Fermi-LAT Upper Limits on Gamma-ray Bursts

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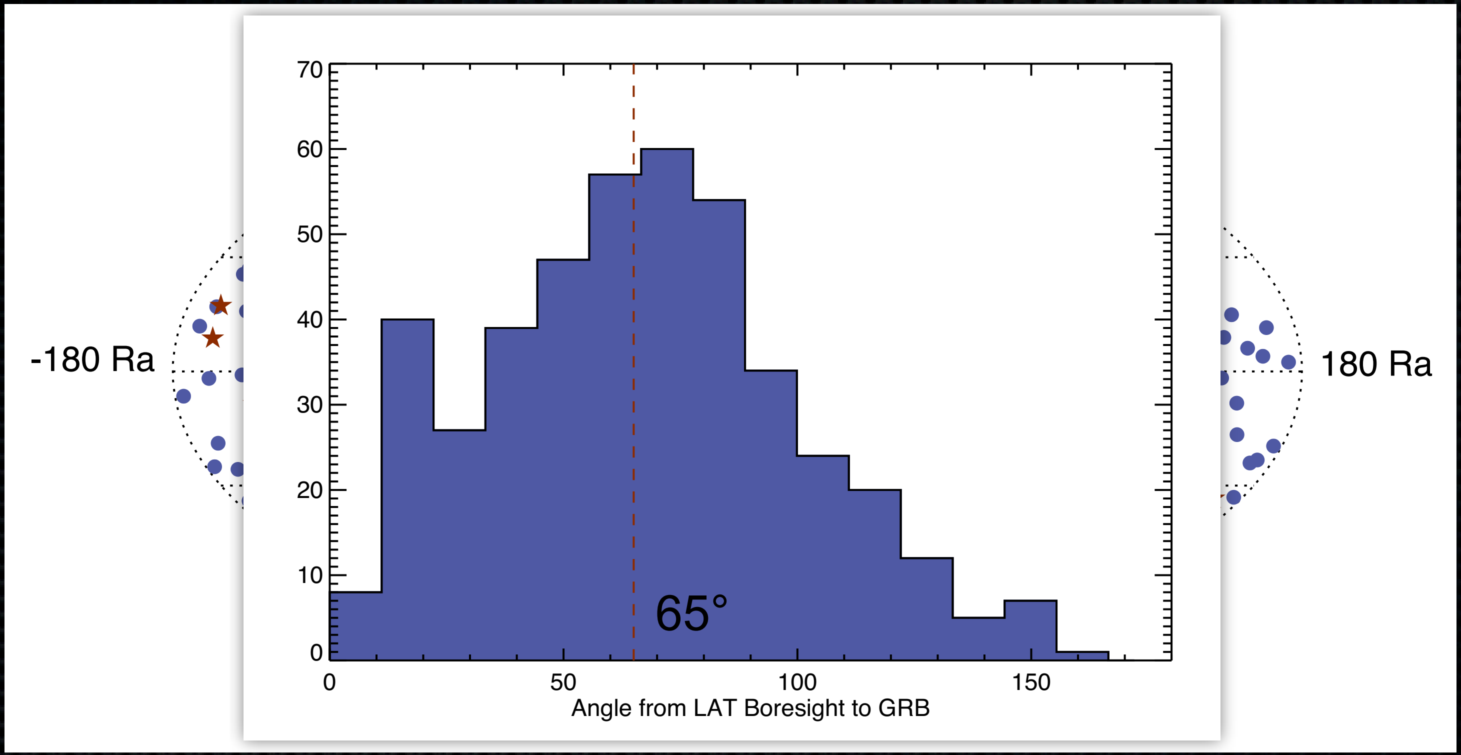
On behalf of the Fermi collaboration

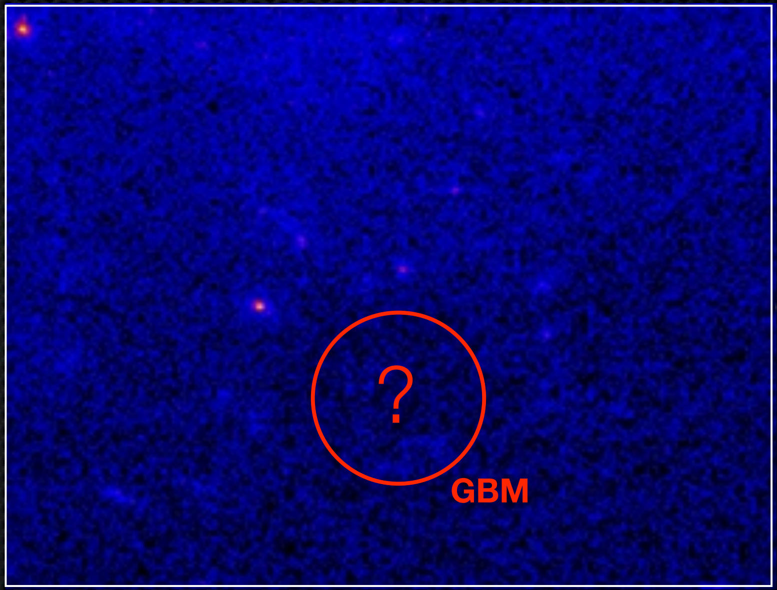
Fermi GRBs as of 101026



- 565 GBM GRBs
- ~48% in LAT FOV
- 18 LAT GRBs
- 6.4% of GRBs in FOV

LAT Upper Limits on GRBs

- What are the upper limits to the 0.1-10 GeV flux for GBM only bursts?
- Can we rule out high energy emission for these events?
- How do these upper limits compare to the expected flux?
- Could point to interesting physics
  - Intrinsic spectral breaks?
  - EBL or γ - γ absorption?



