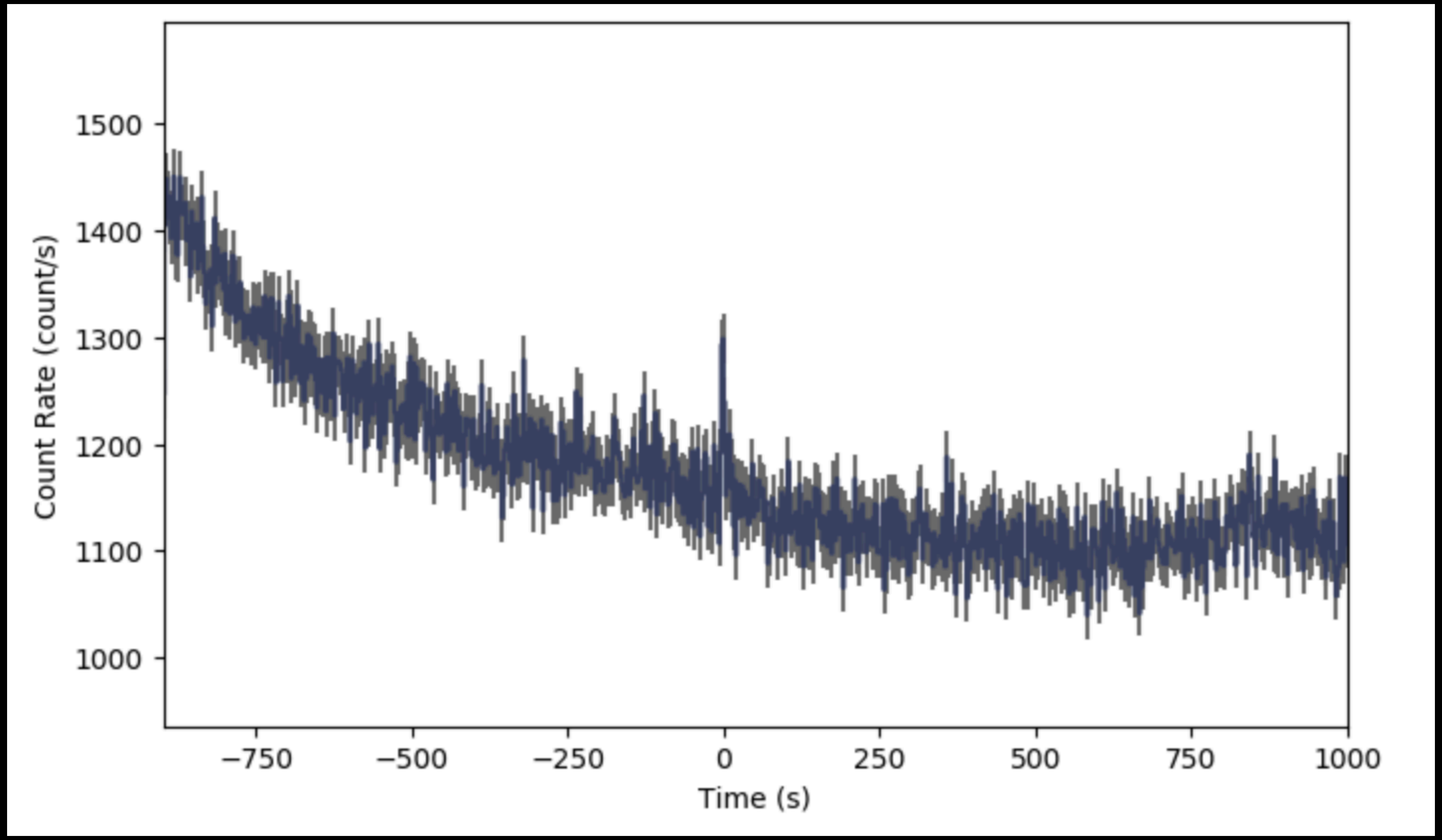
Plot it

```
from gbm.plot.lightcurve import Lightcurve
lcplot = Lightcurve(data=lightcurve)
plt.show()
```



Rebin it

```
# the data binning module
from gbm.binning.binned import rebin_by_time

# rebin the data to 2048 ms resolution
rebinned_ctime = ctime.rebin_time(rebin_by_time, 2.048)

# and replot
lcplot = Lightcurve(data=rebinned_ctime.to_lightcurve())
```



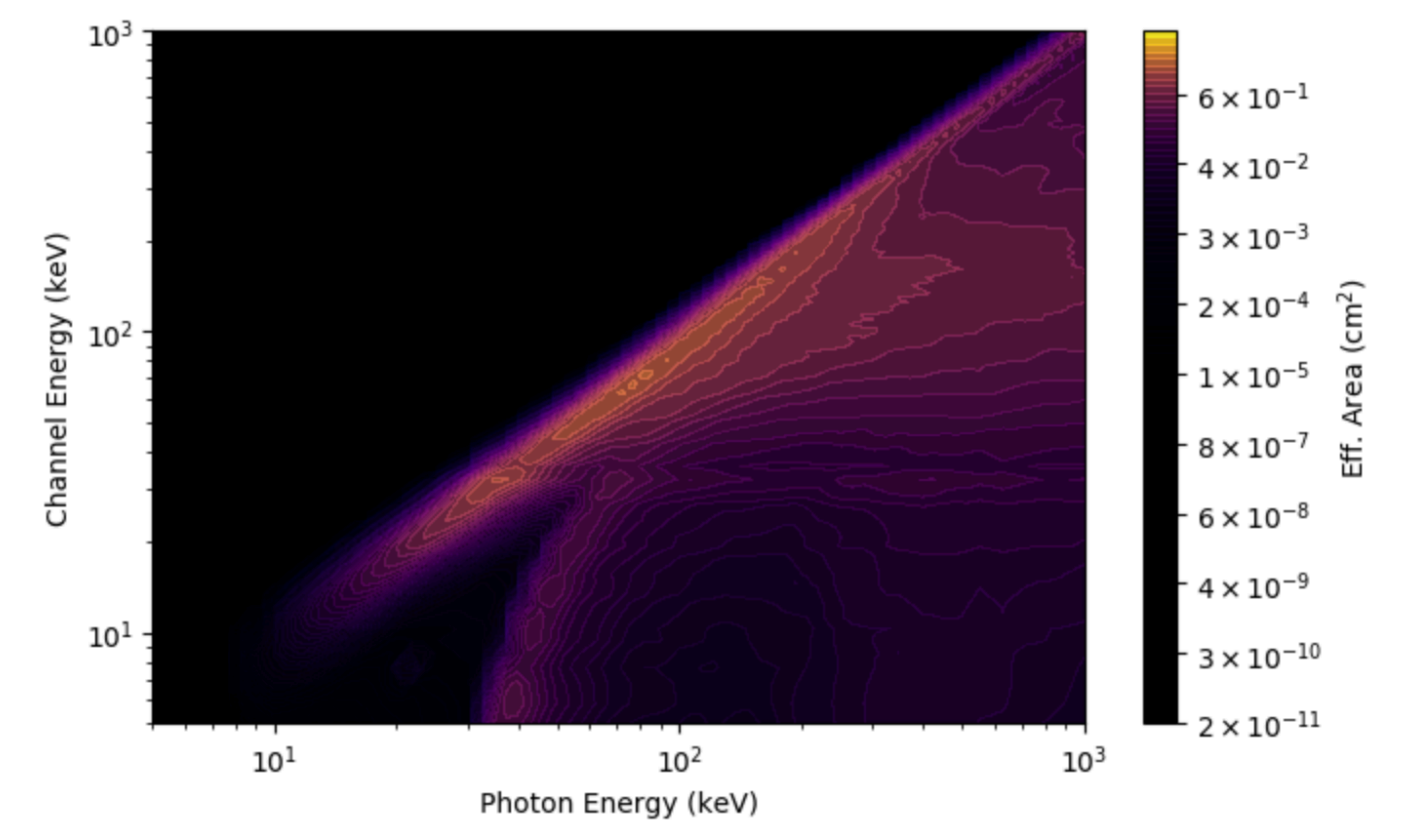
Detector Responses

Read a Response file

```
from gbm.data import RSP
rsp = RSP.open(test_data_dir+'/glg_cspec_n4_bn120415958_v00.rsp2')
```

