Fermi-LAT Stacking Analysis of Swift Localized GRBs

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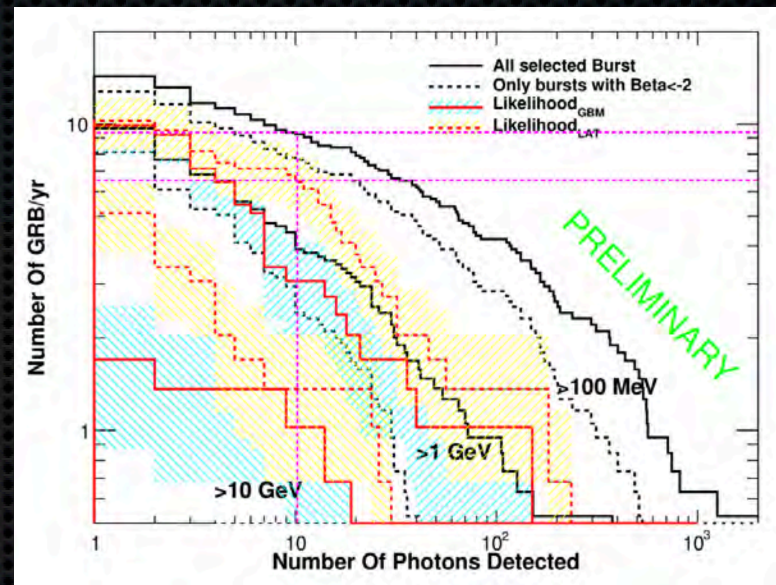
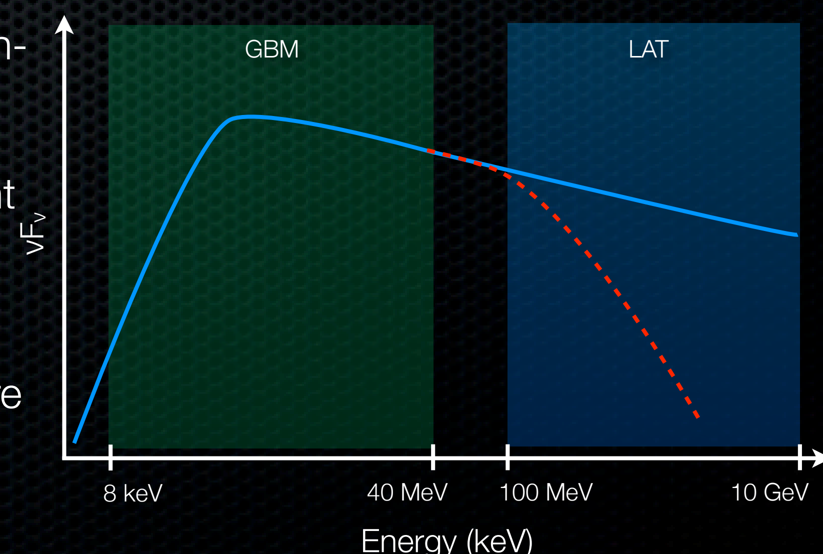
On behalf of the Fermi collaboration

Motivation

- GRBs in the LAT field of view detected >100 MeV: ~8%
  - 9.3 GRBs expected / year with >10 photons above 100 MeV
  - 6.3 GRBs observed / year with >10 photons above 100 MeV
- LAT upper limits of bright/hard GBM bursts indicate spectral steepening and/or cutoffs above > 50 MeV may be common
- Stacking of high-energy spectra with power-law slopes may produce a detectable signal > 75 MeV, whereas high-energy spectra with a exponential cutoff may not.
- GBM localized GRBs have error circles that are significant compared to the size of the LAT PSF, adding ambiguity traditional likelihood or count stacking analysis
- Swift localized GRBs have positional uncertainties that are much smaller than the LAT PSF