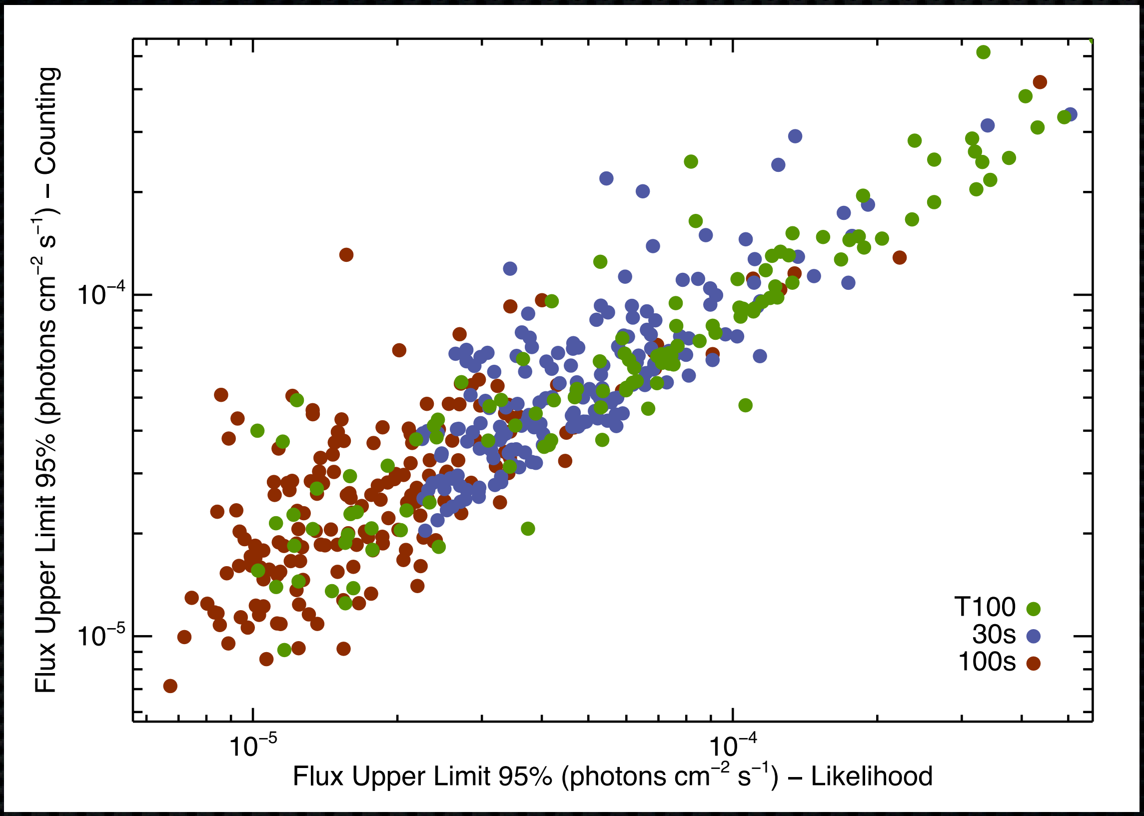
Methodology

- GRB Pipeline at SLAC
  - Analyze the LAT data for all GBM detected GRBs in ~ 1 hour
- Procedure:
  - Select GRBs within the LAT FOV ($\theta < 65°$)
  - Model background using the empirical background estimator
  - Calculate likelihood and counting upper limits
    - For T90, 30s, and 100s time intervals
  - Compare limits to predicted LAT fluence by extrapolating the GBM determined high energy power law index

