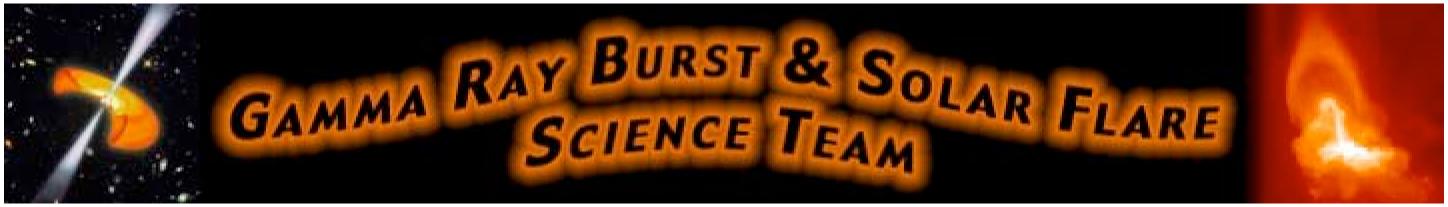


LAT Gamma-Ray Burst – Solar Flare Science Team: Second Progress Report

J.P. Norris

Outline

I. LAT GRB trigger studies: What happens to GRB trigger efficiency when "realistic" on-board background rates and track reconstruction are assumed? – We have some results, suggestions. (J. Bonnell, J. Norris)

II. GRB-SF science team tasks, action items.

III. List of recent literature: GRB prompt emission

I. LAT GRB Trigger Studies

- Compare trigger efficiency for a small set of GRBs (21) for
  - ✓ several decimated background rates {3, 16, 32, 64 Hz}, and
  - ✓ good (i.e., ground quality) vs. rudimentary (on-board) photon direction reconstruction.

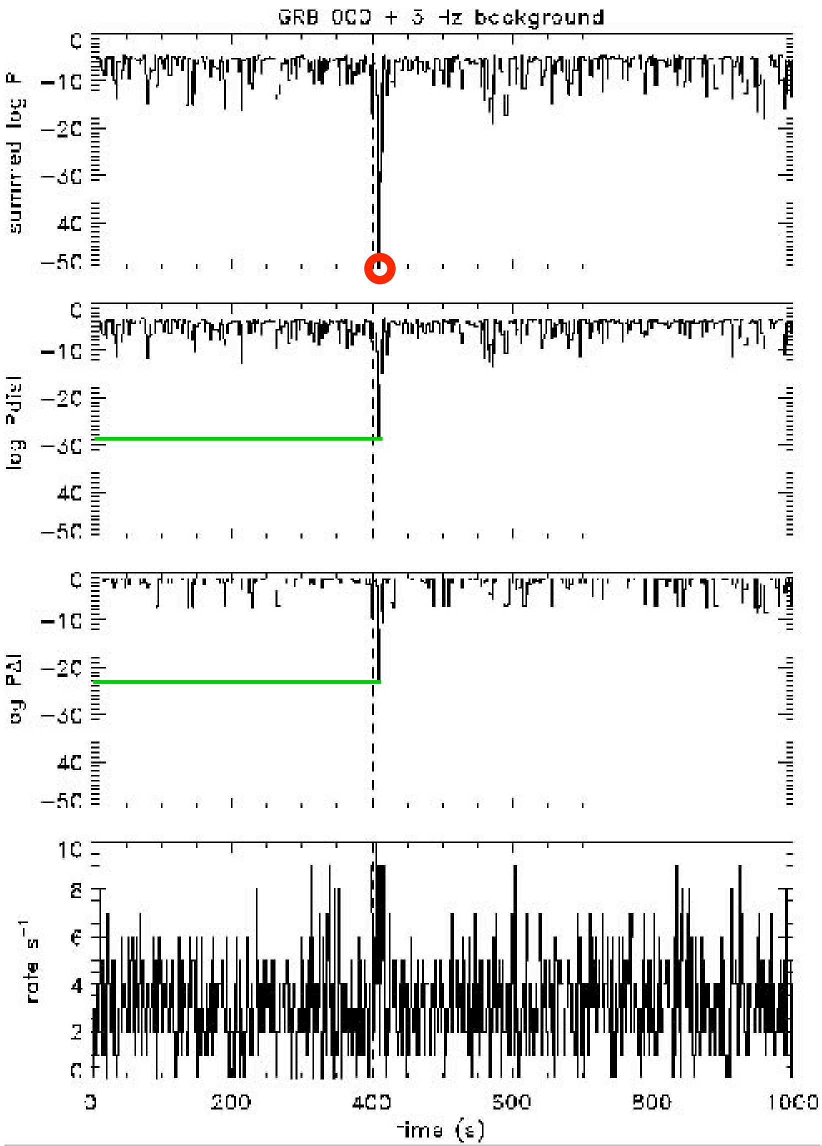
- Simple trigger algorithm — For an N_{event} sliding time window:
  - ✓ For each event, compute the (N-1) distances between it and the other events. Select the event with the tightest cluster — the one with the smallest average cluster distance.
  - ✓ Compute the (N-1) time intervals between cluster's events.