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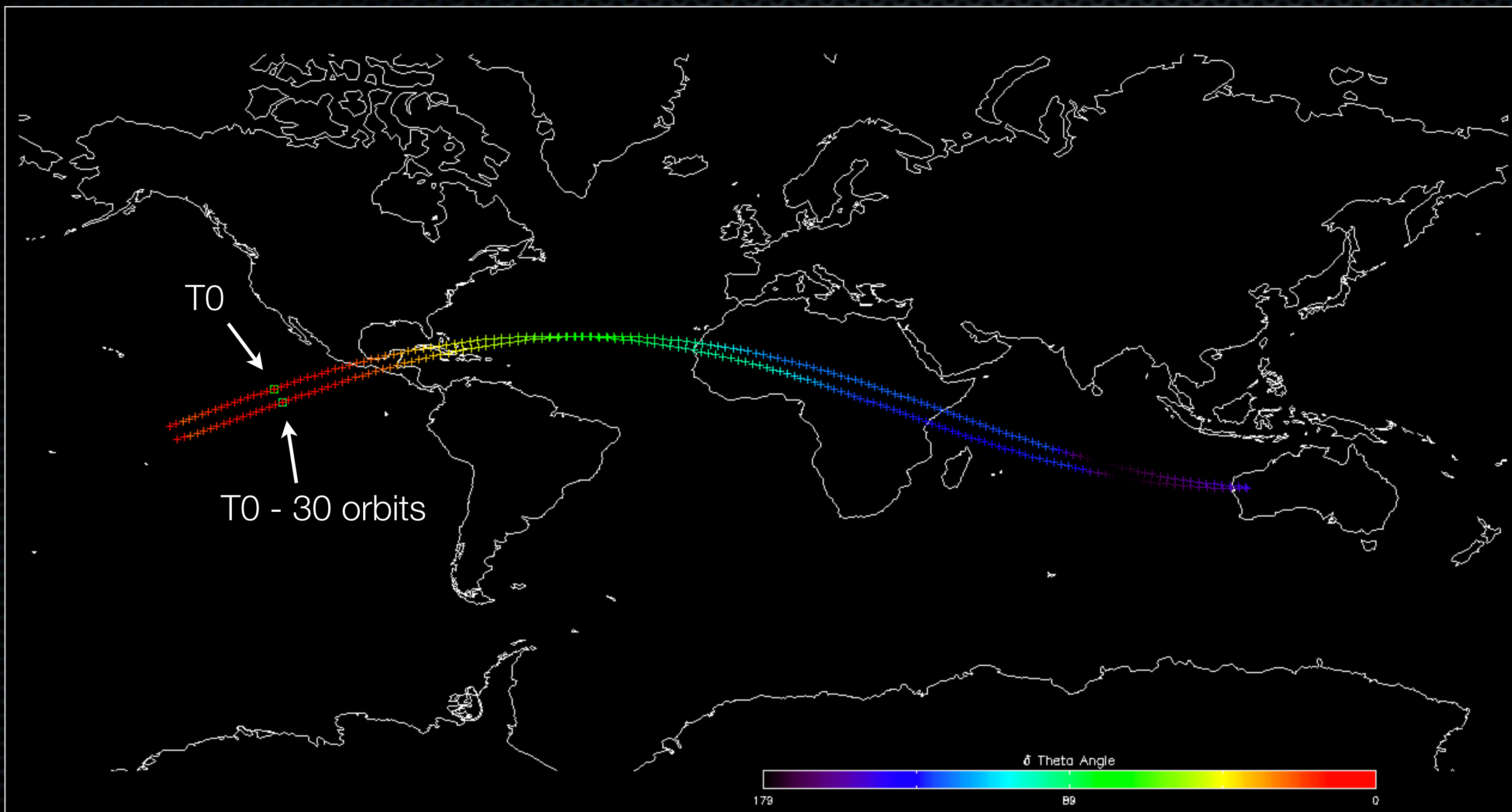
Method

- Select Swift detected GRBs in the LAT FOV
  - BAT_{Error} ~ 50 arcsec, XRT_{Error} ~ 3 arcsec
- Counting Analysis
  - Count photons arriving in a 12 deg ROI from T0 to T0+100s and 75 MeV to 10 GeV
- Composite Likelihood Analysis
  - Perform likelihood analysis on each source independently and add the likelihood profiles to produce a “composite” likelihood surface
- Both methods have their limitations:
  - Counting analysis requires very good estimate of the background
  - Likelihood analysis depends on spectral shape assumptions

