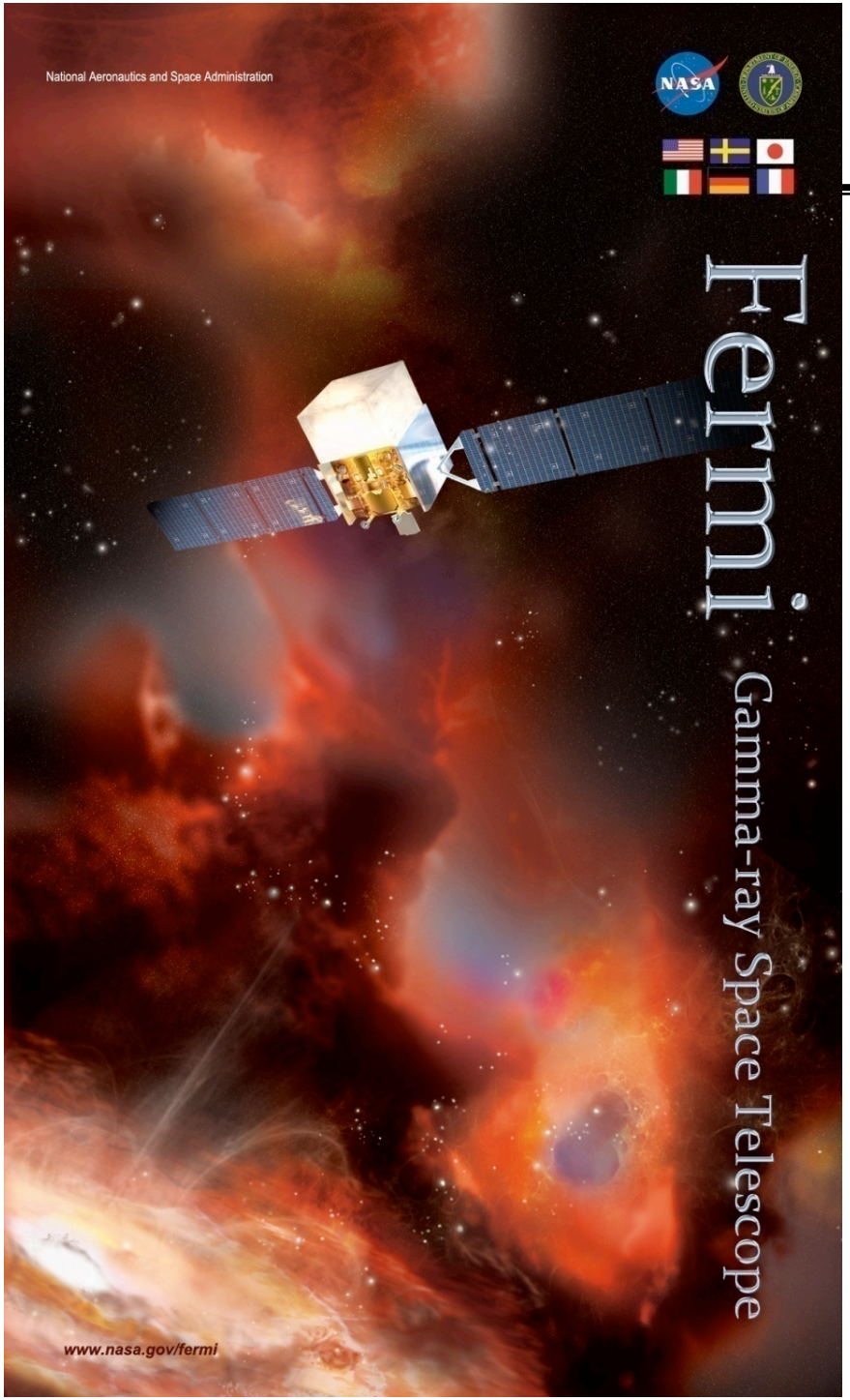


Fermi

Gamma-ray Space Telescope

Analysis Workshop
17 December 2009

Advanced Likelihood

E. Hays

Goals

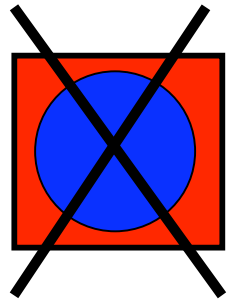
- Quality checks on spectral fitting of point sources
  - Major gotchas
  - Simple checks
  - Models revisited
  - Spectral residuals
  - Spatial residuals
- Useful considerations
  - Impact of region selection
  - Impact of zenith angle selection (relates to above…)
  - Impact of energy selection
  - Impact of spectral model
- Binned vs. Unbinned likelihood