Plot the DRM

```
from gbm.plot import ResponseMatrix

rsp_plot = ResponseMatrix()
rsp_plot.set_response(rsp, color='plasma') # a pretty color gradient
rsp_plot.xlim = (5.0, 1000.0)
rsp_plot.ylim = (5.0, 1000.0)
```



Fold a photon model through the response

```
# a power-law function.
# params is a list of parameters: (amplitude, index)
def powerlaw(params, energies):
    return params[0]*(energies/100.0)**params[1]

# fold a power law with amplitude 0.1 and index -2.0 through the DRM at trigger time
rsp.fold_spectrum(powerlaw, (0.1, -2.0), atime=0.0)
```

```
array([ 2.04555274,  2.41331594,  2.0801156 ,  1.56281085,  1.57124845,
        1.95612002,  2.18619054,  2.68707728,  3.09026986,  3.87129313,
        4.53683755,  5.03903868,  5.73969901,  6.52557411,  8.28145565,
        8.7270274 ,  9.29967452,  9.82871379, 10.27252461, 10.64788631,
       12.61452885, 13.15436336, 14.44362474, 11.80630877,  9.50993977,
```

Observing Conditions

Read a position history file

```python
from gbm.data.poshist import PosHist

# open a poshist file
poshist = PosHist.open(test_data_dir+'/glg_poshist_all_170101_v00.fit')
```

Is a position visible at some time?

```python
t0 = 504975500.0
# the position of our source
ra = 324.3
dec = -20.8
poshist.location_visible(ra, dec, t0)
```

```
array([ True])
```

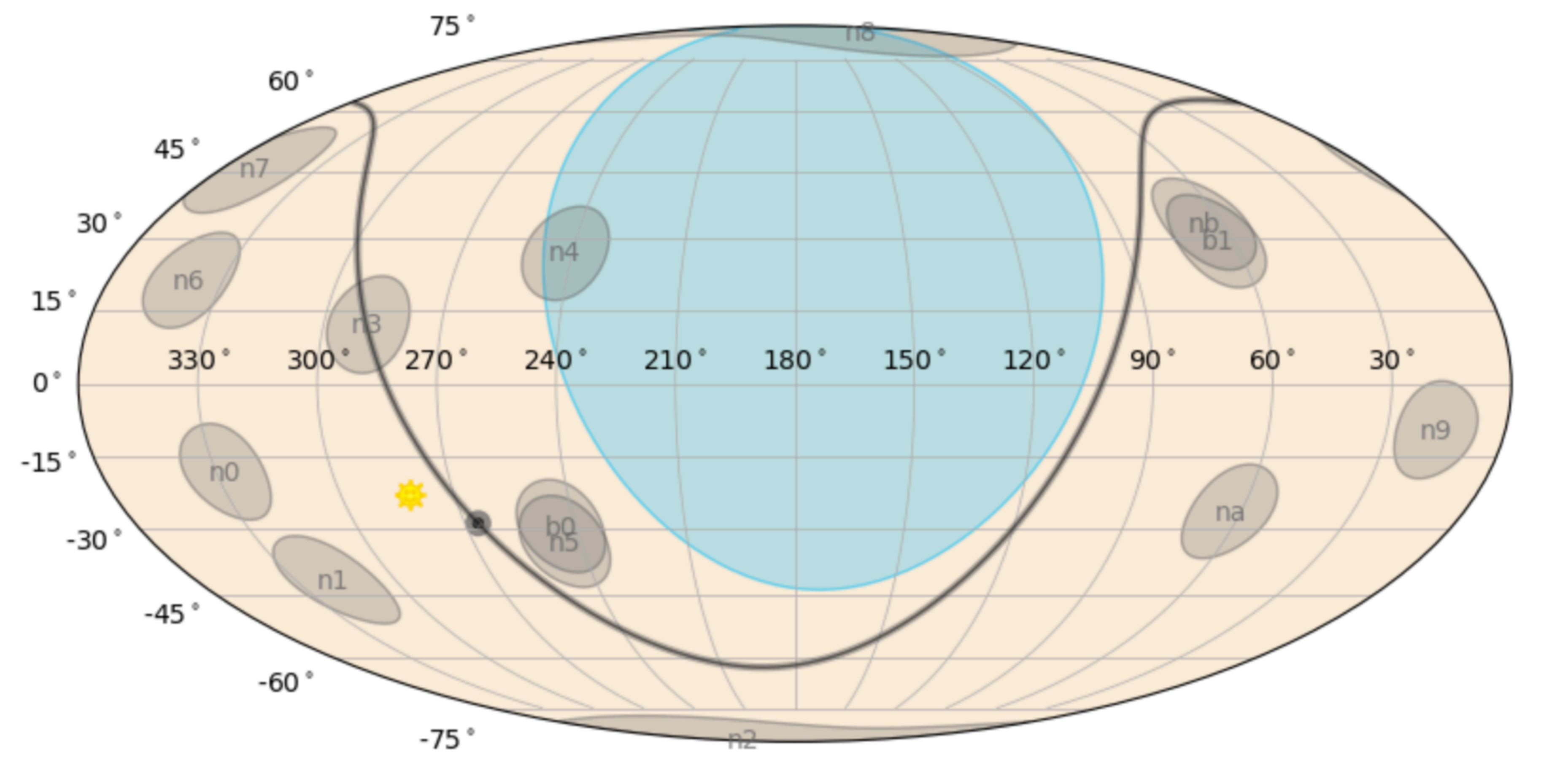
Angle of the position to detector n0:

```python
poshist.detector_angle(ra, dec, 'n0', t0)
```

```
4.2721980564266975
```