Upper Limits Sample

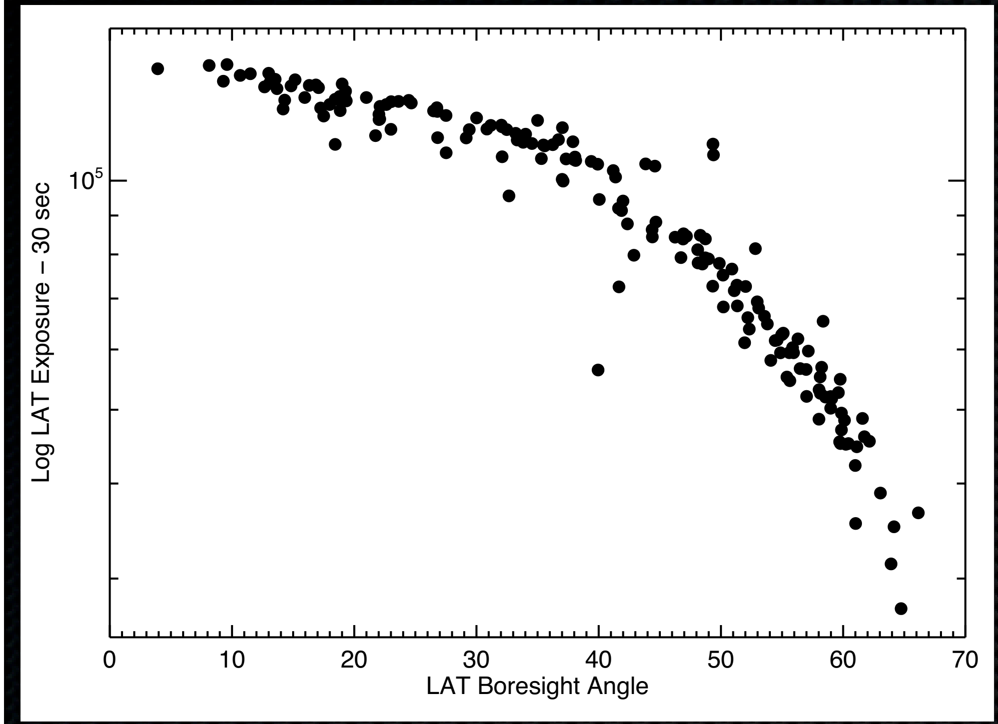
- GRBs Analyzed: 435
  - All bursts listed at the FSSC until March 1st.
- GRBs in LAT FOV: 209 (48%)
- GRBs with likelihood limits: 185 (43%)
  - The loss of 5% of the bursts in the LAT FOV for which we could not obtain upper limits were due to lack of data near the burst (i.e. a SAA transit right before or after the trigger)
- GRBs with counting imits: 179 (41%)
  - The loss of 7% of the bursts in the LAT FOV for which we could not obtain upper limits were due to lack of data AND background modeling for high zenith GRBs

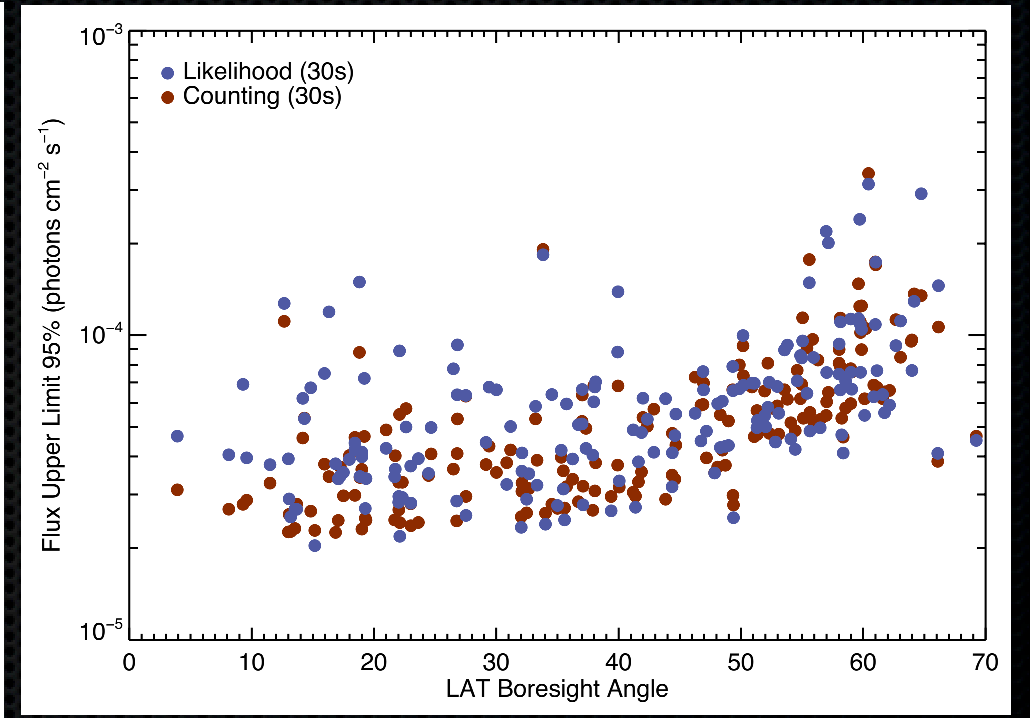
Upper Limits Comparison



- Good agreement between the two methods
- The 100s limits are roughly 0.5 dex deeper than the 30s limits

