The Fluence Duration Bias

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Abstract. The fluence duration bias causes fluences and durations of faint gamma-ray bursts to be systematically underestimated relative to their peak fluxes. Using Monte Carlo analysis, we demonstrate how this effect explains characteristics of structure of the fluence vs. 1024 ms peak flux diagram. Evidence of this bias exists in the BATSE fluence duration database, and provides a partial explanation for the existence of burst class properties.

INTRODUCTION

The fluence duration bias is an instrumental bias causing some gamma-ray burst fluences and durations to be underestimated relative to their peak fluxes. The fluence duration bias does not manifest itself by altering the trigger rate, but instead alters measured burst properties. Elsewhere in this conference [2] we present evidence that the class of Intermediate bursts identified by statistical clustering analysis [3] can be produced from the hardness vs. intensity correlation and the fluence duration bias. We also demonstrate how the bias can be responsible for decreasing fluences and durations of the longest low peak flux Class 1 bursts. In this paper, we describe the fluence duration bias in more detail.

AN EXAMPLE

Figure 1 demonstrates the time history of a bright, Class 1 (Long) BATSE burst (trigger 2831) as measured in the 50 to 300 keV range on the 1024 ms timescale. This burst is complex with an overall duration in excess of 180 seconds.

Figure 2 is a Monte Carlo simulation of what this burst might look like if its 1024 ms peak flux were reduced in intensity to 15% of its measured value (Poisson fluctuations have been added to the reduced signal). If the reduced burst duration is assumed to be identical to that of the unreduced burst, then its measured fluence-to-peak flux ratio is unchanged from the actual value of 19.4 (we measure the result in...
terms of the fluence-to-peak flux ratio, because Poisson fluctuations can also cause a burst’s peak flux to change). If, however, the reduced burst duration is determined from “recognizable pulses” (pulses that are clearly visible above background; our algorithm assumes that the first and last peaks larger than $4\sigma$ above background bound the burst duration because there is no formal algorithm used by a human operator), then the average fluence-to-peak flux ratio drops slightly to 94% of its actual value.

Figure 3 shows what the burst might look like if reduced to 2% of its actual value. Most of the burst fluence is confined to a temporal span of roughly 20 seconds. Our “recognizable pulse” algorithm finds that the burst is still considerably longer than this single pulse, but that the total burst duration is still underestimated for the purpose of measuring fluence. The fluence-to-peak flux ratio for the burst in question is only 61% of its actual value. This underestimate is even larger when the burst is reduced to a value closer to the trigger threshold.

It is difficult to accurately model the process by which the fluence duration interval is chosen, since human interaction plays an important role. We suspect
that the actual amount of the bias is less than the amount described here, since the human eye and mind are good at removing patterns from noise. Nonetheless, there is evidence that the bias is present, and that it is large enough to cause a depletion in the number of small peak flux, high fluence bursts as well as being responsible for producing some Class 3 burst characteristics from Class 1 bursts.

EVIDENCE FOR THE FLUENCE DURATION BIAS IN THE 4B CATALOG

Fluence appears to be one of BATSE’s most accurately measured quantities because its statistical measurement errors are typically only ±5%. However, there is no intensity-dependent component to this measurement error, as might be expected from Figures 1, 2, and 3. It should be mentioned that there are no BATSE bursts with fluences less than zero (as might be expected if background dominated the fluence measurement), and few with fluences less than the fluence found in the 1024 ms peak flux.

The formal fluence error is kept small in part by fitting the background for faint bursts with high-order polynomials. Unfortunately, this process can introduce systematic underestimates of burst fluence by overestimating background [1]. The fluence error can also be reduced by decreasing the fluence duration. Figure 4 plots fluence durations for available bursts in the 4B Catalog. The sample has been limited to Class 1 bursts detected using the same trigger criteria (because Class 2 and Class 3 bursts are clearly shorter than the Class 1 bursts, and because different trigger criteria might alter the composition of the sample in a heterogeneous way).

Figure 4 indicates that there are few long Class 1 fluence durations near BATSE’s detection threshold (1024 ms peak fluxes slightly greater than BATSE’s 0% efficiency of 0.2 photons cm$^{-2}$ second$^{-1}$). This is strong evidence for the existence of the fluence duration bias, and it indicates that the magnitude of the effect apparently strengthens for fainter bursts.
FIGURE 4. Fluence Duration vs. 1024 ms Peak Flux from BATSE 4B Data.

Figures 5, 6 and 7 demonstrate that the fluence duration bias is more difficult to cleanly delineate when peak flux and/or trigger timescales are shorter than 1024 ms (the effect is likewise more pronounced when longer timescales are used). We attribute this to the lower signal-to-noise ratio of shorter timescale measurements, making intensities measured on these timescales less accurate measures with larger intrinsic scatter than 1024 ms. The fluence duration bias is still present on shorter timescales; the scatter of these measures just makes it harder to recognize.

FIGURE 5. Fluence duration vs. 64 ms peak flux for Class 1 bursts triggering on the 1024 ms timescale.

CONCLUSIONS

Monte Carlo modeling of bursts with different temporal structures indicates that fluence duration is easy to underestimate, particularly for faint bursts. This causes some burst fluences and durations to be underestimated. Some bursts, such as trigger 2831, have temporal structures more susceptible to this bias than others. The strength of the bias is hard to judge for an individual burst, as it depends both
FIGURE 6. Fluence duration vs. 1024 ms peak flux for Class 1 bursts triggering on the 64 ms timescale.

FIGURE 7. Fluence duration vs. 64 ms peak flux for Class 1 bursts triggering on the 64 ms timescale.

on burst temporal morphology and on how the human operator selects a fluence duration interval. The magnitude of the bias depends both on the time intervals chosen for the peak flux and trigger flux, since the fluence underestimate must be made relative to a “fixed” brightness measure. The fluence duration bias appears capable of producing observed characteristics of the fluence vs. 1024 ms peak flux diagram, and of making some Class 1 bursts (primarily faint ones) take on Class 3 characteristics. We currently studying this effect in greater detail.

REFERENCES

1. Bonnell, J. T., et al., ApJ 490, 79 (1997).
2. Hakkila, J., et al. this conference.
3. Mukherjee, S., et al., ApJ 508, 314 (1998).