Background Estimation

- Need to have a good estimate of the background for comparison
  - We want to compare our stacking results to those found by stacking the same Ra, Dec and Lat, Lon, but offset in time
- Fermi returns to the same geomagnetic coordinates roughly every 30 sidereal orbits
- Background sample is defined as the burst Ra and Dec, but offset by T0 - 30 sidereal orbits (~171915 sec)

Background Orbit



Data Analysis

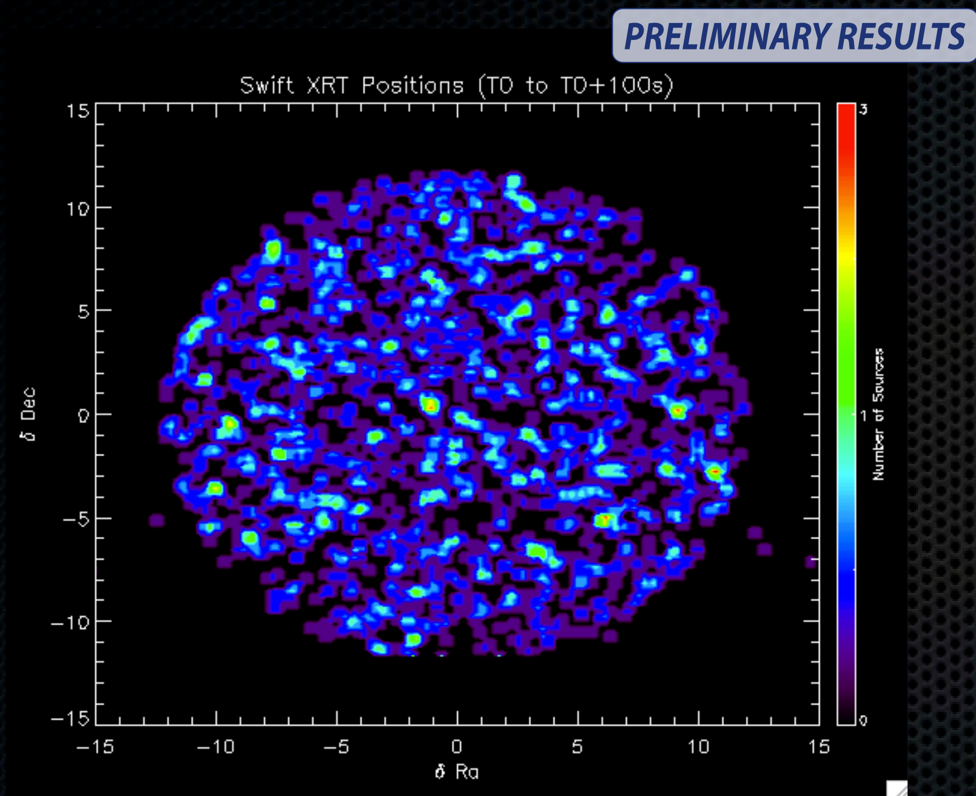
- Sample Selection
  - Swift GRBs since L&EO: 369
  - Swift GRBs since L&EO in FOV: 121
  - Swift GRBs since L&EO in FOV with GTIs: 105
  - Swift GRBs since L&EO in FOV with GTIs not detected > 75 MeV: 81
- Analysis Implementation
  - P7TRANSIENT_V6 data class
  - 75 MeV < E < 10 GeV, T0 to T0+100s, 12 degree ROI