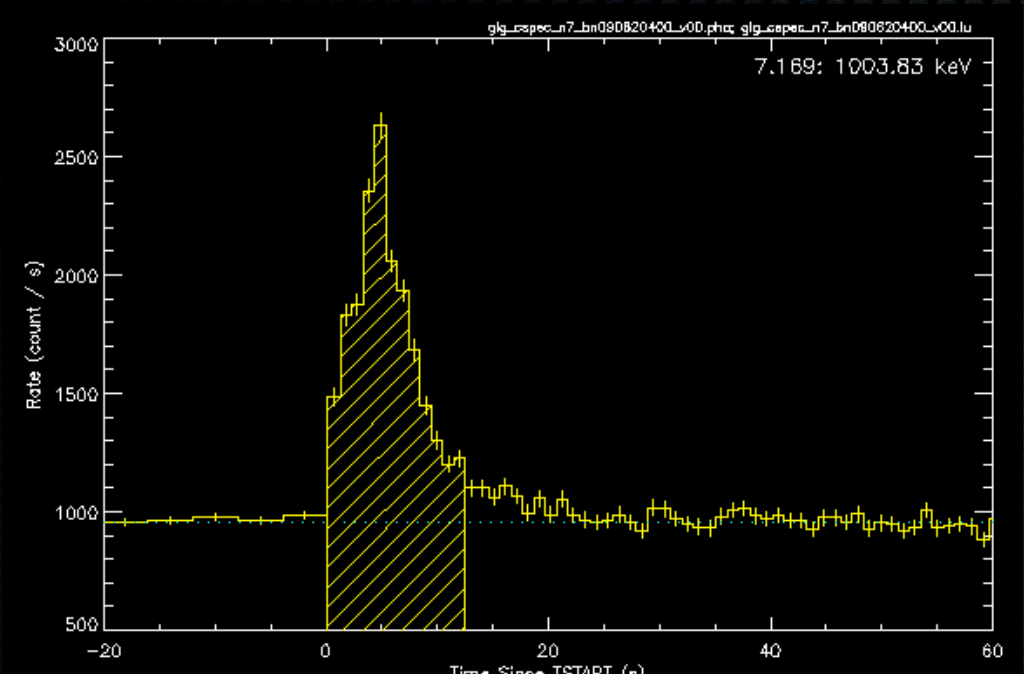
Upper Limits vs. Exposure & Angle

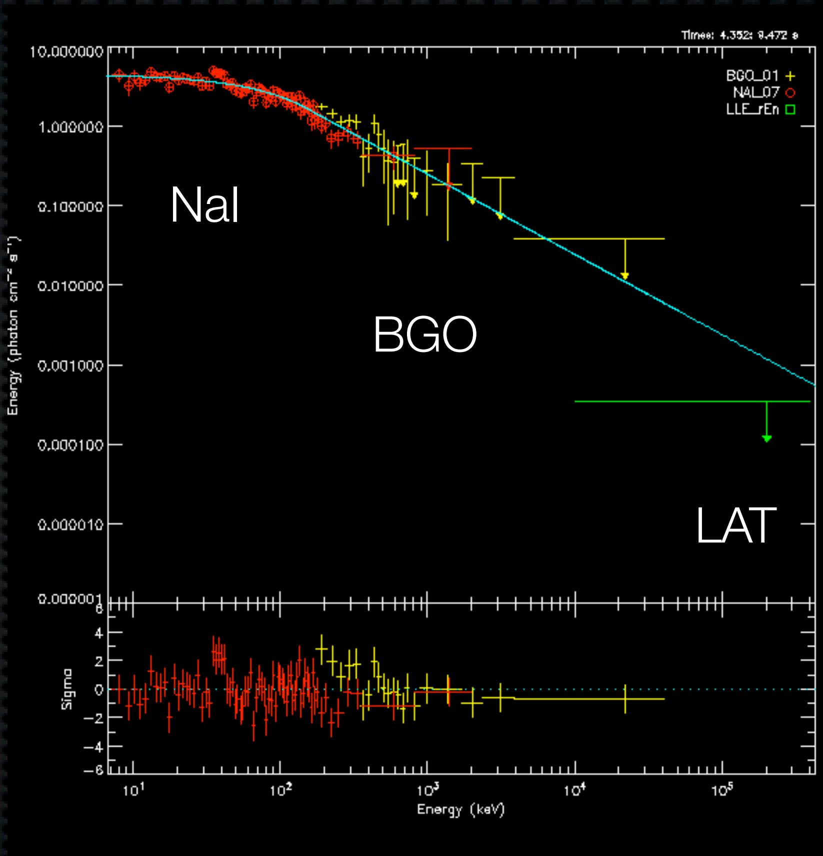




- Exposure falls smoothly vs. LAT boresight angle
- Upper limits are therefore correlated with the LAT boresight angle at trigger