Major gotchas

- **Parameter estimate depends critically on calculating the proper exposure**

selection		livetime	response	minimization
gtselect	gtmktime	gtltcube	gtexpmap gtsrcmaps	gtlike

- **Examples of things that can screw this up**
  - **fselect, fcopy selections do not update the header keywords used in the exposure calculation**
  - **Mismatch of data and IRF set**
  - **Mismatch of initial ROI selection and data cube (binned)**
  - **Mismatch of calculated diffuse response and model diffuse components - Use different names for different models**



Likelihood output - simple checks

Did the fit work and does it make sense?

- **Did the minimization converge?**
- **Are the number of predicted photons reasonable?**
- **Do the parameter values make sense?**
  - **values hitting limits?**
  - **source with extremely soft spectrum or hard spectrum?**
- **Do the parameter errors make sense?**
  - **Too small? Were enough parameters left free?**
  - **Larger than the parameter values - with low TS…better luck next time**
- **Consider the above for target source and field sources**
- **All of the above becomes more critical for faint sources, complex regions, time-binned light curves…**

Likelihood - ROI selection

How big?

- **Big enough to constrain model components - source of interest, diffuse emission, nearby sources**
- **Small enough to avoid significant zenith cut losses to exposure**
  - **Practical advantage! less photons and less sources => less calculations for unbinned analysis**
  - **Analysis disadvantage! likelihood is an inclusive modeling strategy**
- **Recommendations**
  - **10 deg for isolated point source (E>100 MeV)**
  - **Larger regions (15-20 deg) benefit confused sources, aid in separating diffuse at low energy, improve error estimates**
- **Test it**
  - **Are fit results reliable for different ROI radii?**
  - **What is the impact on GTIs?**

Likelihood model - sources

What should be included?

- **All sources that contribute photons to the selected region**
  - **Bright source list sources within ~10 deg of the ROI boundary - accommodates tail of low energy PSF**
  - **Same goes for catalog sources once available**
- **Galactic diffuse model**
- **Isotropic diffuse model**
  - **Important for all parts of the sky…provides a home for residual instrumental effects NOT well modeled by the response**

This is a starting point. Adapt to find what works best for your region and source.

