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Structure in Gamma-Ray Burst Time Profiles: Correlations with Other Observables

Prepared by:	John Patrick Lestrade
Academic Rank:	Associate Professor
Institution and Department:	Mississippi State University Department of Physics and Astronomy
MSFC Colleague:	G. J. Fishman
NASA/MSFC:	
Laboratory:	Space Science
Division:	Astrophysics
Branch:	Gamma-Ray Astronomy

Introduction

One of the current debates raging in the world of gamma-ray burst physics is whether the sources of these enigmatic bursts arise from a single or from multiple distributions. Several authors contend that the histograms of GRB observables imply the latter. The two most-likely candidate components are galactic and cosmological. For example, Atteia et al. (1993) claim that a dip in the $V/V_{\max}$ distribution is a result of such a two-component source distribution. Lamb et al. (1993) have used a parameter called the 'burst variability' calculated by dividing the maximum count rate on the 64-msec timescale by that from the 1024-msec timescale to show that a correlation of this parameter with burst brightness implies a two-component model. Lamb's paper has met vigorous criticism.

We have developed two parameters that measure the variability or structure in the time profiles of BATSE gamma-ray bursts. Both parameters ("structure" and "spike height") are based on the statistics of "runs up" and "runs down" (Knuth, 1981). In short, the structure parameter is the observed number of runs (at several lengths) minus the number expected in a chance distribution. The "spike height" is the sum of all run heights minus the expected sum. These two are straight-forward to calculate, robust, and measure the variability over the complete profile – not just at the peak. For a full description of the algorithm, refer to Lestrade (1993).

We have applied this algorithm to the profiles of 156 GRB's. In this paper we present graphs of the two parameters as functions of 1) burst duration, 2) burst hardness ratio, 3) $V/V_{\max}$, 4) source galactic longitude, and 5) source galactic latitude. We seek correlations as well as groupings in the data that might indicate a multi-component source distribution.

Correlations:

1) Duration: As a measure of duration we take the values of T_{90} in units of 64-msec bins. In this paper, we are considering only those bursts whose durations are longer than 12 seconds (i.e., 200 bins.) As Figure 1 shows, there are no apparent groupings nor significant correlations.

2) Hardness: For the hardness ratio, we use the value h =(chan 3+ chan 4)/(chan 1+ chan 2) from the BATSE DISCSC data. This is approximately equal to the flux above 100 keV divided by the flux below 100 keV (down to the threshold of roughly 25 keV). As before, Figure 2 shows no correlation nor any evidence of grouping.

3) $V/V_{\max}$: The quantity $V/V_{\max}$ measures the relative distance to a burst. Distant, weak bursts have values close to unity while the brightest have values close to zero. For a homogeneous distribution of sources, the distribution should show a uniform distribution between 0 and 1. As is well documented, the ensemble of

GRB's shows a paucity of weak bursts indicating a radial inhomogeneity. In effect, our instruments are seeing to the "edge" of the radial distribution.

Of course, we would expect to see a correlation between the amount of structure in a burst and the burst's distance (or V/V_{max}). This is seen in Figure 3 which shows that the more distant, i.e., weakest bursts, show less structure because the smaller spikes are lost in the background noise. Naturally, as seen in the right part of Figure 3, the more distant bursts have spikes which are less intense.