GBM Spectral Extrapolations



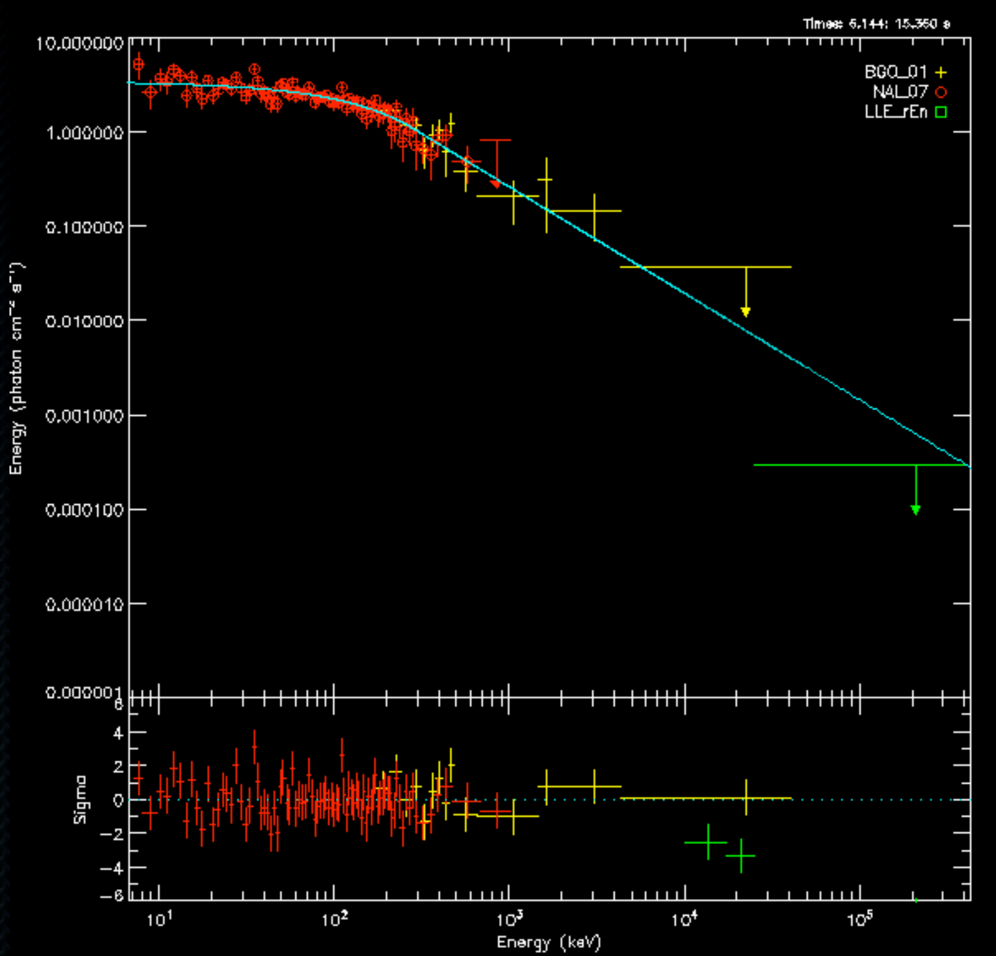


- Fit NaI+BGO spectrum from 8 keV to 40 MeV
- Extrapolate the expected flux in the 100 MeV to 10 GeV range
- Compare upper limits to this expected LAT flux

