AN INTERNALLY CONSISTENT GAMMA RAY BURST TIME HISTORY PHENOMENOLOGY

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ABSTRACT

A phenomenology for gamma ray burst time histories is outlined. Order of their generally chaotic appearance is attempted, based on the speculation that any one burst event can be represented above 150 keV as a superposition of similarly shaped increases of varying intensity. The increases can generally overlap, however, confusing the picture, but a given event must at least exhibit its own limiting characteristic rise and decay times if the measurements are made with instruments having adequate temporal resolution. Most catalogued observations may be of doubtful or marginal utility to test this hypothesis, but some time histories from Helios-2, Pioneer Venus Orbiter and other instruments having one-to several-millisecond capabilities appear to provide consistency. Also, recent studies of temporally resolved Solar Maximum Mission burst energy spectra are entirely compatible with this picture. The phenomenology suggested here, if correct, may assist as an analytic tool for modelling of burst processes and possibly in the definition of burst source populations.

1. Introduction. The gamma ray burst phenomenon continues to be a fascinating and unsolved puzzle. Although clues exist that point to a mechanism or to mechanisms with neutron-star origin, it has become clear that measurements resulting from a new generation of instruments will be necessary to resolve the apparent contradictions that result from the limitations of the existing data. Source fields contain no identifiable source objects*, although they have been found to contain archived optical transients. All attempts to study the event size spectrum show deficiencies in the number of smaller events relative to the expected -1.5-index power law, yet there is no source distribution directional anisotropy that must accompany a real departure from that spectral form. Characterizations of the spectral and temporal qualities of individual burst events are best described as instrumentally subjective, yet, burst event spectra can be obligingly fitted to almost any theoretically conjectured fancy.

Resoluton of these issues awaits the era of results from the high-sensitivity burst monitor and from the improved-resolution burst spectrometer on the Gamma Ray Observatory, from the next interplanetary burst sensor network incorporating Solar Polar Mission, and from the real-time optical transient telescopes. Meanwhile, scrutiny of the existing storehouse of data leads one to speculate as to the possibility that not all its clues may be exhausted.

* Considerations of the 1979 March 5 event are excluded from these generalizations.

2. Overview. Gamma ray burst time histories are sufficiently diverse and chaotic in character as to exhibit few, perhaps no, redeeming features*. Although occasional quasi-periodicities can be inferred or imagined, the evidence remains as essentially consistent with overall randomicity: i.e., the supposed periodicities are rare enough as to be a necessity of chance. Whether another characterizing aspect of time histories (such as number of peaks, clustering of, or intervals between spikes) can be investigated as a research tool appears equally unpromising. Since the data have not been subjected to this sort of analysis, the possibility should not be discounted; X-ray shot noise from a black-hole-candidate source is a possible analog.

Characterizing burst time histories either as brief (or of a single-spike nature) or as lengthy (or of a complex or compound nature) is a temptation many of us could not resist (1,2,3,4). Whether any such separation into two populations is a valid concept or is merely a semantic device remains to be seen. It is, of course, not inconsistent with the speculation put forth here, that complex bursts may be characterized as a superposition of a similarly shaped, or prototypical, single spikes. One detector, on the International Sun-Earth Explorer 3, happened to respond preferentially to fast, spike-like events (4), strengthening the argument that single-spike events exist as a separately identifiable population. However, it is pointed out in a recent study of the Toulouse data from the Venera spacecraft (5), that brief (or rapidly rising, or singly peaked events), may simply be the tips of the iceberg of an entirely random pattern of event shapes, buried in the various instrumental backgrounds. Taken as a separate group, brief gamma ray bursts were found, in that study, to have rise times and decay times each varying over several orders of magnitude. The ratios of rise time to decay time per event were found, however, to vary smoothly and by less than 1 order of magnitude, such as to indicate the hint of a relationship, rather than a random scatter. If this is more than a selection effect, it leads naturally into the suggestion that complex events may be constructed of a multiplicity of single spikes that can, in turn, be speculated to have the same shape per event.