- Compute Log {Joint (spatial*temporal) likelihood} for cluster:

$$\mathrm{Log}(P) = \Sigma\, \mathrm{Log}\{ [1 - \cos(d_i)] / 2 \} + \Sigma\, \mathrm{Log}\{ 1 - (1 + X_i) \exp(-X_i) \} + 2\, \mathrm{Log}\{ N_{events} \}$$

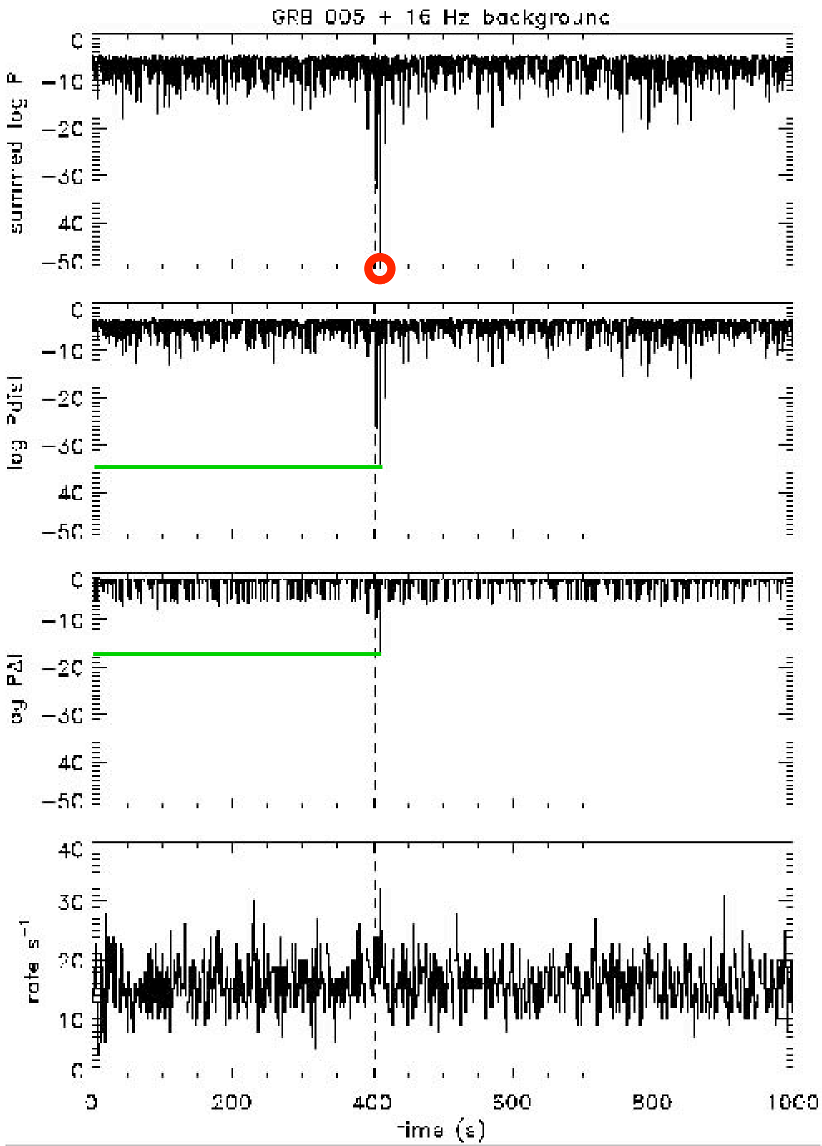
where $X_i = \square t_i$ ("Expected" Backgnd Rate), and d_i = distances.