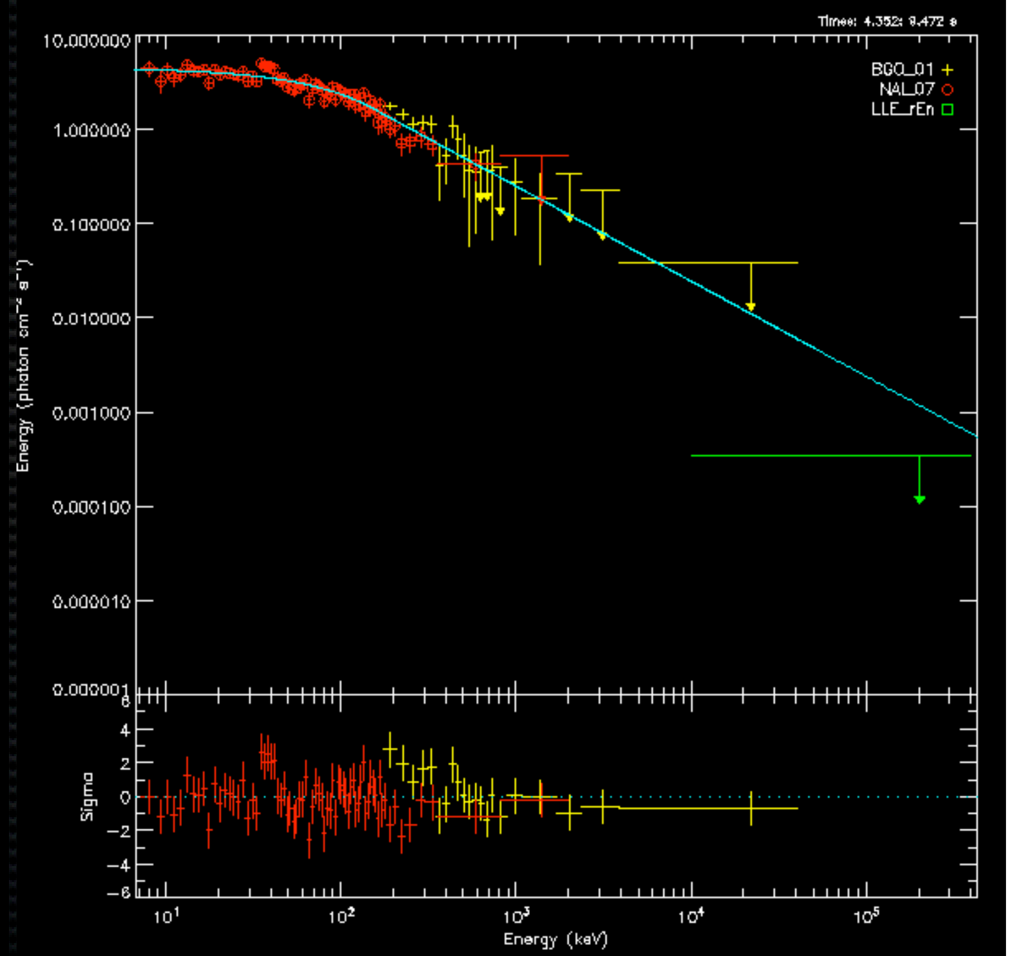
Spectroscopy Sample

- Bright BGO Sample:
  - GBM detected bursts with > 70 cts/s in TRIGDAT
  - 53 GRBs (1.5 years)
- "Gold" Sample:
  - 16 GRBs in LAT FOV with good NaI+BGO fits
- Expected LAT Flux
  - Extrapolate beta to find expected LAT flux
  - We use the full covariance matrix to estimate beta error

Joint Spectral Fits



GRB 0905285



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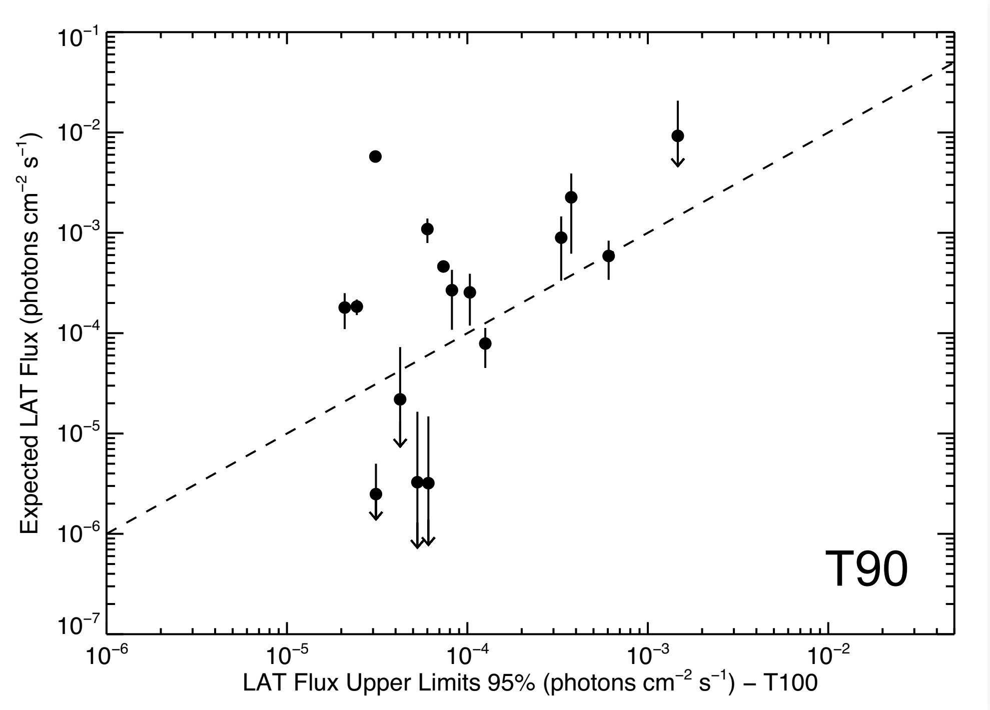
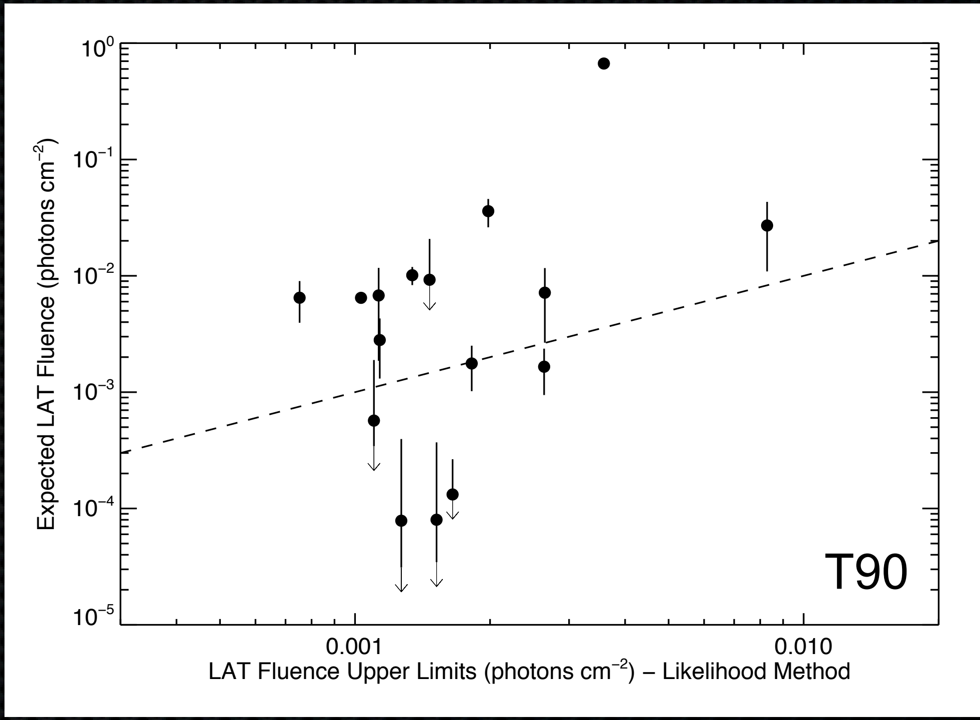
Expected Flux & Fluence Ratios