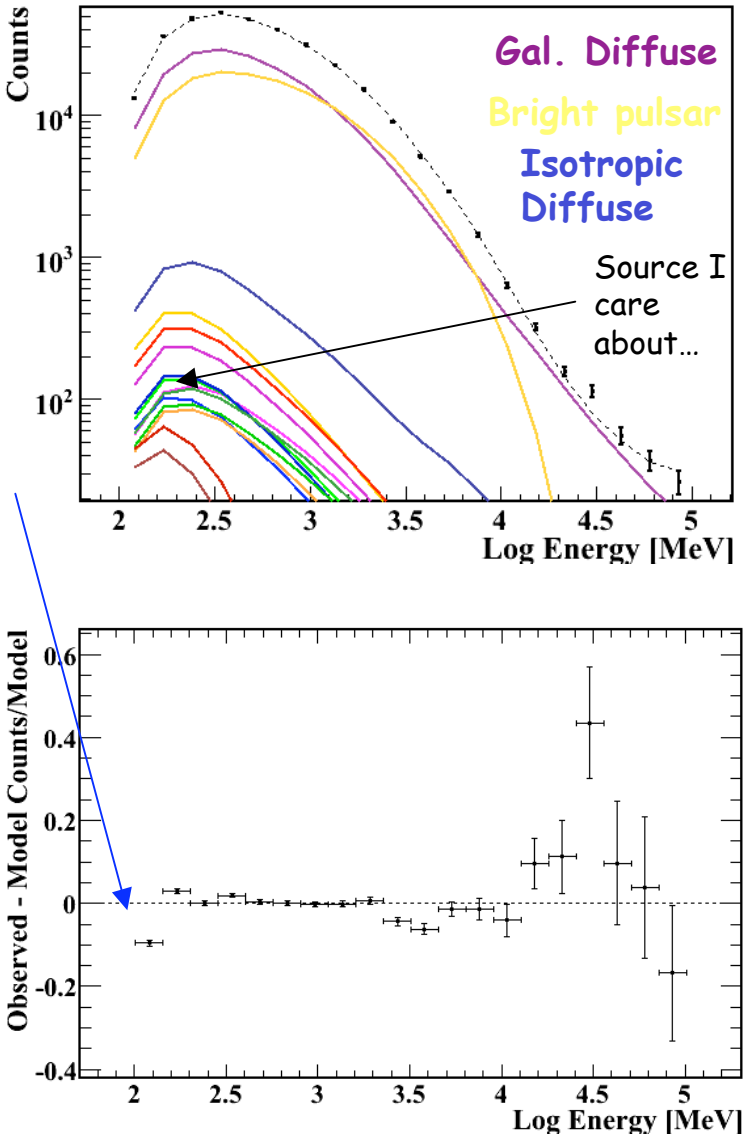
Likelihood Model - spectra

What spectral shape?

- **Power laws are simple and well defined**
  - **For faint sources, difficult to justify more parameters**
- **BUT lots of LAT sources are not simple power laws… some tips to help motivate other spectral forms**
  - **Bright pulsars?**
    - **Try simple exponentially cutoff power laws to improve fits for the pulsar itself *and for nearby sources***
  - **Check the energy distribution for an energy-dependent ROI selection**
  - **Do the power-law fit parameters vary significantly for different minimum energy selections or fits in separate energy bins?**
- **Most accurate and unbiased way to determine spectral parameters and errors is by testing that hypothesis using the likelihood fit**

Spectral Residuals

- **Unbinned analysis produces predicted counts and residuals.** Example is a long integration near the Galactic plane and a bright pulsar
- **Discrepancy at low energy is typical**
  - **Likelihood uses true energy**
- **Discrepancies strongly tied to diffuse model for most analysis**
  - **Diffuse mediates cross talk between your source and neighbors**
  - **Consider relative strength and test impact of model choices and selections on source of interest**



Likelihood - reality checks

Is anything missing in the model?

- **Visual inspection of count maps and residuals**
- **Test Statistic maps (unbinned analysis)**
  - **gttsmap - Tests hypothesis of additional point source over a grid**
  - **Very Calculation Intensive**
    - **try small regions (5 deg) and large grid spacing (0.5 deg)**
  - **Note this can expose deficiencies in the diffuse model in addition to evidence for an additional source**
  - **Warning: gttsmap is not a tool for localization, gtfindsrc does that**
- **Predicted and residual count maps (binned analysis)**
  - **Profiles, radial density, energy dependence**

Likelihood - useful tests

- Overall consistency - lots of good ways to get at this
- Iteration
  - Consistent results if using output model is fit model?
- Data selection consistency
  - Effects of energy selection?
  - Changes with ROI selection? (Keep in mind this also effects good time selection in combination with zenith cut)
  - Consistency with results in distinct energy bins (ala catalog)
  - Separate analysis of front and back events (using appropriate IRFs, diffuse response, and isotropic model)
  - Effects of time selection
- Fit and Minimization choices
  - Impact of starting parameter values in the model?
  - Fit tolerence? (converging to true minimum?)
  - Effects of optimizer?

Binned vs. Unbinned Likelihood

- **Unbinned: Treats each photon independently (position, energy)**
  - **Best theoretical performance**
  - **More sensitive - important for faint sources**
  - **Best option for low statistics scenarios - light curves**
  - **Not for use with spatially extended sources**
  - **More difficult to diagnose problems in individual source fit**
- **Binned: Treats the data in bins of position and energy. Minimal criteria - more photons than bins**
  - **Less computationally intensive than unbinned**
  - **Handles templates for extended sources**
  - **Allows more straightforward diagnostics of fit (source maps, spatial profiles, energy dependent comparisons of prediction and model)**
  - **At highest energies, can run into low statistics even for long integrations**

Use of both allows consistency check
(for data sets where both can be reasonably used)

gtobssim

- **The ultimate test…**
  - **Can you simulate what you found?**