pointlike's MC Simulation Package

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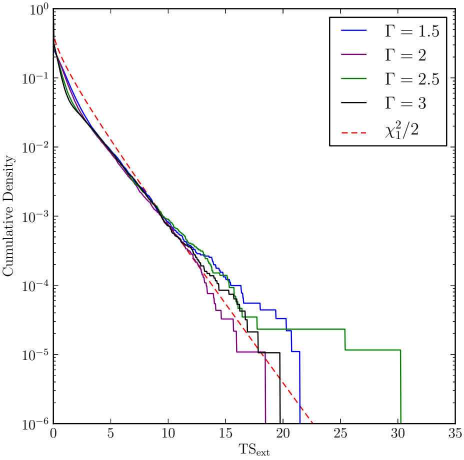
Table 1. Monte Carlo Spectral Parameters

Spectral Index	Flux[a] ($\mathrm{ph\,cm^{-2}\,s^{-1}}$)	$N_{1-100\mathrm{GeV}}$	$\langle \mathrm{TS}\rangle_{1-100\mathrm{GeV}}$	$N_{10-100\mathrm{GeV}}$	$\langle \mathrm{TS}\rangle_{10}$
Isotropic Background					
1.5	3×10^{-7}	18938	22233	18938	
	10^{-7}	19079	5827	19079	
	3×10^{-8}	19303	1276	19303	
	10^{-8}	19385	303	19381	
	3×10^{-9}	18694	62	12442	
2	10^{-6}	18760	22101	18760	
	3×10^{-7}	18775	4913	18775	
	10^{-7}	18804	1170	18803	
	3×10^{-8}	18836	224	15256	
	10^{-8}	17060	50	...	
2.5	3×10^{-6}	18597	19036	18597	
	10^{-6}	18609	4738	18608	
	3×10^{-7}	18613	954	15958	
	10^{-7}	18658	203	...	
	3×10^{-8}	14072	41	...	
3	10^{-5}	18354	19466	18354	
	3×10^{-6}	18381	4205	15973	
	10^{-6}	18449	966	...	
	3×10^{-7}	18517	174	...	
	10^{-7}	13714	41	...	
Galactic Diffuse and Isotropic Background[b]					
1.5	2.3×10^{-8}	90741	63	...	
2	1.2×10^{-7}	92161	60	...	
2.5	4.5×10^{-7}	86226	47	...	
3	2.0×10^{-6}	94412	61	...	

[a] Integral 100 MeV to 100 GeV flux.

[b] **For the Galactic simulations, the quoted fluxes are the fluxes for sources the Galactic center. The actual fluxes are scaled by Equation 12.**

Note. — A list of the spectral models of the simulated point-like sources which were extension. For each model, the number of statistically independent simulations and the ave of TS is also tabulated. **The top rows are the simulations on top of an isotropic ba and the bottom rows are the simulations on top of the Galactic diffuse and background.**



$\sim 90,000$ simulations/model!

gtobssim Overview

- Input to `gtobssim`:
  - XML File
  - Ft2 file/source list
  - templates for certain spectral and spatial models (more soon. . .)
- After running `gtobssim`
  - Remove bad time intervals from simulated data
  - Apply zenith angle cut to simulated data
- *Building the* `gtobssim` *XML file can be error prone*
- Cutting simulated data can be error prone

pointlike's MC Simulation package

- I developed a wrapper around `gtobssim` to automate otherwise time consuming, tedious, or error-prone tasks
- Built around `pointlike`, an alternate maximum likelihood package written in `python`
  - Uses as input a list of `pointlike` objects
  - Builds the XML file for `gtobssim`
  - Converts unsupported models into required templates.
  - Automatically removes bad time intervals + `zmax` cut
- Code is in `pointlike` package: `uw.like.roi_monte_carlo.py`.

Point Sources

```
<source name="source" flux="0.03">
  <spectrum escale="MeV">
    <particle name="gamma">
      <power_law emin="20" emax="1000000" gamma="1.9"/>
    </particle>
    <celestial_dir ra="193.98" dec="-5.82"/>
  </spectrum>
</source>
```

- Supported Spectral Models
  - power law, (dark matter) line, broken powerlaw, and file function
  - `http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/other_sources.html`
- Problematic for all other spectral models!

Point Sources (cont)

- Any spectrum can be simulated using FileSpectrum:

```
<source name="FileSpectrum">
  <spectrum escale="MeV" >
    <SpectrumClass name="FileSpectrum" params="flux=0.,
     specFile=$(FERMI_DIR)/spectrum.dat"/>
    <celestial_dir ra="194.04" dec="-5.789"/>
  </spectrum>
</source>
```

- roi_monte_carlo will automatically build a FileSpectrum for any otherwise-unsupported model
- gtobssim Requires integral of spectral model (done automatically by roi_monte_carlo)
- WARNING! FileSpectrum objects cannot contain 0 pixels (stripped out by roi_monte_carlo)

Diffuse Sources Sources

- MapCube model to simulate diffuse background:

```
<source name="map_cube_source">
  <spectrum escale="MeV">
    <SpectrumClass name="MapCube" params="1.,
      $(FERMI_DIR)/mapcube.fits "/>
    <use_spectrum frame="galaxy"/>
  </spectrum>
</source>
```

- Requires 3D integral of fits file
- Integration automatic by `roi_monte_carlo`

Building the XML file (Isotropic Diffuse Sources)