Fictional Case: 3 Hz Backgnd + Optimal Recon



- Ancient assumptions, which possibly could have been realized with >> on-board CPU power.
- GRB000 attributes:
  - BATSE F_p = 0.5 ph cm^{-2} s^{-1}
  - Duration = 37 s
  - $N_{photons}$ = 26 (LAT-det'd)
  - N_{pulses} = 18
  - □ (p-law) = 2.2
- This weak-to-middling burst is very easily detected with the optimal reconstruction, against a low background rate.

16 Hz Background + Optimal Recon

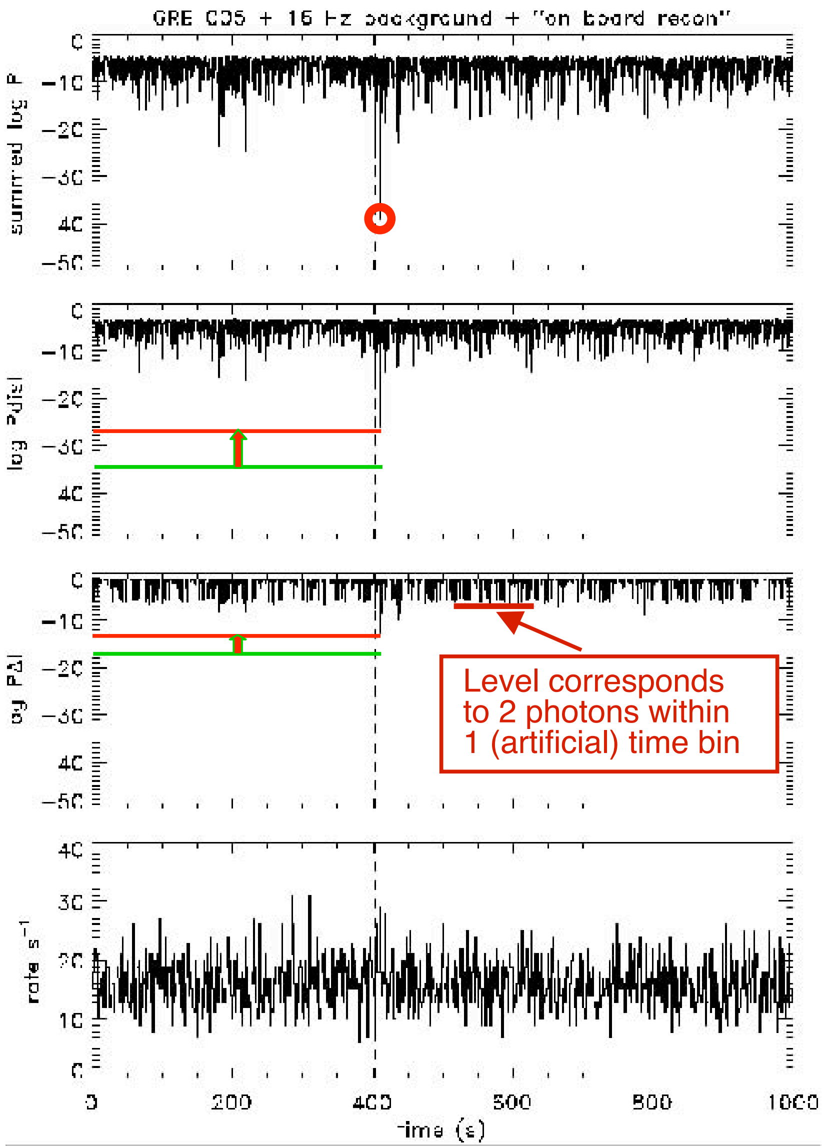


- The 16 Hz background might possibly be realized on-board.
- (Different) GRB005 attributes:

BATSE F_p	=	1.1 ph cm^{-2} s^{-1}
Duration	=	29 s
$N_{photons}$	=	69 (LAT-det'd)
N_{pulses}	=	15
α (p-law)	=	2.2