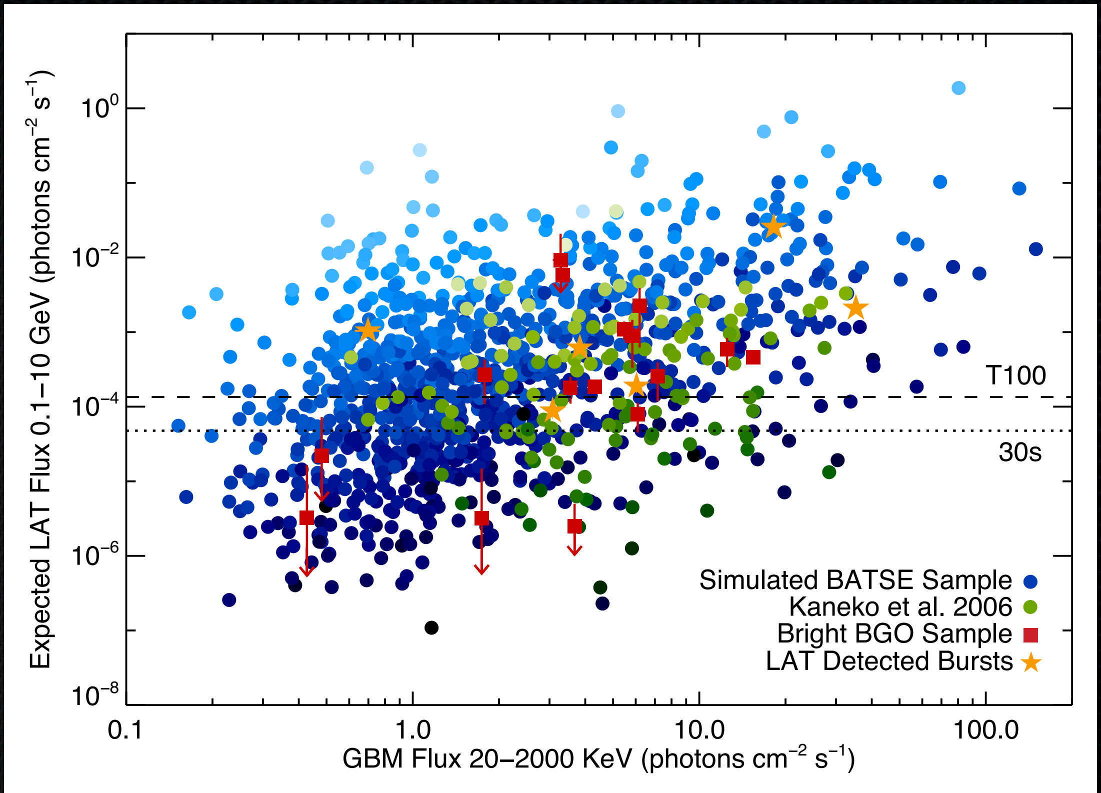




- The expected flux & fluence exceeds the T90 LAT flux and fluence upper limits for a majority of GRBs

How common are breaks?

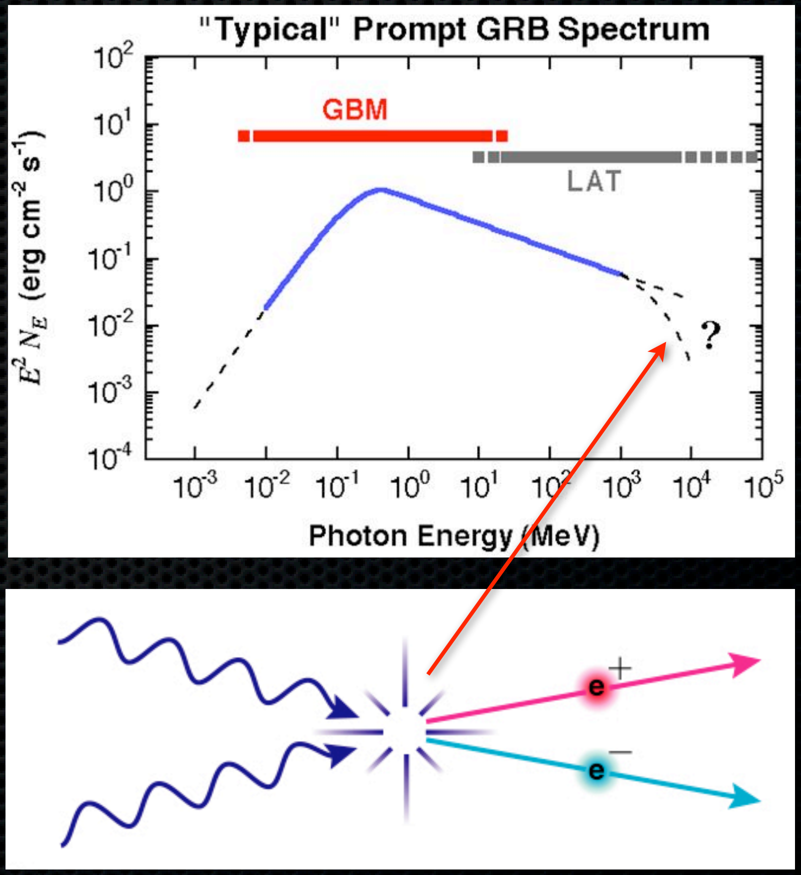
- Roughly 3/4 of the simulated BATSE sample have expected flux values that exceed the median 30s LAT upper limit
- The same proportion holds for the bright BATSE and bright BGO bursts
- This could explain the number of “LAT dark bursts”



