

An O2 Prototype with observationSim and FluxSvc

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The Packages

- **FluxSvc:**
 - `FluxSvc::FluxMgr` provides a non-Gaudi interface to the `FluxSvc` sources.
 - Single and composite source definitions are read in from xml files, with implementations in `FluxSvc::EventSource::[FluxSource, CompositeSource]` classes. Point-like and diffuse sources (using the `MapFlux` package) can be simulated.
 - Orbit and attitude info are obtained via the `astro::Earth[Orbit, Coordinate]` and `FluxSvc::GPS` classes and will ultimately be provided by the O1 tool.
- `observationSim` performs accounting of event and spacecraft data, and folds the source photons through the instrument response using the...
- `latResponse` abstract interface. Concrete implementations exist for GLAST25 and EGRET response matrices.

Instrument Response Functions

It is conventional to represent the instrument response in terms of three functions:

$$D(E'; E, \hat{p}) \equiv \text{Energy Dispersion} \quad (1)$$

$$P(\hat{p}'; E, \hat{p}) \equiv \text{Point Spread Function} \quad (2)$$

$$A(E, \hat{p}) \equiv \text{Effective Area} \quad (3)$$

The energy dispersion and point spread function are the probability densities of measuring an apparent energy E' and apparent direction \hat{p}' , respectively, for a detected photon that has true energy E and direction \hat{p} .

The total response of the instrument is given by

$$R(E', \hat{p}'; E, \hat{p}) = D(E'; E, \hat{p})P(\hat{p}'; E, \hat{p})A(E, \hat{p}) \quad (4)$$

$$= \frac{d\sigma}{dE' d\hat{p}'}(E, \hat{p}). \quad (5)$$

As the latter relation indicates, this quantity can be interpreted as the differential cross-section of the telescope. Note that the total response need not factor into the three constituent parts, D , P , and A .

Generating photons with FluxSvc

- Photon intensity from source i :

$$\left. \frac{dN}{dEdtdAd\Omega} \right|_i = \left(\left. \frac{dN}{dtdA} \right|_i \right) \left(\left. \frac{dN}{dE} \right|_i \right) \left(\left. \frac{dN}{d\Omega} \right|_i \right). \quad (6)$$

Factoring into these components is convenient, but not required.

- In order to determine the trial event rates, the LAT is presented as a sphere of radius R such that

$$\pi R^2 \geq A(E, \hat{p}) \quad \forall E, \hat{p} \quad (7)$$

$$\approx 1.2 \text{ m}^2 \quad (\text{GLAST25}). \quad (8)$$

⇒ Trial event rate:

$$\left. \frac{dN}{dt} \right|_i = \pi R^2 \int_{E_{\min}(\approx 30 \text{ MeV})} \left. \frac{dN}{dEdtdAd\Omega} \right|_i dEd\Omega \quad (9)$$

- Draw trial arrival times (for source i),

$$t_{i,n+1} = t_{i,n} + \Delta t_i, \quad (10)$$

where

$$\Delta t_i \stackrel{d}{\sim} \exp\left(-\Delta t \left. \frac{dN}{dt} \right|_i\right), \quad (11)$$