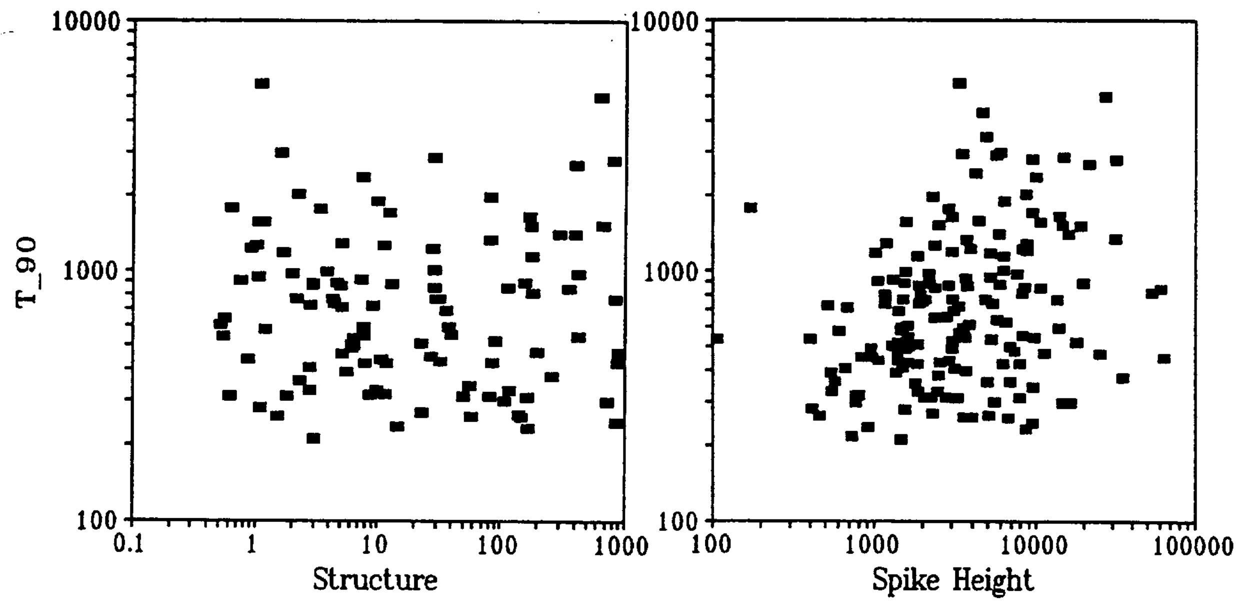

Figure 1. Burst Duration versus Structure and Spike Heights

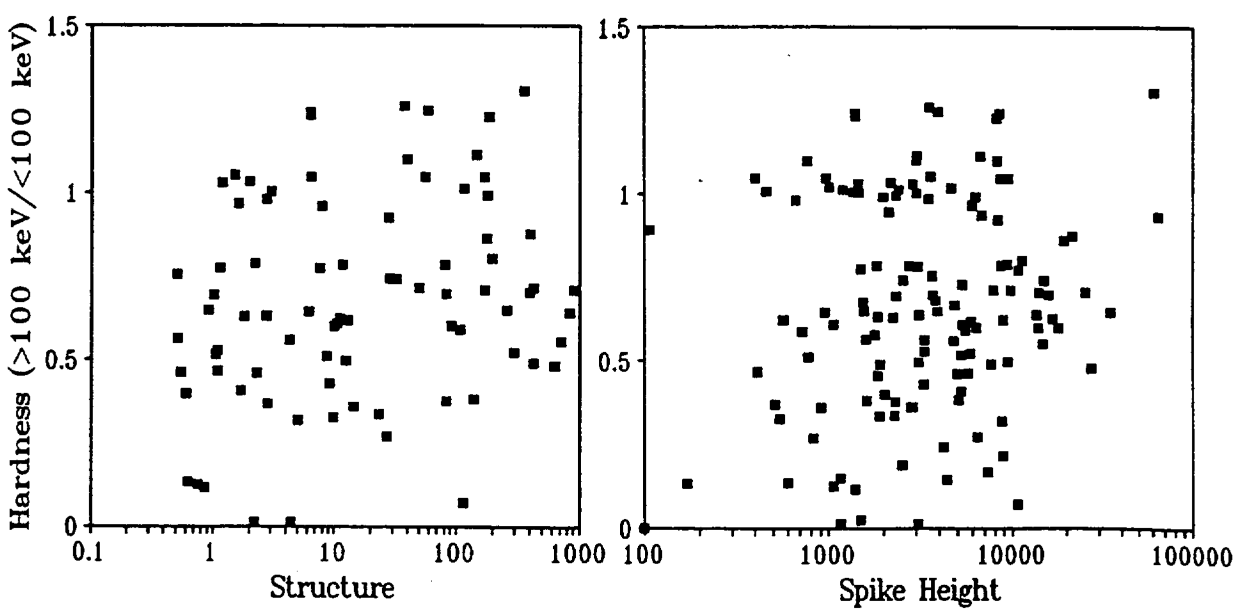

Figure 2. Burst Hardness Ratio versus Structure and Spike Heights

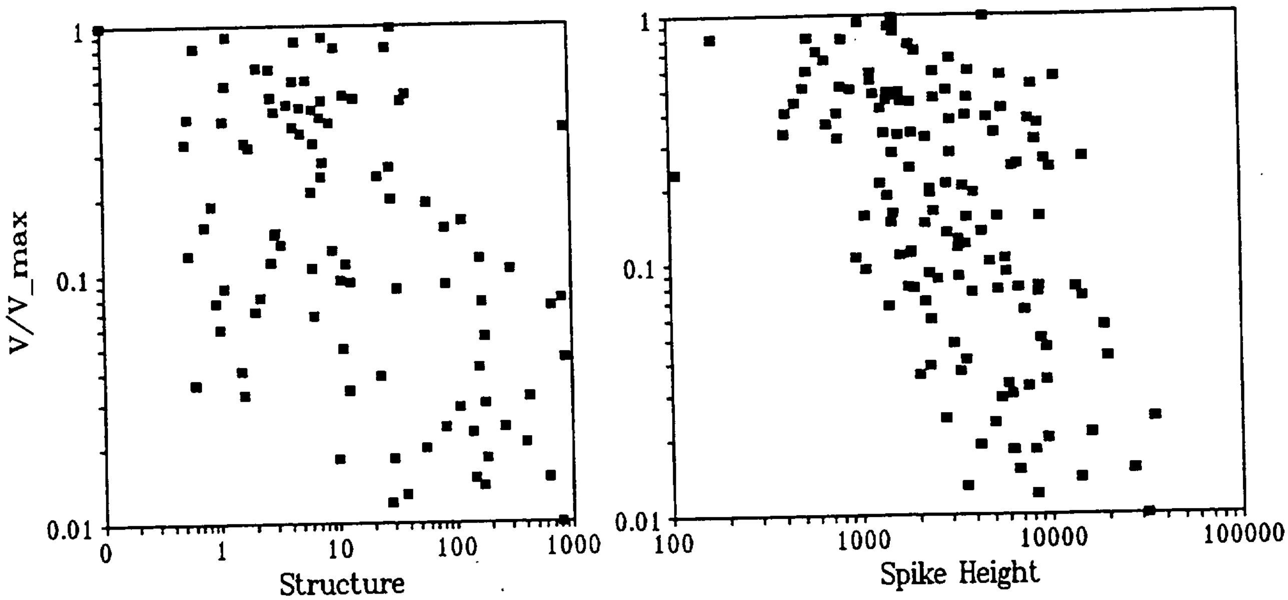

Figure 3. Burst V/V_{max}versus Structure and Spike Heights

4) Sky Position: Finally, Figures 4 and 5 present graphs of galactic longitude and latitude versus structure and spike height. Figure 4 shows no significant features in galactic longitude. However, Figure 5 shows that bursts that come from high latitudes (i.e., > 45°) show less variance in the spike height parameter than those that come from low latitudes (i.e., within 45° of the galactic plane).