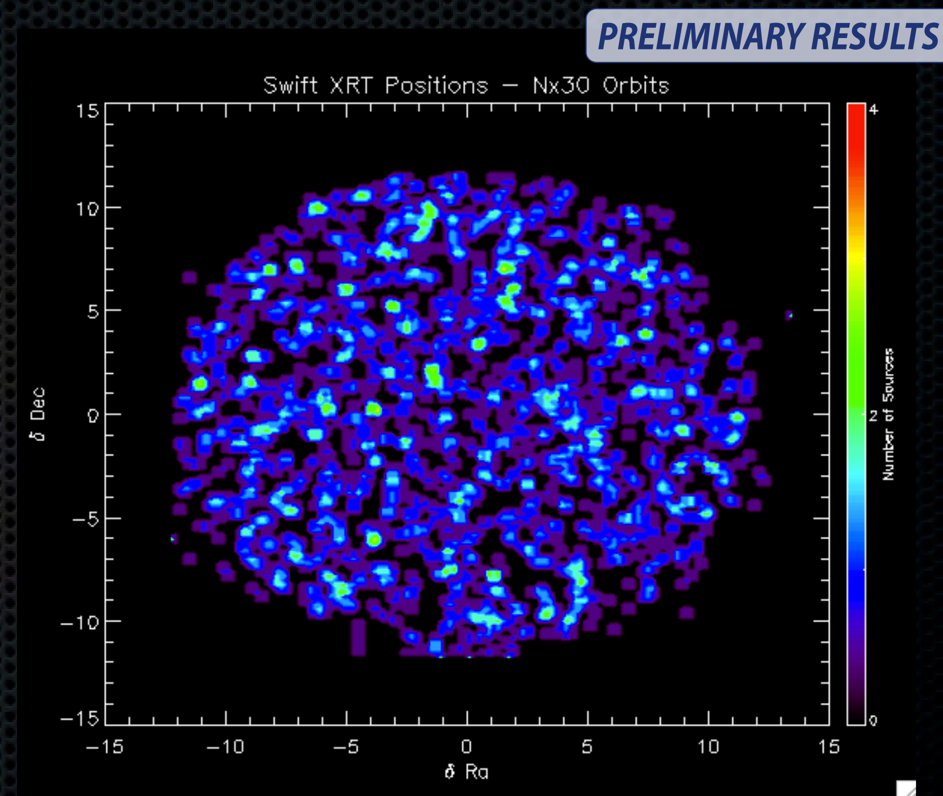
Counting Analysis Results

Interval	Signal	Background	Significance
T0+100s	1432	1349	2.26σ

- We find a 2.26σ excess when counting all photons that are detected from T0 to T0 + 100s, 75 MeV < E < 10 GeV, within a 12 degree ROI