- and true photon energies and directions,

$$E_i \stackrel{d}{\sim} \left(\frac{dN}{dE}\right)_i, \quad (12)$$

$$\hat{p}_i \stackrel{d}{\sim} \left(\frac{dN}{d\hat{p}}\right)_i. \quad (13)$$

- Accept this event if

$$\xi < \frac{A(E_i, \hat{p}_i)}{\pi R^2}, \quad (14)$$

where

$$\xi \stackrel{d}{\sim} \Theta(\xi)(1 - \Theta(\xi - 1)) \quad (15)$$

$$\in [0, 1). \quad (16)$$

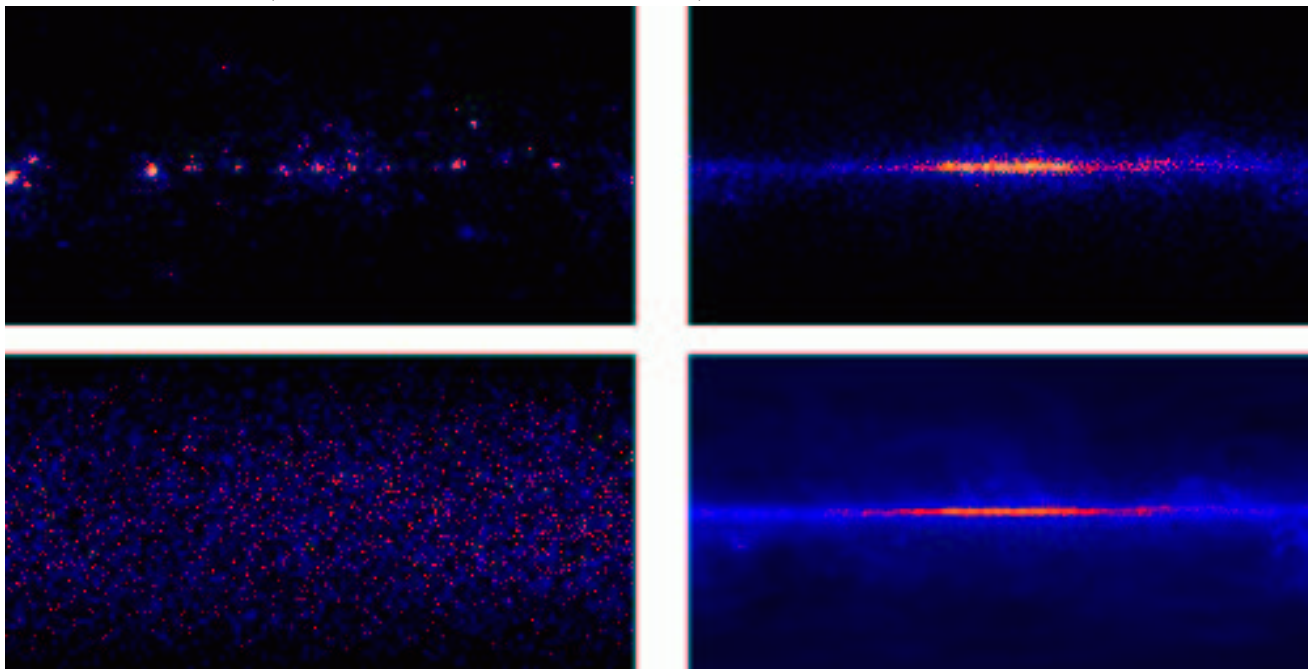
- Given an accepted photon, fold through the rest of the instrument response:

$$E'_i \stackrel{d}{\sim} D(E'; E_i, \hat{p}_i), \quad (17)$$

$$\hat{p}'_i \stackrel{d}{\sim} P(\hat{p}'_i; E_i, \hat{p}_i). \quad (18)$$

Output

- Event lists (FT1 format) comprising apparent direction, apparent energy, arrival time, etc..
- Spacecraft/LAT data (FT2 format) including attitude, longitude and latitude in Earth coordinates, SAA flag, livetime, etc..
- Sample images (10 orbits): 3EG sources, Galactic diffuse simulation and EGRET model, extragalactic diffuse (clockwise from upper left).



Limitations on Modeling Variability

Drawing trial event times based on the interval distribution

$$\Delta t \stackrel{d}{\sim} \exp\left(-\Delta t \frac{dN}{dt}\right) \quad (19)$$

has the advantage that time is treated as a continuous variable. Unfortunately, this method is only strictly valid for sources that do not vary in time.

For non-periodic, flaring sources, the flare time scale must be much longer than $(dN/dt)^{-1}$ in order for this method to be applicable. For 3C 279, $dN/dtdA \sim 10^{-2}-10^{-1} \text{ m}^{-2}\text{s}^{-1}$ for photon energies $E > 30 \text{ MeV}$ (3EG). Taking the effective area of the LAT to be $\pi R^2 \sim 1 \text{ m}^2$, the flare time scale, τ_{fl} must satisfy

$$\tau_{\text{fl}} \gg 10-100 \text{ s}, \quad (20)$$

which is perhaps not a strong constraint on the flaring sources we'll likely be modeling.