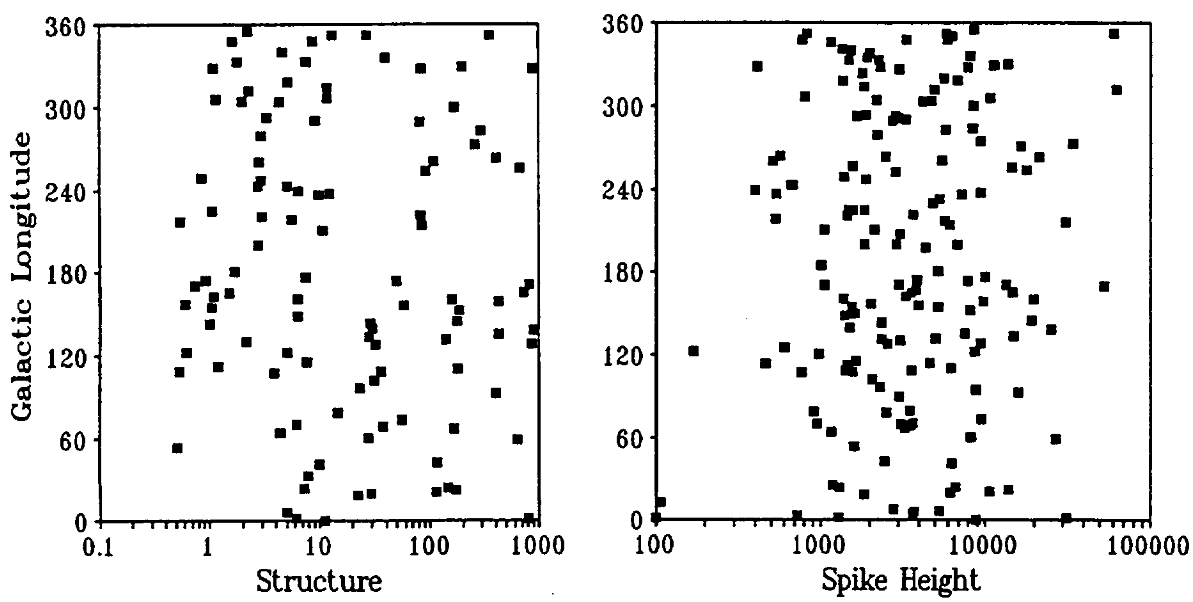

Figure 4. Burst Galactic Longitude versus Structure and Spike Heights

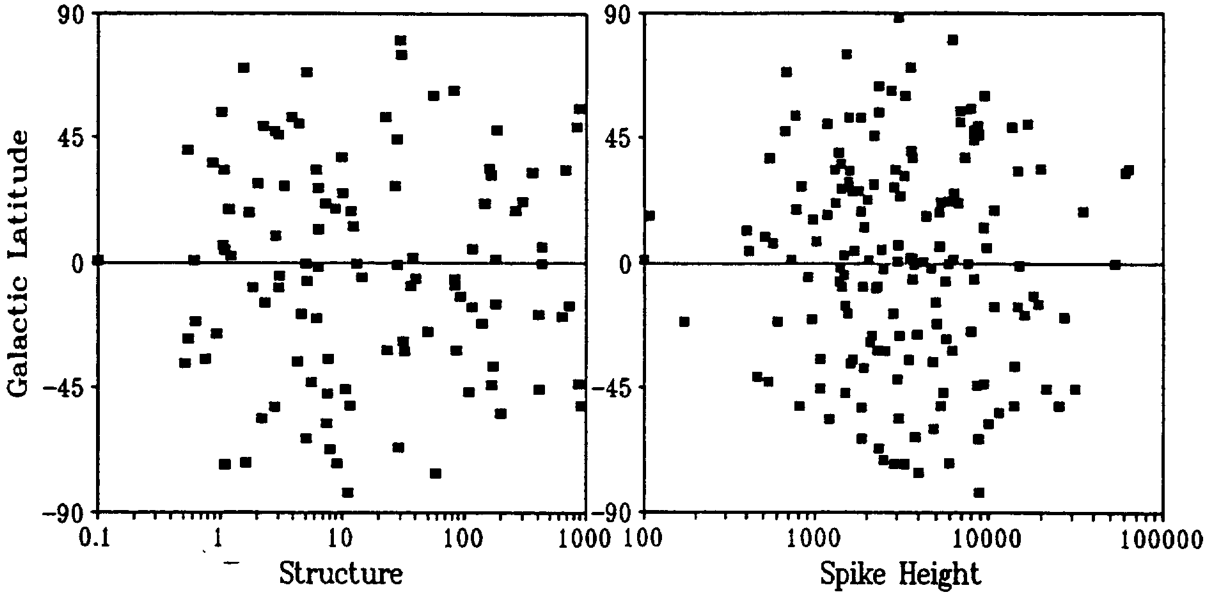

Figure 5. Burst Galactic Latitude versus Structure and Spike Heights

Conclusion:

The result seen in the Latitude-Height graph is not expected. It is possible that this is just a statistical anomaly. We will soon do a complete statistical analysis to determine its significance. If the result stands up under further scrutiny, it will certainly be adopted by the "galactic" modelers as evidence that at least some bursts arise from neutron stars which are confined to the plane of the galaxy.

References:

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3. Knuth, D. E., The Art of Computer Programming, Seminumerical Algorithms, 2nd (Addison Wesley, Reading, Mass., 1981), p. 65.
4. Lestrade, J. P., The Statistics of Runs Up and Down for BATSE GRB Time Profiles *Ap. J.* , in prep., 1993.