Source Detection & Characterization

- What do we need to do?
- Rundown of parametric & nonparametric candidates
- Unbinned vs. binned likelihood
- Plan for validation, selection of methods
- Data simulator
What Do We Need?

♦ Four related but distinct activities:
  – Monitoring [on board or on ground] for flares on timescales less than intervals between data dumps
  – All-sky searches to monitor for flares on timescales of orbits, establish flux histories
  – General analysis of point sources - positions, spectra, variability [not including pulsar-specific analysis]
  – Special analysis of extended emission

♦ Most appropriate analysis method may not be the same for all four, considering, e.g., time available,
Rundown of Candidates

♦ Parametric
  – Likelihood analysis – binned and unbinned
  Tradeoffs – speed and numerical accuracy [Pat Nolan]

♦ Non-parametric
  – 2-dim Bayesian blocks [Jeff Scargle]
  – Wavelet transform processing [Regis Terrier]
  Advantages - an interstellar emission model is not needed
  TBD – sensitivity, statistical properties, how handle energy-dependent angular resolution
Unbinned vs. Binned Likelihood

♦ Principal advantage of unbinned is sensitivity, but how great is the advantage?
♦ Results from simulation of the simplest non-trivial case: isolated point source against an isotropic background

Remember, this is only one of many ‘figures of merit’ that could be used

Data from 1-year sky survey; exposure is spatially uniform, and dist. of obs. time with inclination angle is known
Photon spectral index for source: -2, for background: -2.1, both non-breaking

Used GLAST25 PSF, A(\text{eff}), i.e., AO-response versions
Unbinned vs. Binned (2)

- ~53,000 photons $>300$ MeV, high-latitude background, $2 \times 10^{-8}$ cm$^{-2}$ s$^{-1}$ ($>100$ MeV) source

Software Workshop, 16-19 January 2001, S. Digel
Different kinds of binning possible: spatial, inclination, energy, front vs. back, ...

Considered several spatial grid sizes, 1 or 3 bins in energy, and subdivision into front vs. back photons

For binned analysis, the ‘effective’ PSF is relevant, averaged over energy, with weighting by distribution of inclination angles & $A(\text{eff})$, for the assumed spectrum.
Profiles of effective PSFs:

Immediate inferences (easier with hindsight):

- Sensitivity of binned likelihood decreases for bin sizes $>\sim 0.3^\circ$
- Decrease is even more dramatic if have subdivided the energy range
- Expect to TS to have a fairly strong dependence on energy binning
Unbinned vs. Binned (5)

- Bottom line, average Test Statistics for source detection:

<table>
<thead>
<tr>
<th>Grid Size (deg)</th>
<th>Combined Front+Back</th>
<th>Separate Front &amp; Back</th>
<th>Combined w/ 3 Energy Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>380</td>
<td>390</td>
<td>440</td>
</tr>
<tr>
<td>0.2</td>
<td>370</td>
<td>370</td>
<td>410</td>
</tr>
<tr>
<td>0.5</td>
<td>280</td>
<td>290</td>
<td>320</td>
</tr>
<tr>
<td>1.0</td>
<td>220</td>
<td>230</td>
<td>190</td>
</tr>
</tbody>
</table>

Unbinned: 512
Unbinned vs. Binned Summary

- Sensitivity of unbinned analysis can be approached relatively rapidly with binned analysis *in the case of detecting an isolated point source*.
- Tompkins (1999) was right that can approach sensitivity of unbinned analysis by choosing the right binning.

His analysis predicted greater sensitivity advantages (factor ~10 in TS) for binning in energy, but started at 100 MeV and used early GLAST params. (with gaussian PSF).
Plan for Selection of Method(s)

- GLAST science is more than just detecting an isolated point source
- Describe requirements and constraints (time available, computer power) for the source detection activities
- Time in schedule is another constraint
- Test the methods
  - Also, for binned analyses, need to define optimum binning
  - The data simulator will be useful for validation: including interstellar emission model, transient sources, and ideally also pointing/livetime information for exposure generation
Data Simulator

♦ Also needed for Mock Data Challenges
♦ Ideally, will not stand alone from Glastsim, although full implementation including absolute time and orbit/attitude of GLAST will be challenging