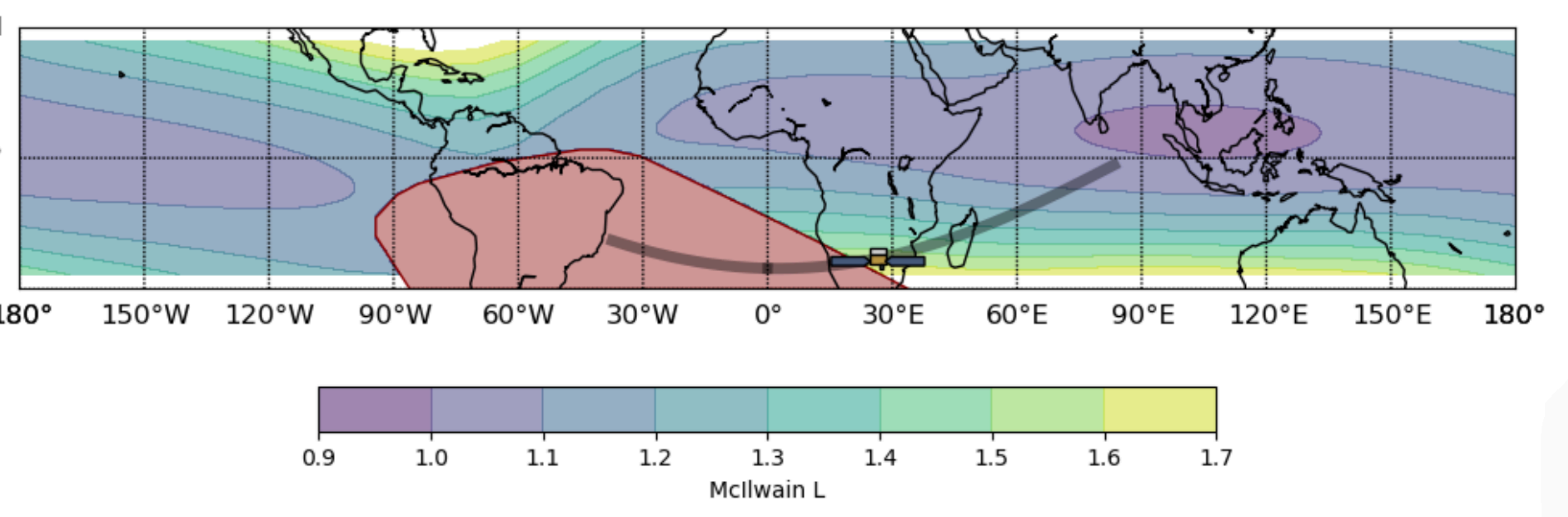
Plot the detector pointing

```python
from gbm.plot.skyplot import SkyPlot, FermiSkyPlot

# initialize plot
skyplot = SkyPlot()
# plot the orientation of the detectors and Earth blockage at our time of interest
skyplot.add_poshist(poshist, trigtime=t0)
plt.show()
```



Plot the orbital position

```python
from gbm.plot.earthplot import EarthPlot

# initialize plot
earthplot = EarthPlot()

# let's how the orbital path for +/-1000 s around our t0
earthplot.add_poshist(poshist, trigtime=t0, time_range=(t0-1000.0, t0+1000.0))
```



Localizations

Read a HEALPix localization file

```
from gbm.data.localization import GbmHealPix

# open a GBM localization
loc = GbmHealPix.open(test_data_dir+'/glg_healpix_all_bn190915240_v00.fit')
```

The confidence level at a point

```
loc.confidence(40.0, 4.0)
```

0.865783539232832

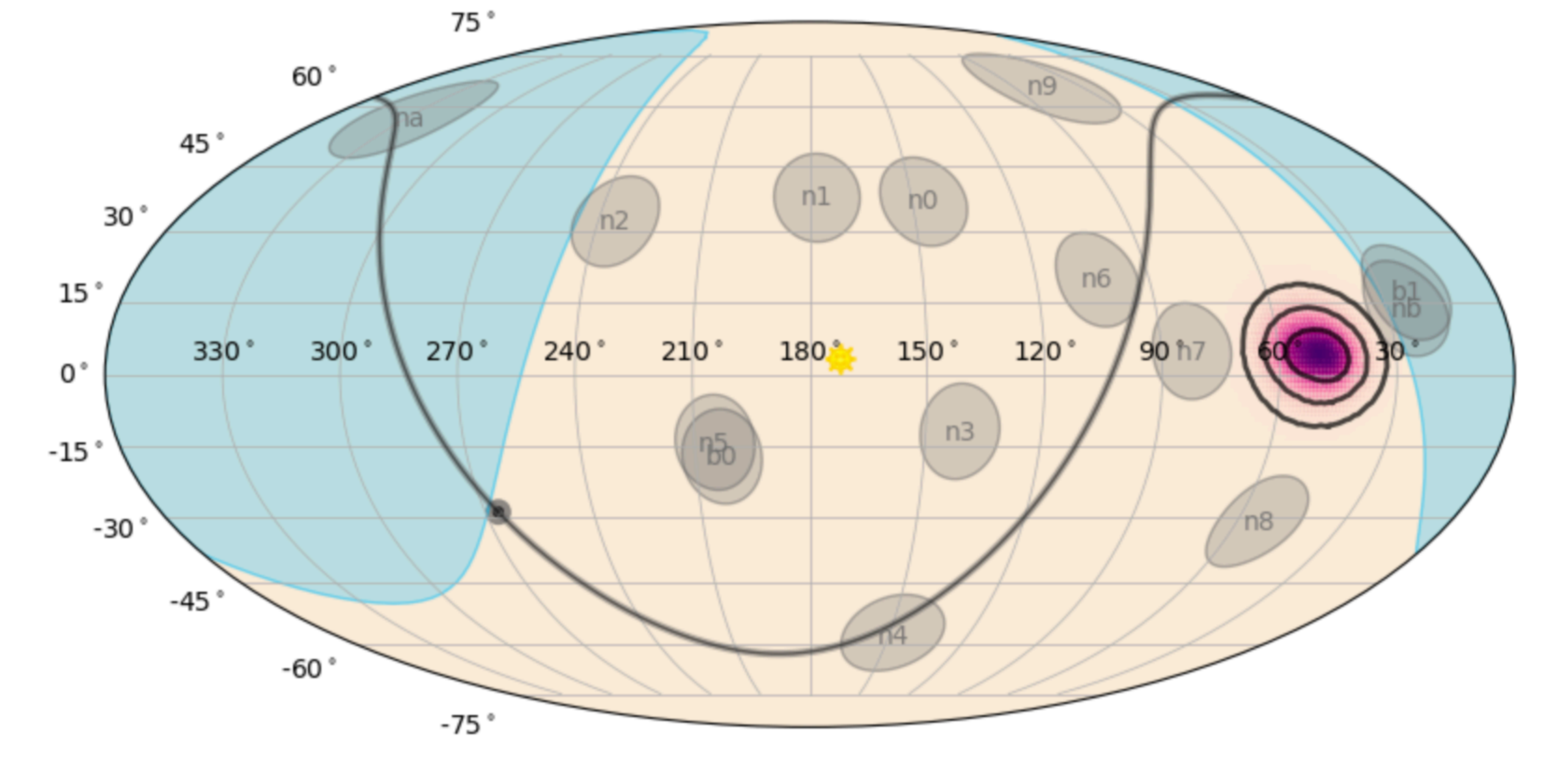
Area of the 90% conf. region

```
loc.area(0.9) # 90% confidence in units of sq. degrees
```