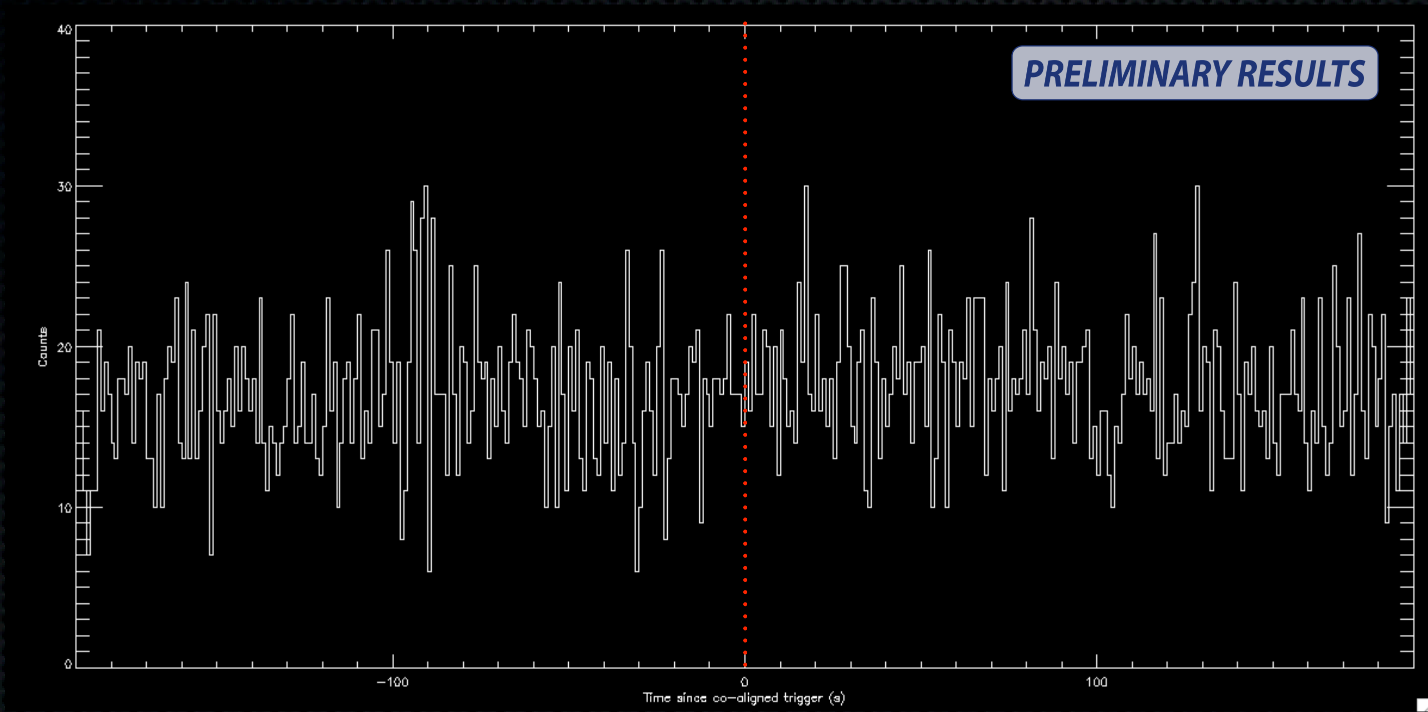
Stacked Intensity Map





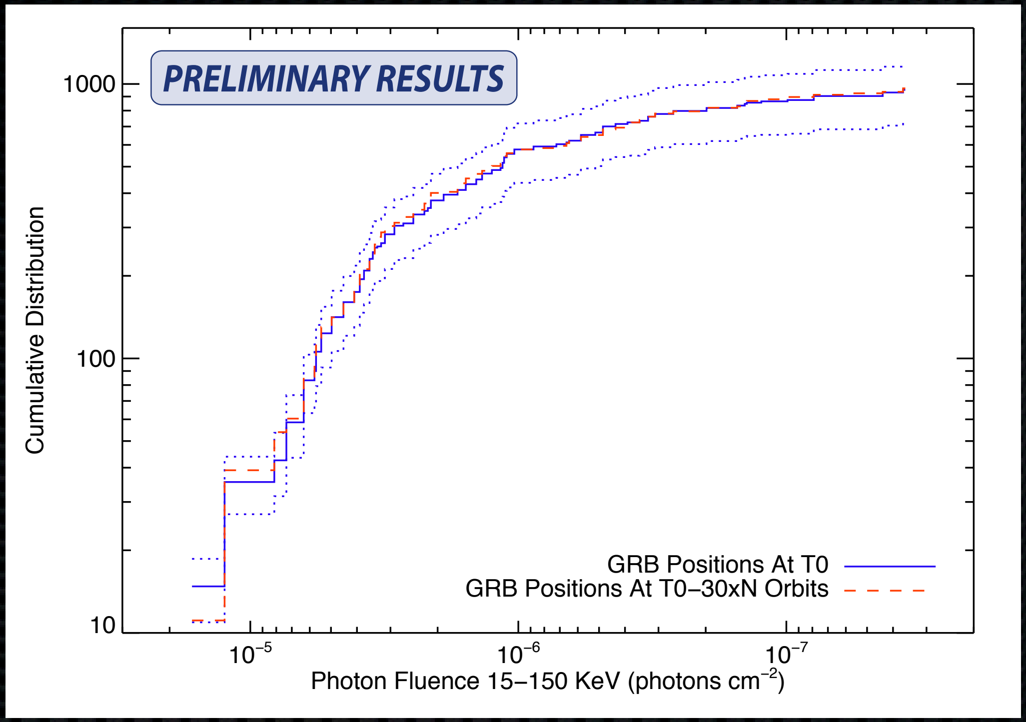
- The stacked intensity map for the co-aligned burst locations matches that of the background sample

Stacked Light Curve



- No significant correlation between signal excess and co-aligned burst trigger

Cumulative Distribution



- Cumulative LAT signal sorted by burst fluence (15-150 KeV) compared to their background levels measured at T0-30xN orbits
- No significant detection as a function of burst brightness

