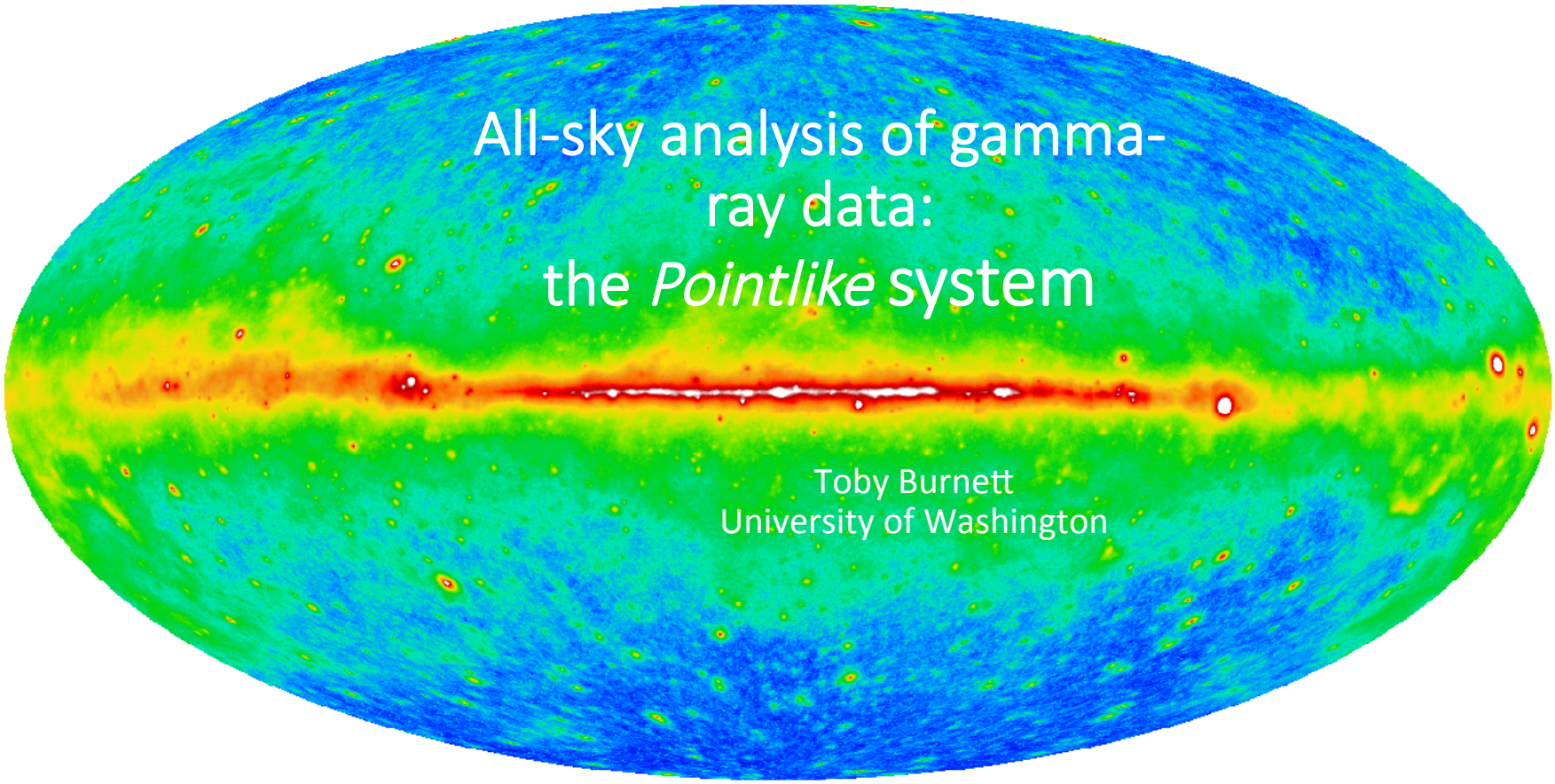


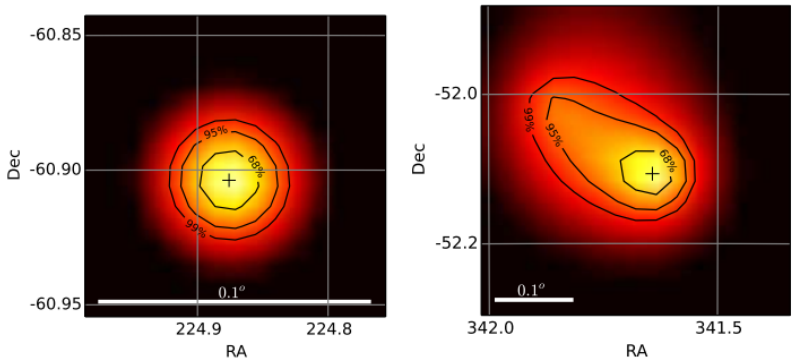
All-sky analysis of gamma-ray data: the *Pointlike* system