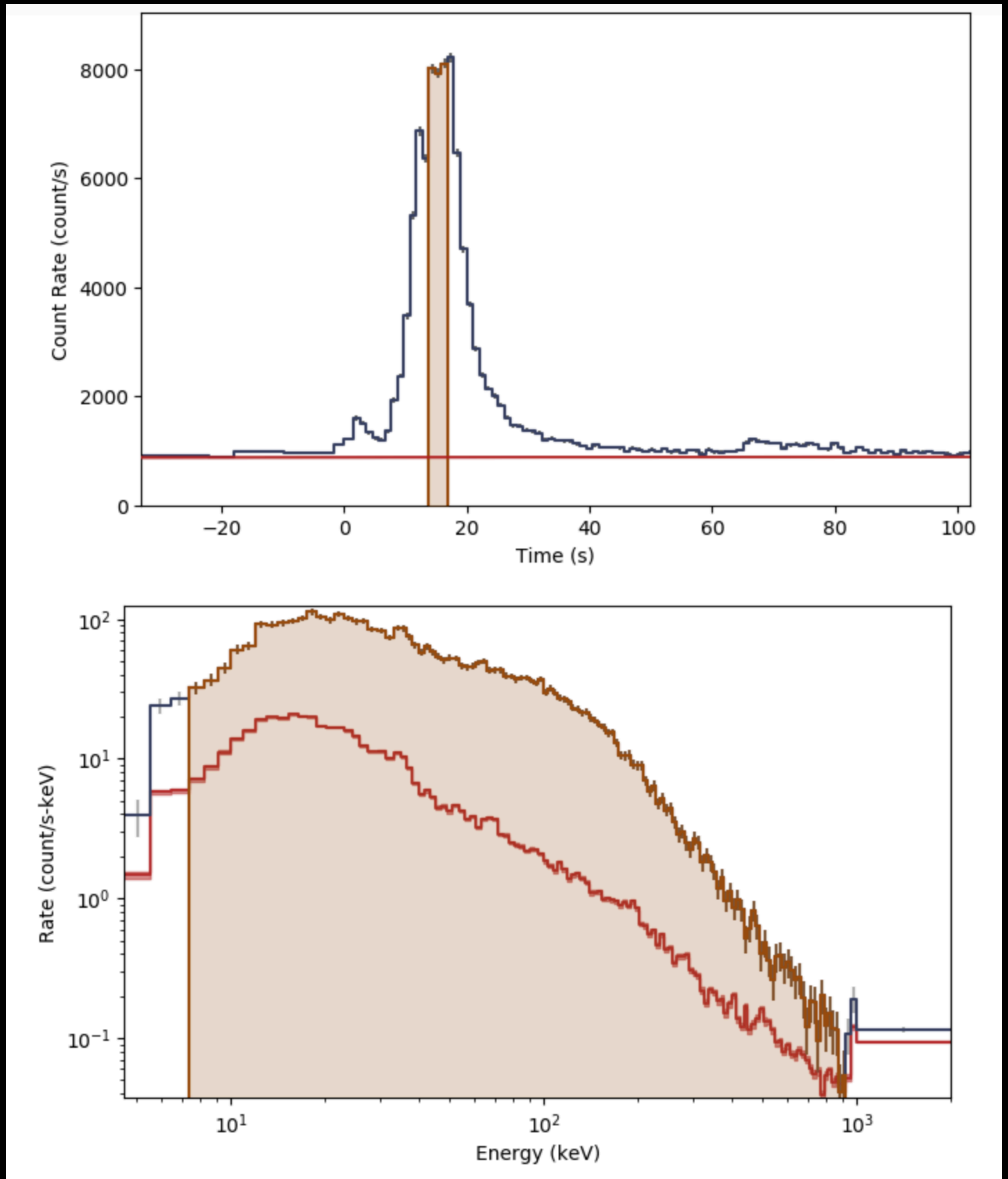
281.1633711457409

Plot the localization

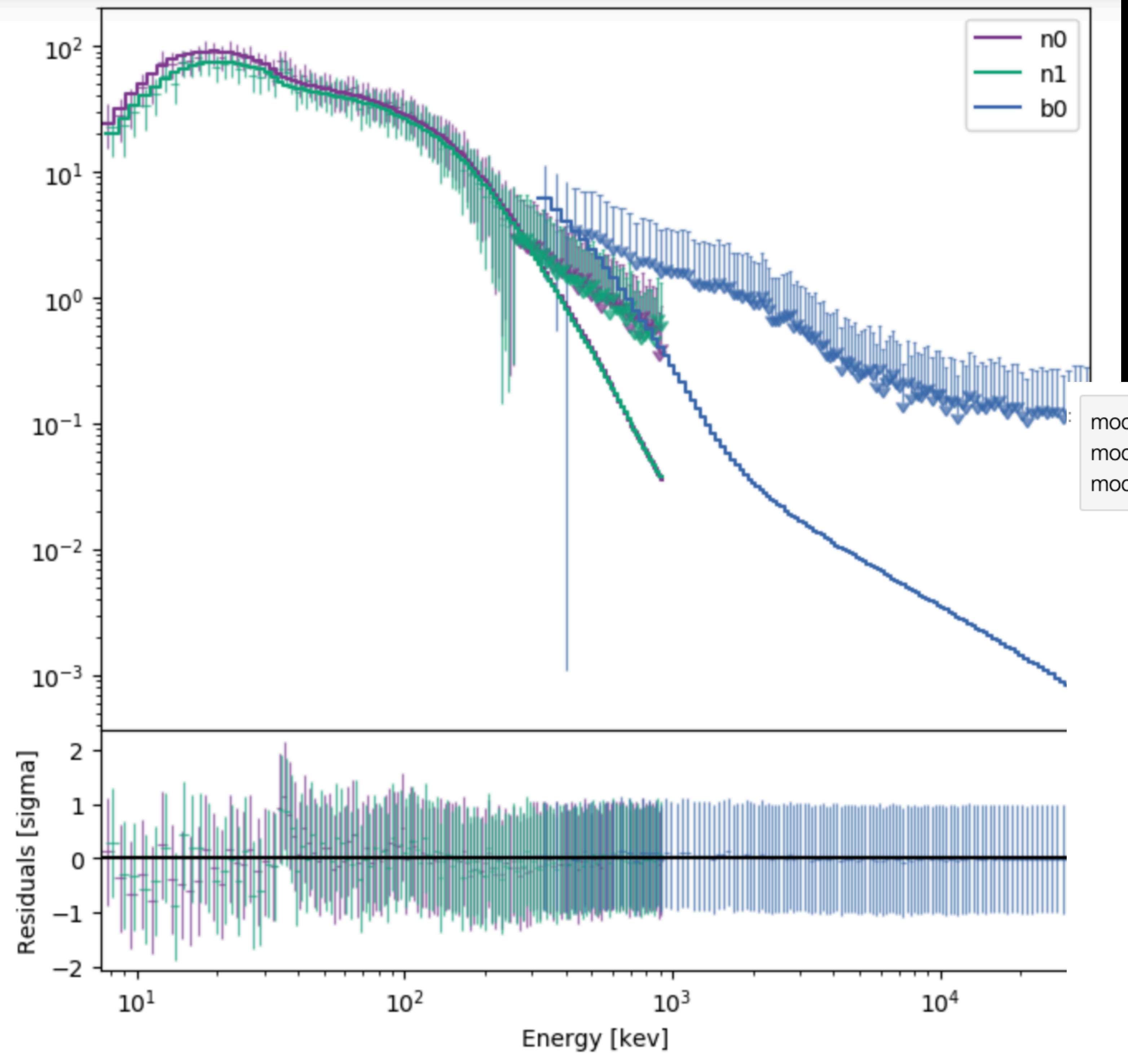
```
from gbm.plot.skyplot import SkyPlot

# initialize
skyplot = SkyPlot()

# add our HEALPix object
skyplot.add_healpix(loc)
```