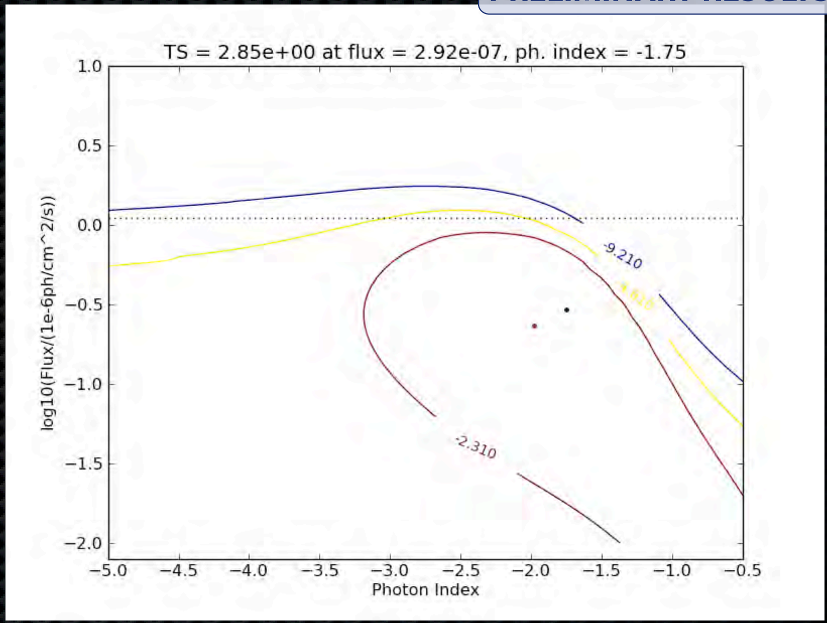
Composite Likelihood

- Analysis Technique
  - Compute maps of delta-log-likelihood (-2*(logLike - logLike0)), scanning over Integral and Index parameters
  - Coadd maps of delta-log-likelihood to obtain composite likelihood surfaces.
  - Compute 68, 90, 95% CL contours using likelihood profile
  - Compute marginal likelihoods for flux and index separately.
- Analysis Implementation
  - Unbinned analysis from 0.1 < E < 10 GeV, 100s, 10 deg ROI

Marginal Distribution

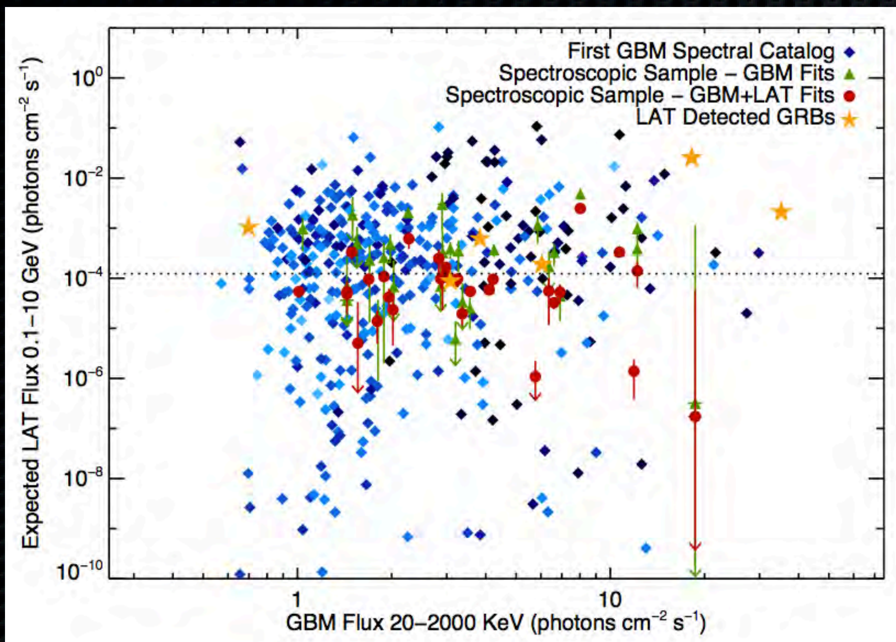
- Delta-log-likelihood with 68, 90, and 95% contours shown.
- Maximum is the best-fit model for given TS value (black point).
- The red point indicates the modes from the marginal likelihoods.
- The dotted line corresponds to the 95% CL upper limit inferred from the marginal likelihood of the flux.