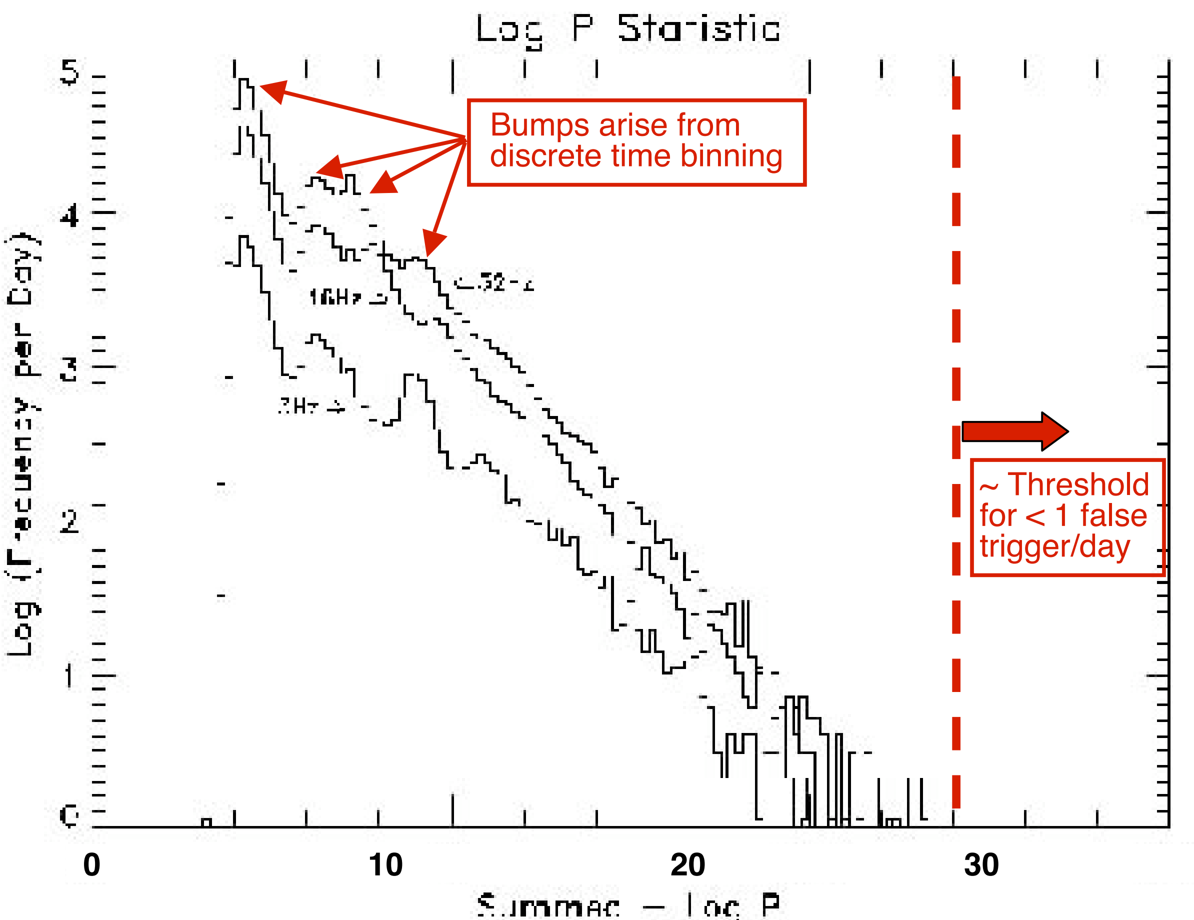
- This burst (with 2.7× the LAT "fluence" of previous burst) is also easily detectable, against a possibly achievable on-board background rate – **but the assumed recon is optimal.**

16 Hz Background + “On-board” Recon



- Again, 16 Hz background. Now, the “on-board” recon assumes localization errors that are 2□ the ground-based optimal.
- GRB005 attributes:
  - BATSE F_p = 1.1 ph cm^{-2} s^{-1}
  - Duration = 29 s
  - $N_{photons}$ = 69 (LAT-det’d)
  - N_{pulses} = 15
  - □ (p-law) = 2.2
- Still detectable, against a <u>possibly achievable</u> on-board background rate, since:
- Expect < 1 false trigger with Log(P) < -40 per year …

One Day’s Worth of Trigger Likelihoods



Joint likelihood distributions for background rates of 3, 16 and 32 Hz — obtained for 1 day’s operation of a 20-event (5-event step) sliding window trigger.

… For a fixed length N_{event} window, the likelihood distribution shapes are essentially independent of rate, scaling linearly:

The trigger threshold scales with backgnd rate, as well as with the “desired interval with no false trigger”:

With $N_{event} = 20$, the threshold required for 0 false triggers in 100 days is T ~ 39.