Spectral Fitting

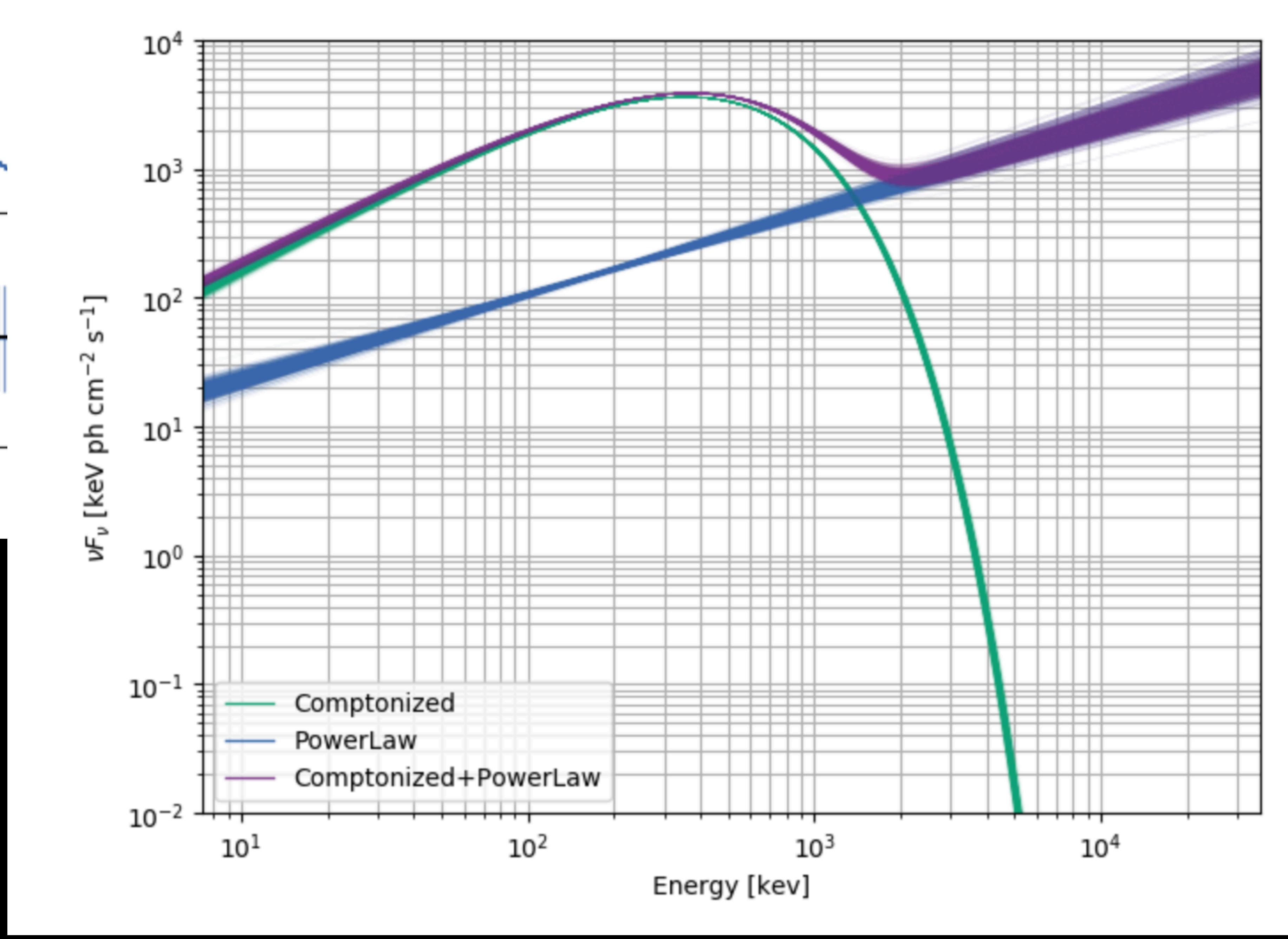


modelplot = ModelFit(fitter=specfitter)



Can fit multiple components, plot the fit, and the spectrum for each component

```
modelplot = ModelFit(fitter=specfitter, view='nufnu')
modelplot.ylim = (0.01, 10000.0)
modelplot.ax.grid(which='both')
```



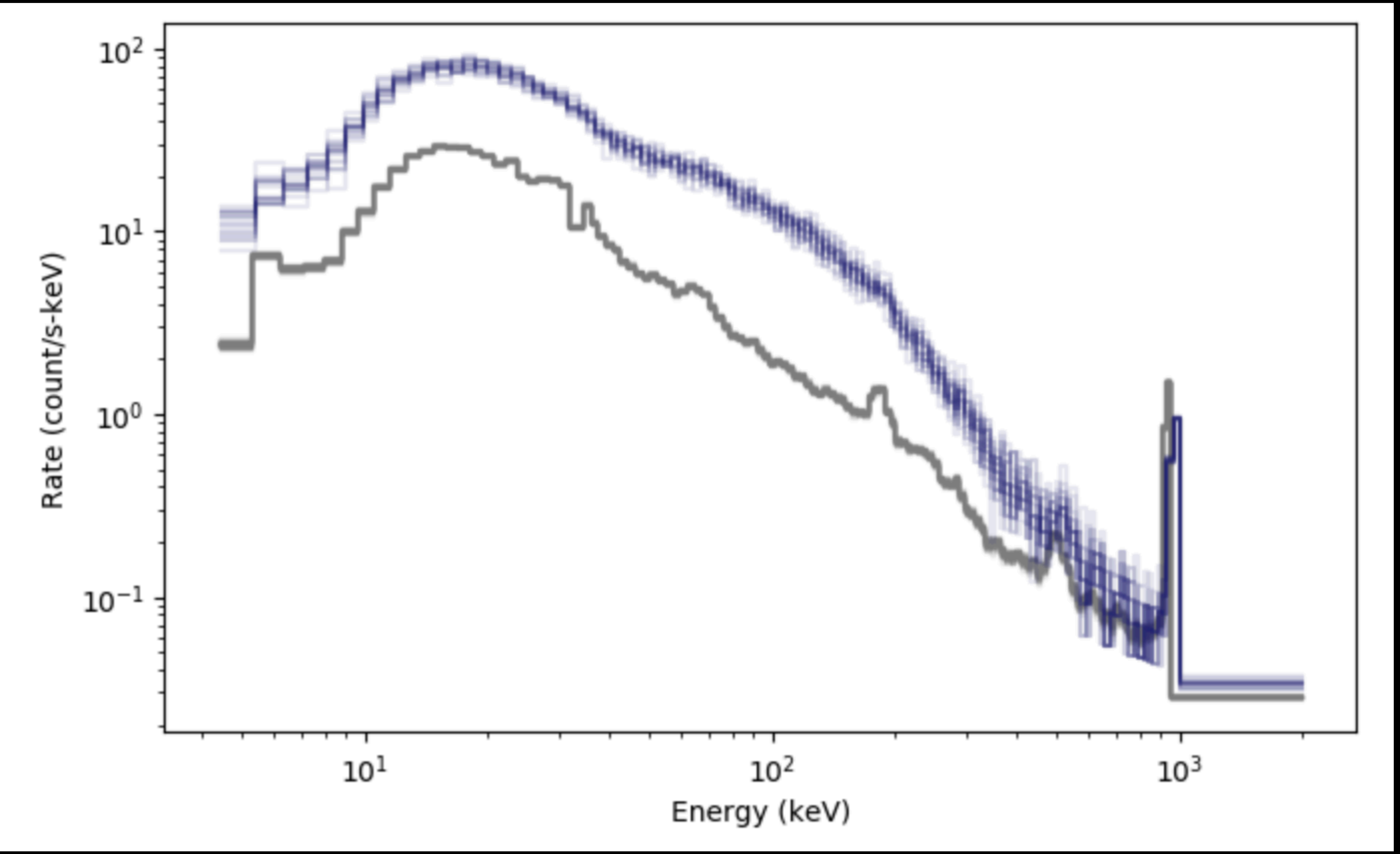
MLE with PG-Stat

```
# we initialize with our PHAs, backgrounds, and responses:
specfitter = SpectralFitterPgstat(phas, bkgds.to_list(), rsps.to_list(), method='TNC')
# a power law, cut-off power law, and a Band function
from gbm.spectra.functions import PowerLaw, Comptonized, Band
```

