Detecting Gamma-Ray Bursts in the DC1 Data

David Band (GSSC)
Goal

- Develop a LAT burst trigger for use on the spacecraft and on the ground. Ground-based trigger may be end of Level 1 pipeline or provided to users.
- Regimes:
  - Onboard burst photons are mixed with large non-burst event rate. Filtering to reduce the background will filter out burst photons.
  - Ground based—burst photons mixed with small non-burst event rate.
- Criteria:
  - Understand and control the false positive triggers
  - Understand the burst detection sensitivity
- Here: Method applied to DC1 data, therefore applicable to ground-based trigger.
Method

• Break up sky in instrument coordinates into regions, and apply rate triggers to each region. The regions are ~PSF in size (builds in knowledge of the instrument).
• Use two (or more) staggered regions so that the burst will fall in the interior of a region.
• Rate trigger—statistically significant increase in count rate averaged over time and energy bin.
Estimating the Background

• The rate trigger requires an estimate of the background (=non-burst event rate). Typically the background is estimated from the non-burst lightcurve.

• BUT here the event rate is so low that a region’s background estimated only from that region’s lightcurve will be dominated by Poisson noise. The event rate per region is a few×10^{-2} Hz.

• My current method is to average the background over the FOV, and apportion it to each region proportional to the effective area for that region.
Problem with Background Estimation

- Problem: On short (~100 s) timescales the background is NOT uniform over the FOV. The ridge of emission along the Galactic plane causes many false triggers.
- Solution (not implemented yet): Better model of the background.
Region in Galactic Coordinates
Rate Trigger

- I use $\Delta t=1, 2, 4, 8, \text{ and } 16 \text{ s}$ applied every second.
- The trigger is disabled for 100 s after each trigger.
- Because the expected number of events per region is much less than 1, I use Poisson probabilities.
- If there are 100 regions over the sky, $\Delta t=1 \text{ s}$, and we allow one false positive per year, then $P_0<3\times10^{-10}$. This was the threshold I used; fainter bursts might be found if I used a larger $P_0$.
- Because of the problems estimating the background the false positive rate was much higher.
- See LAT_trigger_DC1.pdf or LAT_trigger_DC1.ps at http://glast.gsfc.nasa.gov/ssc/dev/grb_tools/
Sensitivity and Significance

- Given $\Delta t$, $P_0$, $A_{\text{eff}}$, and the background rate (here 3, 30 or 300 Hz), one can estimate the burst flux for a trigger.

- Here $\Delta t=1$ s, $A_{\text{eff}}=10^4$ cm$^2$.

![Graph showing trigger probability as a function of threshold flux for different background rates and $P_0=3\times10^{-10}$ at 3, 30, and 300 Hz.](image)
Results

- In the ~6 days of DC1 data, I found 16 bursts and 29 false triggers.
- Note that my spatial grids extend to inclination angles of 65° and 70°.
- The software I used was all home-grown IDL procedures.
More Plots

Note the absence of non-burst events!

Grids inappropriate for this burst
The Detected Bursts

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Improvements to THIS Method

- Better background
- Improve grid
  - Better staggered or more grids?
  - Different region size?
  - Alternatively, HTM or HEALPIX pixels?
- Time bin stride—test time bins every $\frac{1}{2}$ time bin?
- Operationally, increase $P_0$ when GBM triggers?
Lessons Learned

• The major issue for this method (and probably all spatial-temporal triggers) is estimating the background (=non-burst event rate). The event rate is NOT uniform over the FOV on short timescales.

• Useful plots:
  – Count map of sky in different coordinate systems (instrument, celestial, Galactic) over specified time range. Control over plotting limits necessary.
  – Lightcurve of counts from specified spatial area (e.g., circle around burst location). Control over plotting limits, circle radius, burst location necessary.