Toby Burnett
University of Washington

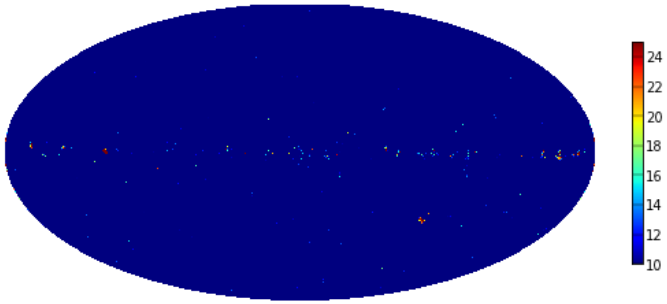
Why might this be relevant to a future detector?

Fermi-LAT experience with point sources, used for catalog

- Localization



- Detection of faint sources



How is it different?

- The computational problem:
  given a collection of gammas described by, after reconstruction:
  energy, incoming direction, time, conversion point, instrument direction
  - construct a model of the gamma-ray sky for a given time period.
- Solution: use maximum likelihood
  $\mathcal{L}(\theta|x)=\mathrm{P}(x|\theta)$
  θ: *model parameters*
  x: *data*
- Pointlike: designed to be fast and flexible
  - Fast:
    - Interactive
    - Few-hour turnaround for all-sky fits
  - Flexible: easy to add features (almost all code in Python).

Fast enough to be interactive

Example with 6 years of Fermi data: 16M photons

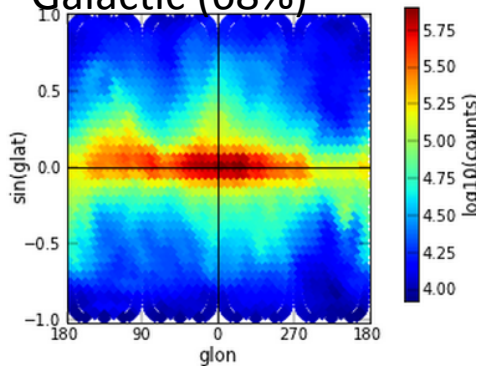
Timing, after loading data, model details (20 s)

Location, sources (variable)	**Galactic Pole 28(0)**	**Galactic center 80(10)**
Setup	19 s	44 s
Evaluate likelihood	2 ms	5 ms
fit	190 ms	5 s

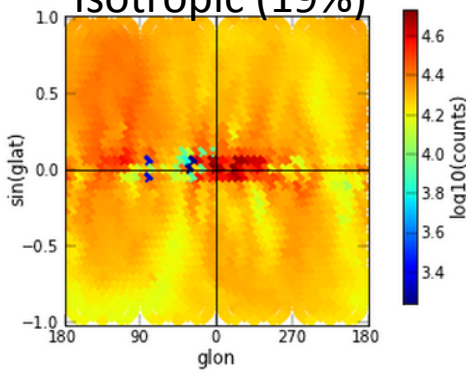
So, choose any region, have a fit within a minute

Flexibility: modify background representation

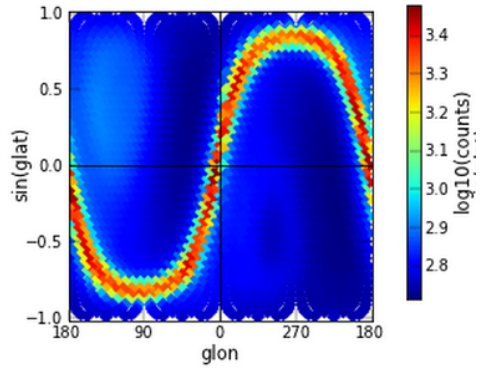
Galactic (68%)



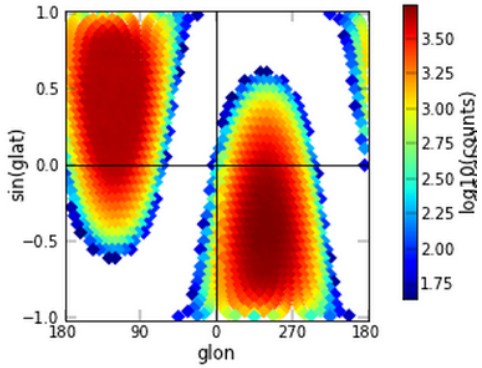
Isotropic (19%)



Sun/Moon(0.7%)



Limb (1.2%)



Some details about design

Binned vs. unbinned

Best resolution is from unbinned likelihood, evaluating the likelihood for every photon.