Simulations

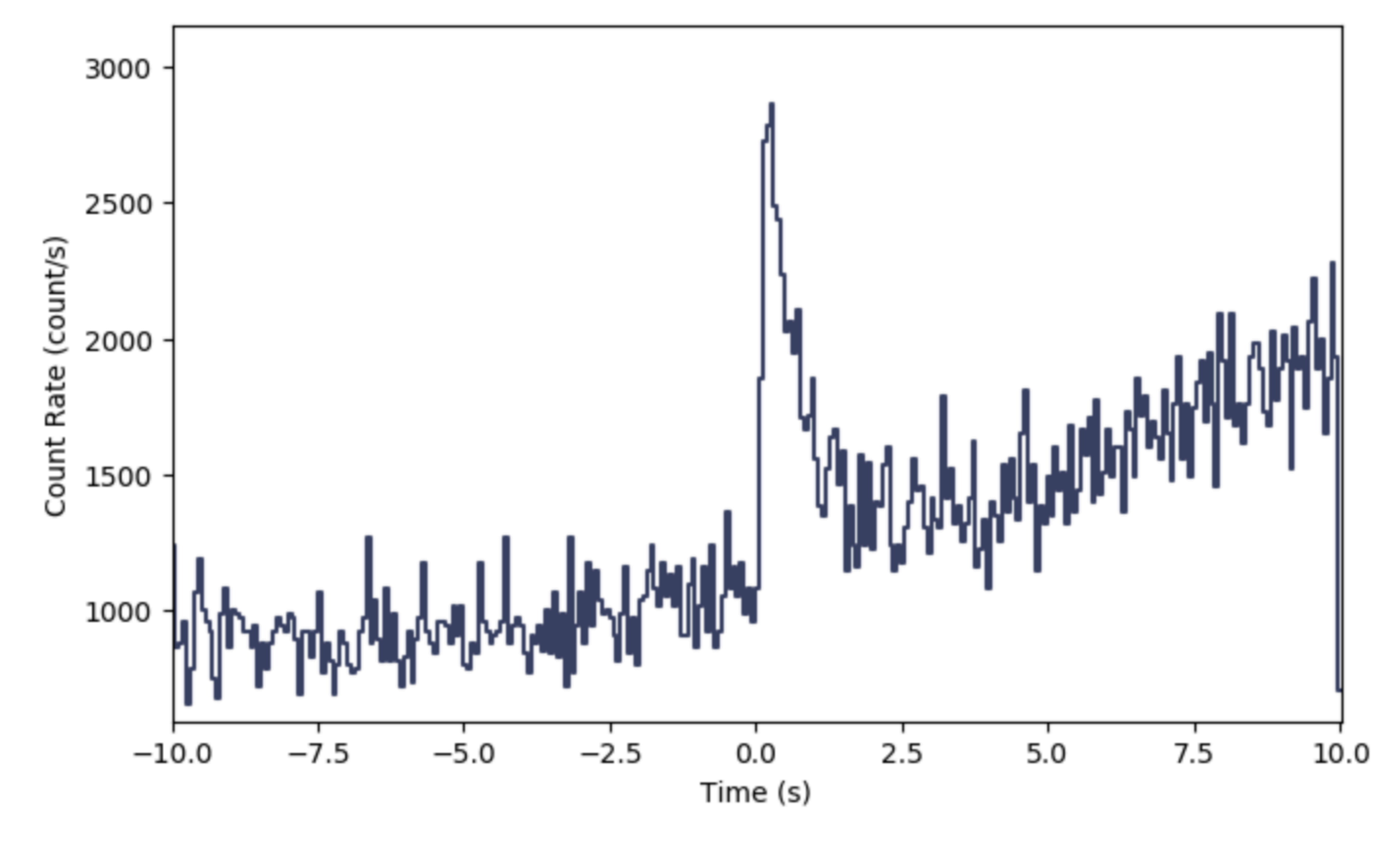
Simulate a spectrum (20 sims shown)

```
from gbm.simulate import PhaSimulator
pha_sims = PhaSimulator(rsp, Band(), band_params, exposure, spec_bkgd, 'Gaussian')
```



Simulate TTE/spectra

```
# a Norris pulse shape and a quadratic background
from gbm.simulate.profiles import norris, quadratic

norris_params = (0.05, 0.0, 0.1, 0.5)
quadratic_params = (1.0, 0.05, 0.003)

# source simulation
tte_sim = TteSourceSimulator(rsp, Band(), band_params, norris, norris_params)
tte_src = tte_sim.to_tte(-5.0, 10.0)

# background simulation
tte_sim = TteBackgroundSimulator(spec_bkgd, 'Gaussian', quadratic, quadratic_params)
tte_bkgd = tte_sim.to_tte(-10.0, 10.0)

# merge the background and source
tte_total = TTE.merge([tte_bkgd, tte_src])

# bin to 64 ms resolution so we can make a lightcurve plot
phaii = tte_total.to_phaii(bin_by_time, 0.064)
lcplot = Lightcurve(data=phaii.to_lightcurve(energy_range=(8.0, 900.0)))
```



The Gamma-ray Data Tools

- Generalize the tools to a core set of functionality
- Different Mission/Instrument Modules
- Leadership Council to consider new features and instruments for official releases
- Initial release soon on NASA GitHub with Fermi GBM, other modules to follow as they are finished and tested