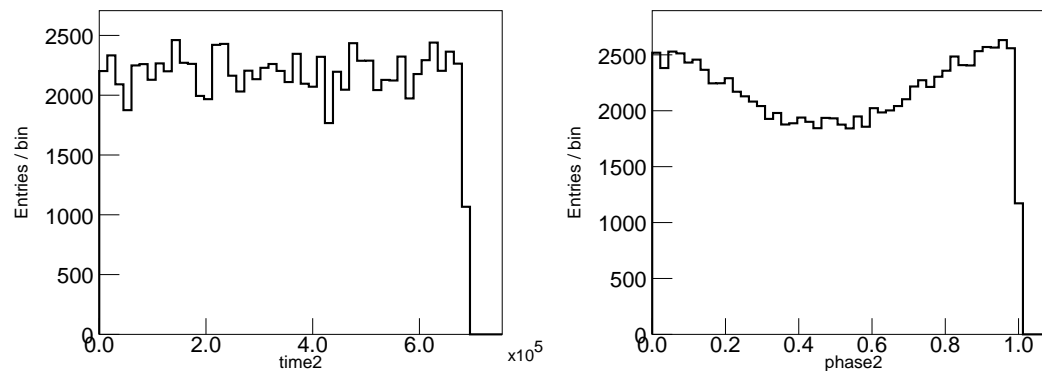
Periodic Sources

However, for periodic sources the time scale mismatch effects are compounded. Consider a source with 100% modulation:

$$\frac{dN}{dt} = N_0(1 - \sin(2\pi t/P)), \quad (21)$$

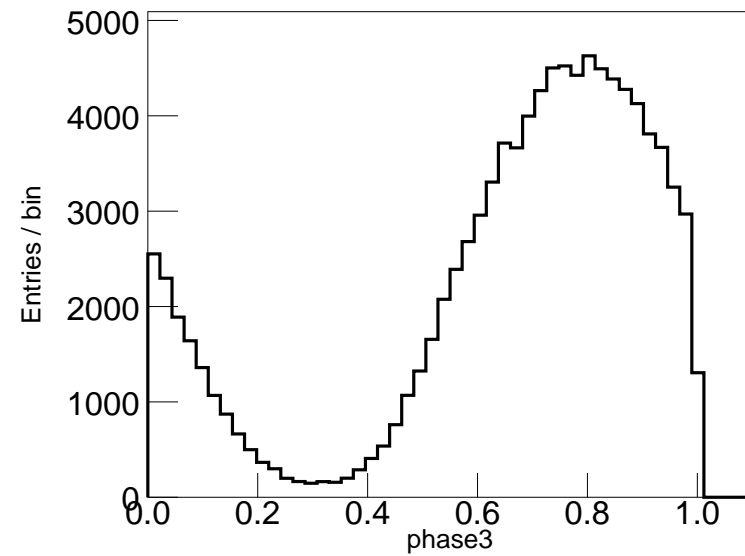
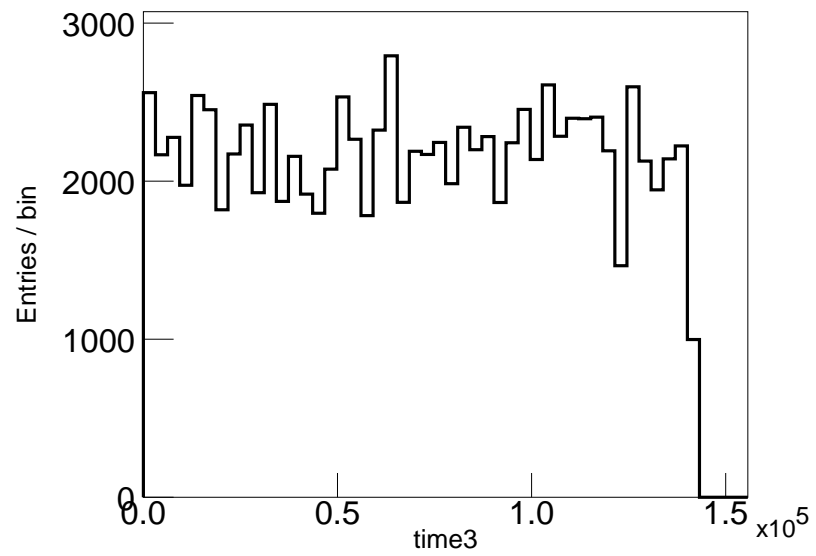
where N_0 is the mean rate event rate and P is the period.