But if bin size is small compared with resolution in that variable, only have to evaluate the likelihood for the bin, apply to all events in it.

Convert photon list to set of lists for each energy bin, and event type

List contents: HEALPix index and count to describe the incoming direction (nside chosen so size small compared with PSF). So a sparse representation.

Fermi Example.

Current 6-year "Source" dataset has 16M photons, standard "FT1" files: 16.5 GB

Bin in 40 energy bands, two event types: 96 MB, factor of 172.

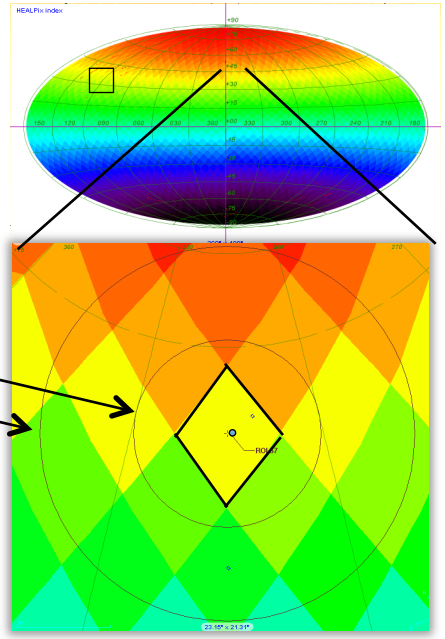
Errors: event types vs. covariance matrix from reconstruction

Every event may have known correlated errors from reconstruction

Different types of event can be grouped, and each assigned errors from the average, determined by Monte Carlo

The pointlike sky model

- Tessellate sky using HEALPix nside=12: 1728 regions
- Each ~5° square pixel defines:
  - Center of circular regions for:
    - data (5 deg)
    - sources (12 deg)
  - sources inside are varied; those outside fixed to results of previous iteration
  - Note ~x3 overlap of data: not independent
- Iteration procedure:
  - Each region fit (full likelihood maximized) independently
  - Each fit remeasures point source positions: Apply updates between cycles.
  - Check changes in log(L): iterate until none changes by more than 10 (3-5 iterations required)



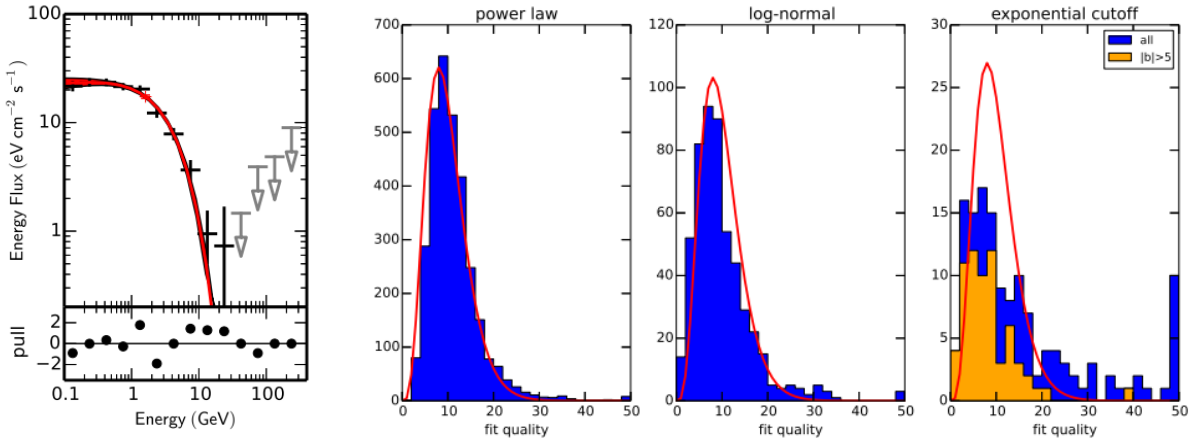
Colors: HEALPix index

Check validity of fits

Likelihood is only valid if the probably is correct: Two checks:

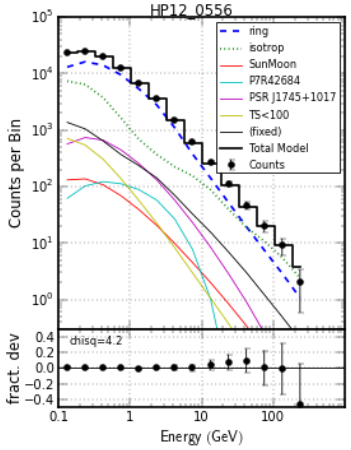
- Spectral model is correct description

Define a chi-squared-like quantity for each source



Example: PSR J1459-6053

- Background is correct



Conclusion

- Not in Fermi tools, but essential for catalog analysis
- Very flexible design, applicable to other detectors