Legacy

CGRO/BATSE
HETE-2/FREGATE
RXTE/ASM
SUZAKU/WAM

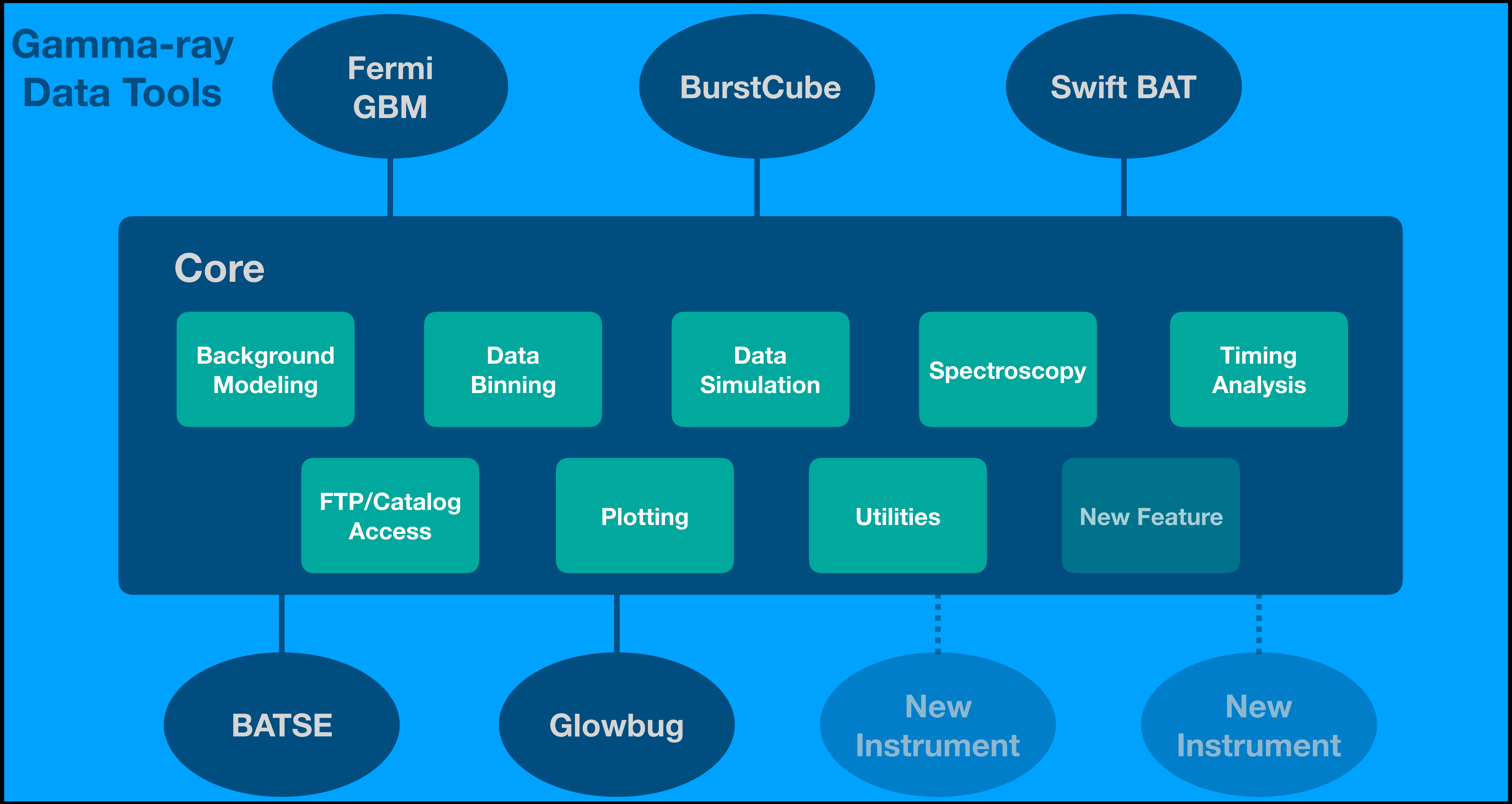
Current

AstroSat/CZTI
Fermi/GBM
Fermi/LAT
INTEGRAL/SPI
INTEGRAL/SPI-ACS
MAXI/GSC
Swift/BAT

Upcoming

BurstCube
Glowbug
StarBurst

The Gamma-ray Data Tools



USRA

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- NASA MSFC ISFM Directed Work Package (pending)

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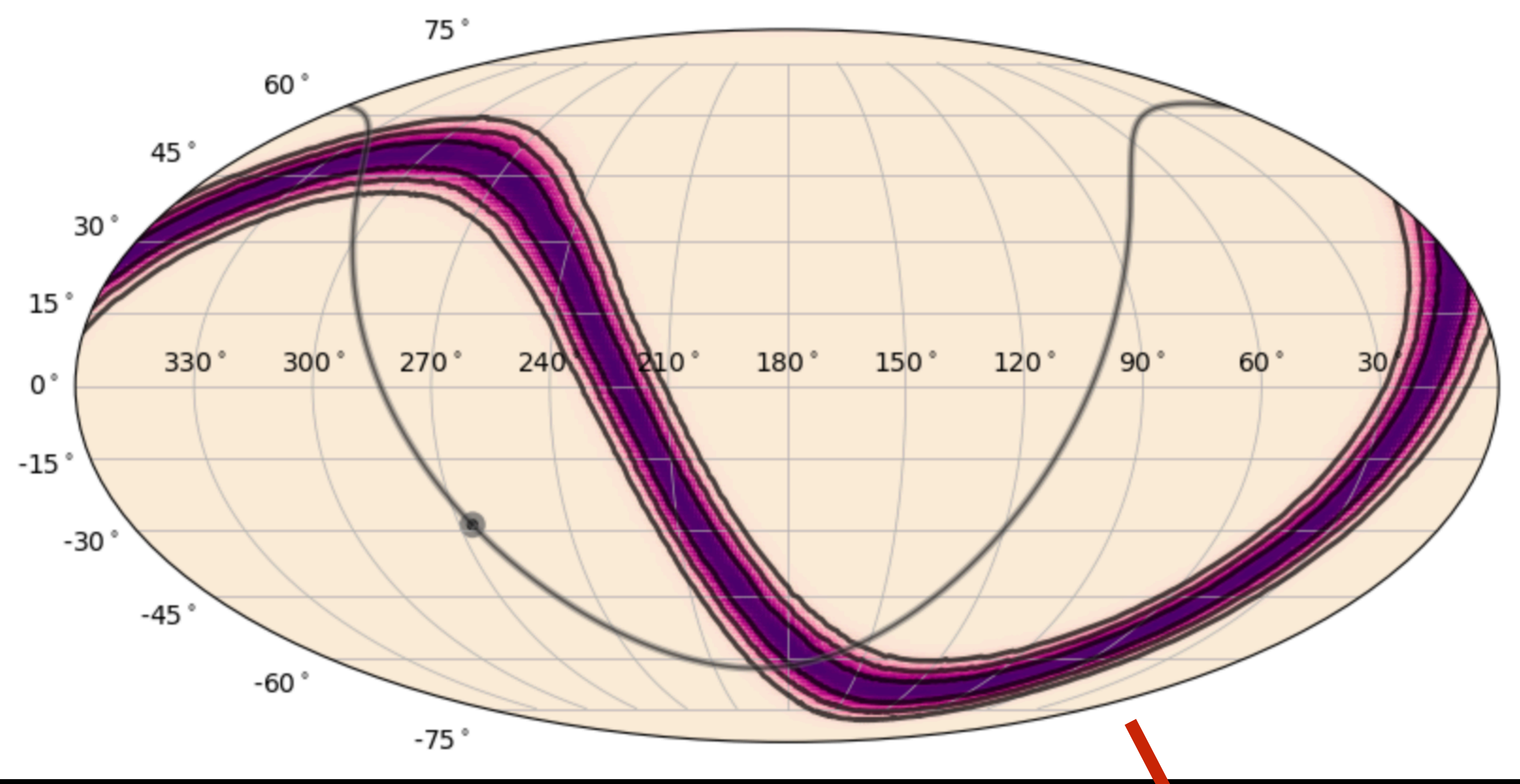
Univ. of Toronto: A. Tohuvavohu