- FileSpectrumMap for simulation the isotropic diffuse:

```
<source name="isotropic">
  <spectrum escale="GeV" flux="1.">
    <SpectrumClass name="FileSpectrumMap"
     params="flux=17,fitsFile=$(FERMI_DIR)/iso_spatial.fits,
specFile=$(FERMI_DIR)/iso_spectral.dat,emin=100.,emax=1100"/>
    <use_spectrum frame="galaxy"/>
  </spectrum>
</source>
```

- Must integrate isotropic spectrum
- Must generate allsky spatial `fits` file predicting 1
- Must add energy range from isotropic file
- All done automatically by `roi_monte_carlo`

Extended Sources

```
<source name="gaussian_source">
  <spectrum escale="MeV">
    <SpectrumClass name="GaussianSource"
      params="0.1,2.1,45,30,3,0.5,45,30,2e5"/>
    <use_spectrum frame="galaxy"/>
  </spectrum>
</source>
```

- `gtobssim` only natively supports an Elliptical Gaussian spatial model with a power law spectral model.
- WARNING, the ellipse angle is defined west of celestial north)!

Extended Sources (cont)

- Any extended source can be represented by a `FileSpectrumMap`

```
<source name="filespectrummap_test">
  <spectrum escale="GeV" flux="1.">
    <SpectrumClass name="FileSpectrumMap" params="
      flux=17,
      fitsFile=$(FERMI_DIR)/spatial.fits,
      specFile=$(FERMI_DIR)/spectral.dat,
      emin=100, emax=1100"/>
    <use_spectrum frame="galaxy"/>
  </spectrum>
</source>
```

- Have to:
  - Build fits template for spatial model
  - Build text file for spectral model
  - Integrate spectral model
- Process automatic by `roi_monte_carlo` for any of `pointlike`'s extended sources (disk, Gauss, NFW,

Common Gotcha's (Energy Dispersion)

- Energy dispersion means photons with energies outside simulation range can disperse into energy range
- All spectral models must be simulated for energies well outside of simulation range
- Handled automatically by `roi_monte_carlo`.
- Parameter `roi_pad` (default=2) will pad a given amount to energy of all spectral models.
- `acutal_emin = simulation_emin/roi_pad`
- `acutal_emax = simulation_emax*roi_pad`

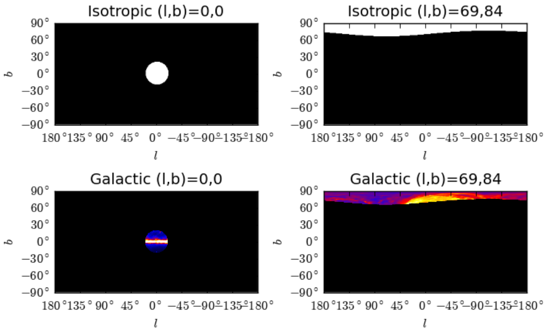
Common Gotcha's (ft1 cuts)

- Must remove bad time intervals
  - gtobssim takes as input an FT2 file (does not store GTIs)
  - But gtlike analysis uses ltcube only over good time intervals
  - No ScienceTool for applying gtmktime unless you know exact filter applied to ft1 file which generated ltcube
  - roi_monte_carlo uses a compbiation of pyfits and gtmktime to apply exact GTIs from an ft1 or ltcube file.
- zenith angle cut must be consistent with zmax flag in gtltcube
  - Flag in roi_monte_carlo to automatically apply zmax after simulation.

All sky vs region simulations

- `gtobssim` will simulate over all sky for allsky `MapCube` files.
- `use_ac` parameter is applied AFTER the simulation!
- This is very inefficient when simulating only a particular region in the sky
- As far as I can tell, non-allsky mapcubes will cause strange projection effects
- lonMin and lonMax parameters for spatial models does not work correct.

MapCube Cutting



- My solution for simulation small regions of the sky is to set to 0 pixels far away from ROI
- Done automaticlly by `roi_monte_carlo`
- Dramatic speedup for simulations of small regions
- Also, cut out energy bins in `MapCube` far away from simulation energy range.

uw.like.roi_monte_carlo Usage

- First, build a list of pointlike soruces
- Most easily, you can use `pointlike`'s XML parser:

```
from uw.utilities.xml_parsers import parse_sources
ps,ds=parse_sources(xmlfile)
sources=ps+ds
```

- You can also build source programatically with `pointlike`:

```
from uw.like.pointspec_helpers import PointSource
from uw.like.Models import PowerLaw
skydir = SkyDir(34,-100, SkyDir.EQUATORIAL)
model = PowerLaw(norm=1e-10, index=2)
ps=PointSource(name='ps', model=model, skydir=skydir)
```

Run the Simulation

```
from skymaps import SkyDir
roi_dir = SkyDir(30, 0.5, SkyDir.GALACTIC)

from uw.like.roi_monte_carlo import MonteCarlo
mc = MonteCarlo(
    sources=sources,
    seed=0,
    emin=1e3,
    emax=1e4,
    roi_dir=roi_dir,
    maxROI=10,
    irf='P7SOURCE_V6',
    ft1='ft1.fits',
    ft2='ft2.fits',
    gtifile='ltcube.fits',
    zmax=100,
)
mc.simulate()
```

Conclusion

- `roi_monte_carlo` in `pointlike`
- Automatically distributed with the ScienceTools
- `roi_monte_carlo` usage documented on Confluence: `https://confluence.slac.stanford.edu/x/MIAcBw`
- The code has been successfully used by several other people (see work by Stephan Zimmer)