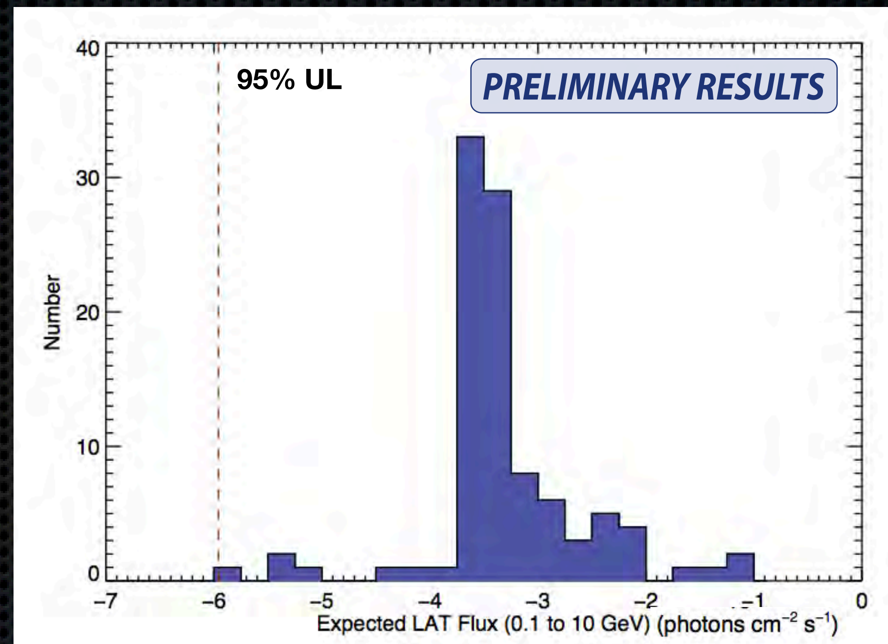
PRELIMINARY RESULTS



Interval	95% CL	Best Fit Flux	Best Fit Index	TS
T0+100s	1.10E-06	2.92E-07	-1.75	2.85

Expected LAT Flux

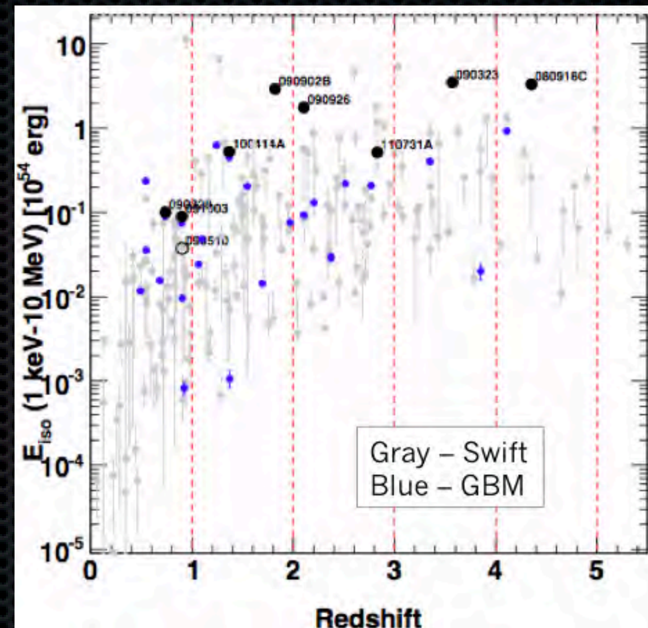




- Randomly select 81 bursts from the GBM spectral catalog, extrapolate the expected LAT flux, and calculate the expected flux
- The composite likelihood upper limits is orders of magnitude below the photon flux expected from the composite spectrum

Interpretation

- There does not appear to be a large population of GRBs just below the LAT sensitivity
- High energy spectral turnovers in GRB spectra could explain this lack of emission above 75 MeV
- LAT detected GRBs are different than typical GRBs
  - High Eiso values and Lorentz factors



- LAT emission may not be due to the extension of the prompt spectrum, but instead due to to the interaction of the relativistic blast wave interacting with the ISM (e.g. GRB 110731)
  - Correlated variability in some bursts (e.g. 090217) complicates this explanation
- Future spectral fitting using LAT Low Energy (LLE) upper limits may shed further light on the nature of the prompt high energy spectra