But …

Summary of Trigger Study, Caveats

- … For "tolerable" false trigger, ~ 1 per day, trigger yields are:
  - 3 Hz 16/21 GRBs (all using optimal recon)
  - 16 Hz 10/21
  - 32 Hz 9/21
  - 64 Hz 6/21
- Besides on-board recon, other factors may cause lower yield:
  - Backgnd distributions may have extended tails;
  - Our set of 21 GRBs is small, slightly skewed to bright end;
  - Bad luck: distribution may be peaked at steeper values
- Therefore, it may be prudent to consider
  - Extra on-board cuts prior to GRB event buffer, lowering rate;
  - GBM as prime trigger for searching for LAT GRB photons.
- Regardless, extra cuts would be beneficial for purpose of ID'ing LAT photons for refined GRB localizations.

II. Near-term GRB-SF Science Team Tasks

1. Finish LAT trigger studies: Use larger GRB sample, higher fidelity on-board recon. Answer: what background rates can be achieved for a GRB “rate buffer”, with which on-board cuts?

2. LAT alert considerations — Compare LAT GRB localizations achievable in different scenarios:
   - On-board computation with on-board recon, using:
     - only LAT events
     - GBM burst onset time to help ID LAT photons
     - GBM rates to help ID LAT photons

     [Note: We requested statement in GBM-LAT ICD that, upon “GRB trigger,” GBM shall provide rates at 64 ms (TBR) in 50-300 keV band (TBR) to the LAT.]

   - Computation at MOC with optimal recon, for small set of LAT photons sent to ground in sparce alert message.

3. Synthetic GRBs at GBM energies (from “GRBmaker”) web-posted for M. Kippen to detect, return for LAT use.

II. Near-term GRB-SF Science Team Tasks

4. **Progress on GRB physical modeling:**
   - N. Omodei's model: redesign to include shell geometries, additional emission mechanisms. Connection to fitting engine under consideration. All in C++.
   - J. Cannizzo-N. Gehrels' afterglow model. For prompt γ-ray emission, requires translation from Eulerian to Lagrangian grid … under consideration. Also in C++.
   - Bright BATSE bursts, 16-channel data (~ 15-2000 keV) posted on website. Usable for practice fitting.
5. **SSC decision to implement EGRET photon data in LAT-like environment — including exposure approach, likelihood algorithm, data structures. Various applications: GRB aspects; do other science; exercise LAT-like algorithms, etc.**
6. **Solar flare modeling (G. Share - N. Omodei - J. Cohen-Tanugi).**

GLAST

III. Some recent literature on GRB prompt emission

1. “The physics of pulses in gamma-ray bursts: emission processes, temporal profiles and time lags,” F. Daigne & R. Mochkovitch, 2003, submitted MNRAS
2. “Gamma-ray Burst Spectra and Light Curves as Signatures of a Relativistically Expanding Plasma,” F. Ryde & V. Petrosian, 2002, ApJ, 566, 210
3. “On the Spectral Energy Dependence of Gamma-Ray Burst Variability,” N.M. Lloyd-Ronning & E. Ramirez-Ruiz, 2002, ApJ, 576, 101
4. “Afterglow lightcurves, viewing angle and the jet structure of γ-ray bursts,” E. Rossi, D. Lazzati, & M.J. Rees, 2002, MNRAS, submitted (astro-ph/0112083)
5. “Discovery of a Tight Correlation between Pulse Lag/Luminosity and Jet-break Times: A Connection between Gamma-ray Burst and Afterglow Properties”, J.D. Salmonson, & T.J. Galama, 2002, ApJ, submitted (astro-ph/0112298)
6. “Implications of the Lag-Luminosity Relationship for Unified Gamma-Ray Burst Paradigms,” J.P. Norris, 2002, ApJ, 579, 386
7. “A Possible Cepheid-Like Luminosity Estimator for the Long Gamma-Ray Bursts,” D.E. Reichart, D.Q.Lamb, E.E.Fenimore, E.Ramirez-Ruiz, T.L.Cline, & K.Hurley, 2001, ApJ, 552, 57
8. “The Unique Signature of Shell Curvature in Gamma-Ray Bursts,” A. M. Soderberg & E.E. Fenimore, 2001, eds. Costa, Frontera, Hjorth, in “GRBs in the Afterglow Era” (Heidelberg: Springer), p. 87
9. “The External Shock Model of Gamma-ray Bursts: Three Predictions and a Paradox Resolved,” C.D. Dermer, M. Bottcher, & J. Chiang, 1999, ApJ, 515, L49