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TRIGGER EFFICIENCIES OF BATSE AND PVO

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ABSTRACT

Observed distributions of GRB fluxes or $V/V_{\max}$ are, at low equivalent intensities, affected by detection threshold effects. Therefore, it is difficult to properly interpret the equivalent low-intensity ends of these distributions without careful evaluation of these effects. In this paper, we present results of calculations of the trigger efficiencies of BATSE and PVO as a function of burst peak flux. These efficiencies take into account all trigger conditions, typical burst characteristics and γ -ray background conditions. We find a strong dependence of trigger efficiency on the GRB time profiles. We briefly discuss the implications that this has for the observed GRB peak flux distribution. Although our assessment of the trigger efficiency is not yet comprehensive, it clearly indicates the care one should consider in the interpretation of the GRB data set.

INTRODUCTION

Population studies of γ -ray bursts (GRBs) remain essential to the understanding of the GRB phenomenon. Unless GRBs can be identified with well-understood counterparts in any wavelength regime, population studies will remain the only option to narrow down possible explanations for their nature. With the increasing size of the sample of detected GRBs, particularly since the launch of CGRO, population studies are increasing in accuracy and thus become more susceptible to systematic errors. Therefore, a complete understanding of these errors becomes increasingly important.

In this report we concentrate on one source of systematic error: the trigger efficiency. We define the trigger efficiency to be the probability that a burst, which is not blocked by any external body and occurs at a time when the triggering mechanisms of the instrument are completely enabled, triggers the instrument into a special burst mode operation. In short, the trigger efficiency describes how efficiently an instrument detects bursts. It is particularly important in the region of low burst intensities, where relatively many GRBs reside. For BATSE, this is also the most interesting part of the $\log N - \log P$ distribution (N is the number of bursts with a peak flux larger than P) because that is where deviations occur from that expected for a spatially homogeneous distribution of bursts (prescribed by a $-3/2$ power law).

Recently, Fenimore *et al.*⁴ combined $\log N - \log P$ distributions as observed by BATSE and PVO to extend the dynamic range of the peak flux in order to evaluate the possibility of a cosmic origin for the GRBs. Due to the uncertainty in the trigger efficiency, Fenimore *et al.* excluded bursts in that range of the peak flux where the trigger efficiency was less than 1 (amounting to $\sim 60\%$ of all BATSE and $\sim 45\%$ of all PVO bursts). With improved values for the trigger efficiencies of both instruments, more data may be utilized in such an analysis and, thus, the BATSE and PVO observations may discriminate even better between different models or may evaluate more accurately to model parameter values.

Each GRB is subsequently convolved with the response of both instruments. This is done for photon energy ranges of 50 to 300 keV for BATSE and 100 to 2000 keV for PVO. Subsequently, the resulting lightcurves (one for each of the 8 BATSE detectors and one for the sum of both PVO detectors) are randomized according to the available count rate statistics (on a 64 ms time resolution). The data thus obtained are analyzed for trigger conditions similar to how it is done by the instruments in reality. For BATSE^{5,6} this means checking whether on time scales of either 64, 256 or 1024 ms, count rates of at least two detectors rise at least 5.5σ above the 17 s averaged background level. For PVO^{2,3} the trigger analysis involves checking whether on time scales of 1/4, 1 or 4 s, the total countrate of both detectors rises at least 11.3σ above the 16 s averaged background level.

SIMULATION RESULTS

Figure 1 shows the trigger efficiencies that result from our calculations, for each time scale and instrument. We did not include overwriting events for BATSE to provide easy comparison with calculations done in other studies.

Figure 1. Trigger efficiencies for BATSE (a) and PVO (b), for the three time scales appropriate to the respective instruments: the solid curve for the longest, the dashed curve for the middle and the long-dashed curve for the shortest time scale of each instrument (see text). The dotted curves in (a) refer to the trigger efficiencies as calculated by Fishman *et al.*⁶.

A comparison between our trigger efficiency calculations for BATSE and those performed by Fishman *et al.*⁶ reveals two important differences. Firstly, our results show more sensitivity towards lower peak fluxes for the 64 and 256 ms time scales. This is due to the effect that upward statistical fluctuations within the time profile may trigger detection of an otherwise undetectable event. Secondly, our efficiency curves show more complex behavior, in the sense that be-

values). Also, two systematic effects occur: first, for a time scale shorter than the peak width, upward statistical fluctuations are more readily picked out during the determination of peak flux, thus the peak flux is overestimated; second, for time scales longer than the peak width, the observed peak fluxes will be systematically smaller than the true peak values. The first systematic effect is only important when statistical fluctuations are relatively large (i.e. at low fluxes), while the second one applies to all values for the peak flux. The magnitude of these systematic effects depends on the distribution of time profiles.

Clearly, compared to the distribution implied by the GRB model employed by Fishman *et al.*⁶, the one resulting from our empirical GRB model shows a somewhat stronger instrumental roll-over and a shift in peak flux. However, this stronger instrumental effect is not strong enough to account fully for the roll-over observed with BATSE which is attributed to an intrinsic dearth of weak GRBs. The actual observed roll-over extends over a wider dynamic range in peak flux than shown in Fig. 2.

CONCLUSION

We have performed calculations of the trigger efficiencies of BATSE and PVO as part of a program to combine observations from BATSE and PVO. These calculations reveal a number of instrumental effects that argue for careful interpretation of data near the detection threshold (whether in peak flux, fluence or $V/V_{\max}$). We have assessed numerical results which prove a strong dependence on the distribution of time profiles.

We stress that our results are not complete. To arrive at more accurate trigger efficiencies, the following uncertainties need to be resolved. Firstly, the signature of the parent time profile distribution below peak widths of 64 ms is uncertain (we limited ourselves to a sample of time profiles from BATSE and PVO databases with a time resolution of 64 ms). Secondly, as noted before⁶, atmospheric scattering will affect the trigger efficiencies. We did not evaluate this effect.

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