Backup

Custom HEALPix Maps

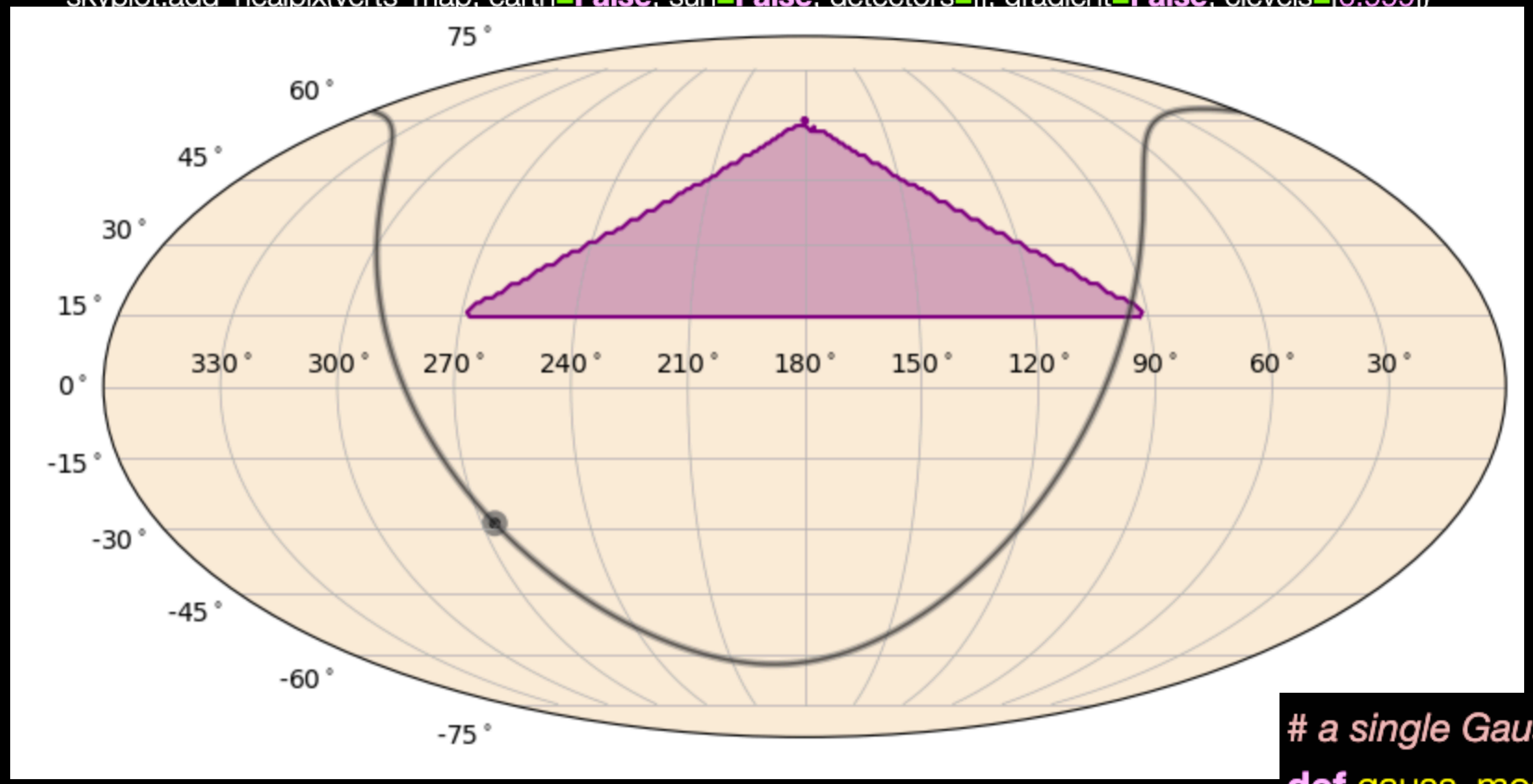
Annulus on the sky (e.g. IPN)

```
annulus_map = HealPix.from_annulus(300.0, -30, 80.0, 3.0, nside=128)

skyplot = SkyPlot()
skyplot.add_healpix(annulus_map, earth=False, sun=False, detectors=[])
```



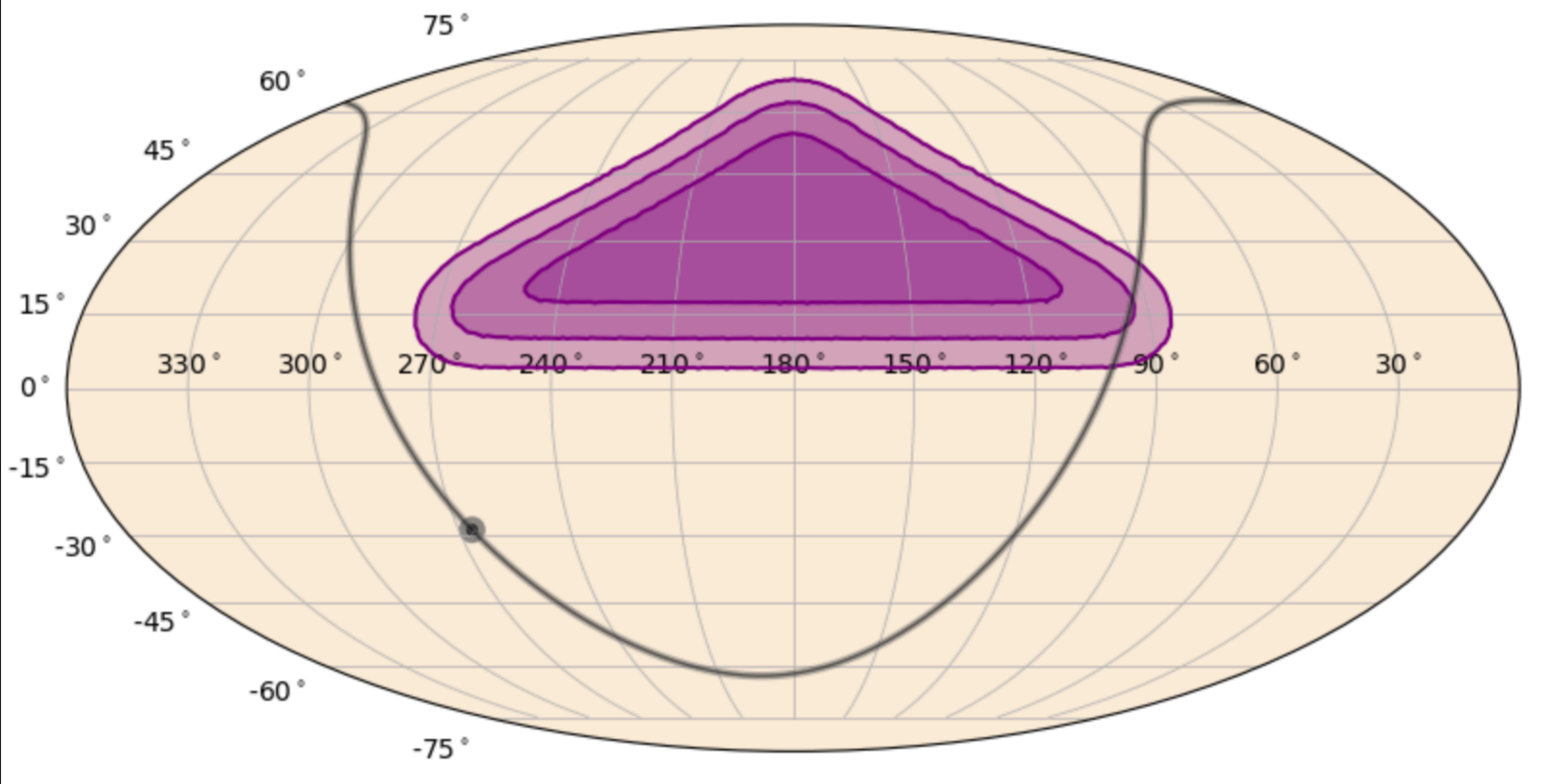
List of vertices

```
ra_pts = [270.0, 180.0, 90.0]
dec_pts = [15.0, 60.0, 15.0]

verts_map = HealPix.from_vertices(ra_pts, dec_pts, nside=128)
skyplot = SkyPlot()
skyplot.add_healpix(verts_map, earth=False, sun=False, detectors=[], gradient=False, clevels=[0.999])
```



Map convolutions

```
# a single Gaussian of sigma_deg radius
def gauss_model(sigma_deg):
    sigma = deg2rad(sigma_deg)
    return ([sigma],[1.0])

# convolved with a 5-deg radius Gaussian
verts_convolved = verts_map.convolve(gauss_model, 5.0)
```



Map multiplication

```
# multiply the Vertices-convolved map with the annulus map
multiplied = HealPix.multiply(verts_convolved, annulus_map)
```