Using a simple Monte Carlo simulation implementing eq. 19 shows that for $P = 1/N_0$, the observed modulation amplitude is about 25%; but, far, far worse, the observed mean event rate is too low by a factor of ~ 7 !

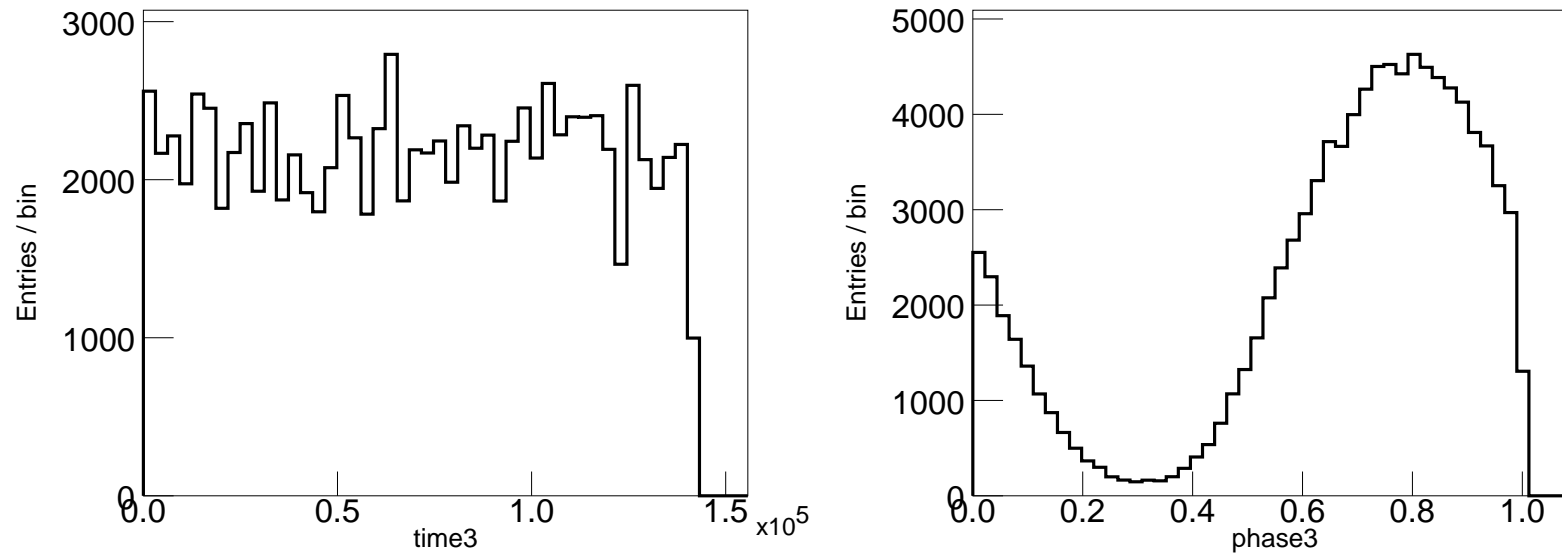


For these sims, $N_0 = 1$ and we generate 10^5 events so that the duration should be $\approx 10^5$. Note that the phase is also off; the minimum should be at 0.25.

Even for $P = 100/N_0$, the mean event rate is still off by $\sim 50\%$:



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The Solution?: Don't do that! For periodic sources like this (or short time scale transients), one has the option of implementing the `FluxSvc::EventSource::interval(double time)` method to by-pass the use of eq. 19, but real work still needs to be done to model these sorts of sources properly, e.g., sampling forward in time with sufficient resolution, computing the expected counts in each time bin, drawing from Poisson distributions, etc..

To Do

- Use O1 data.
- Move non-Gaudi parts of FluxSvc to flux package.
- A more efficient algorithm? Most of the flux is at low energies where the effective area is smallest \Rightarrow fraction of trial events accepted is $\sim 5\%$.
- May need to select from a variety of different IRFs depending on
 - where the photon trajectory intercepts the LAT (the “launch point” in FluxSvc argot),
 - $(\hat{p} \cdot \hat{x}_{sc}, \hat{p} \cdot \hat{y}_{sc}, \hat{p} \cdot \hat{z}_{sc})$, i.e., the “launch direction” in spacecraft coordinates,
 - various degrees-of-freedom that are “internal” to the reconstruction, e.g., classification tree stuff, vertex opening angles, etc..