  - It appears that high energy spectral breaks may be very common among GRBs

Interpretation?

- Intrinsic spectral breaks?
  - No evidence for broken power law has not been
- Extragalactic background light?
  - Should not be this strong and low E
- Pair creation opacity?
  - GRBs may have a broad distribution of bulk Lorentz factors
  - LAT "dark" bursts may represent the low portion of the distribution



Lorentz Factor Estimations

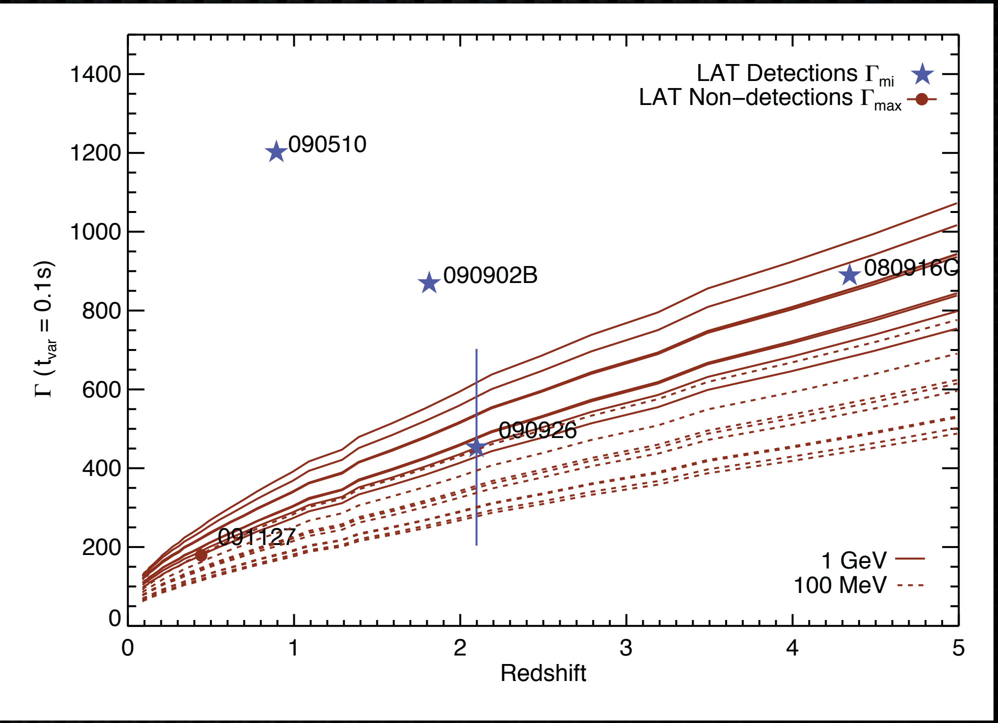
- Optical depth to pair production

$$\tau_{\gamma\gamma}(E_0) = \sigma_T \left(\frac{d_L(z)}{c\Delta t}\right)^2 E_c f(E_c)(1+z)^{-2(\beta+1)} \Gamma^{2(\beta-1)} \left(\frac{E_0 E_c}{m_e^2 c^4}\right)^{-\beta-1} F(\beta)$$

- Find Γ_{min} when $\tau_{\gamma\gamma} < 1$
  - E_C = highest energy photon detected
- Find Γ_{max} when $\tau_{\gamma\gamma} = 1$
  - E_C = first energy bin with an upper limit below the model
- Need to know β, Δt, z, E_C
  - Make some assumptions; find β and E_C through spectral fitting

Lorentz Factor Distribution

- 3 LAT detected bursts have $\Gamma_{min} > 800$
- Assume $\Delta t \sim 0.01$s and $1 < z < 5$
- Using $E_c \sim 1$ GeV
  - $\Gamma_{max} \sim 100\text{-}800$
- Using $E_c \sim 100$ MeV
  - $\Gamma_{max} \sim 50\text{-}600$
- LAT bursts may represent the high end of the Γ distribution



Conclusions

- GRB may have a wide range of Lorentz factors
- LAT “dark” bursts likely represent the low end of the Lorentz factor distribution
  - $\Gamma_{max} \sim$ 100-800
- LAT detections represent the high end of the Lorentz factor distribution
  - $\Gamma_{min} >$ 800
- Pair production opacity could explain the large number of LAT non-detections of bursts with hard spectra

Fluence-Fluence Comparison