3. Background. A proper study of burst time histories can be made only with observations having continuous high temporal resolution. The early Vela measurements were made with instrumentation having a geometrically expanding time base, thus indicating only that event shapes varied dramatically and often possessed fine time structures at least at the onset. Data collected in the mid-1970's with instruments such as Helios-2 indicated that indeed fine time structure could persist throughout burst events. The Los Alamos observations from Solrad-11A and 11B (6) showed continuing structure in one event on time bases down to about 10 msec and yet indicated that continuing structure in another extended event did not exist on a similar time base, thus fitting a structure cutoff on a qualitatively longer time scale. The instrument sensitivity was insufficient to have found structures much finer than 10 msec, however, leaving the question open as to whether the more rapidly varying event also possessed a temporal cutoff. These results also lead quite naturally to the suggestion that all burst events have perhaps not only a limiting time scale but, in fact, a generally characteristic fluctuation time near that limit.

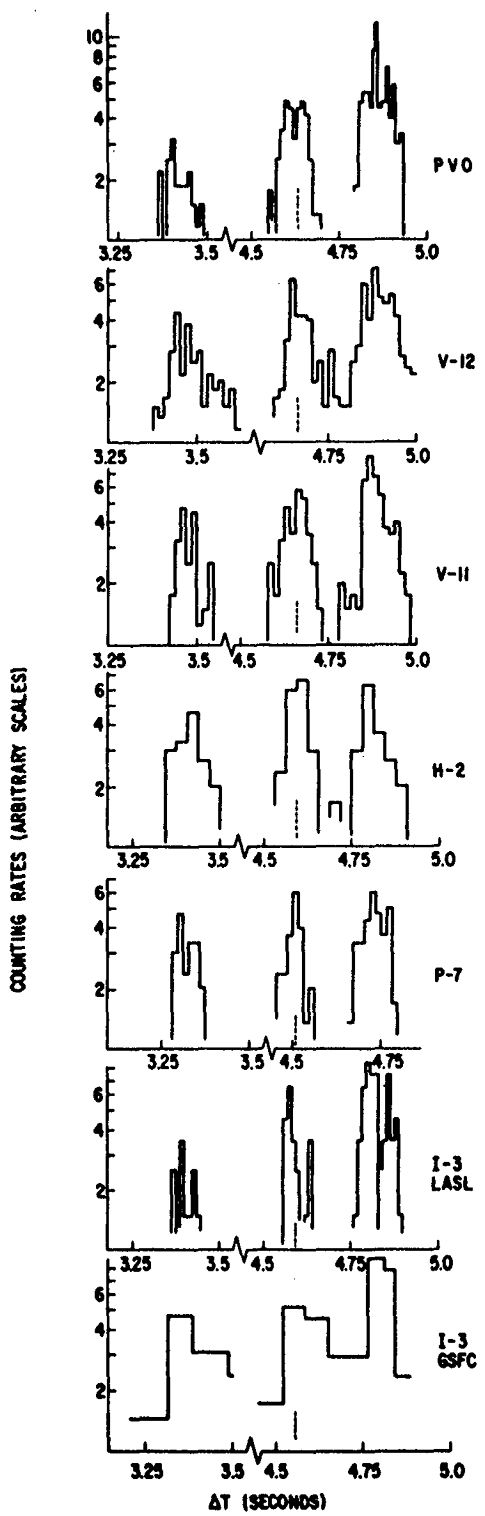

Fig. 1. Three features in the 1978 Nov. 19 event (7).

Finally, the 1979 March 5 event provided the first and only evidence for intensity variations in the sub-millisecond region (7). As mentioned earlier*, this event is the exception to all the rules. The relevance here of its (faster than 0.2 msec) intensity risetime is that, with the temporal resolution of ISEE-3, PVO, Helios-2 and similar instrumentation, it is clear that other equally intense events do not possess such fast features. Thus, burst events may always show fluctuation scale cutoffs, given sufficiently sensitive detectors. This also supports the concept of a characteristic fluctuation time per event.

4. <u>Spectral Implication</u>. Deciphering the spectra of gamma ray bursts is a most difficult task, since the spectra appear to fluctuate as rapidly as counts can be accumulated. The no-doubt most reliable current measurements, from the Solar Maximum Mission (8), however, indicate the following. Given the isolation of a single counting rate increase, its spectral hardness is maximized during the portion of rising intensity, rather than at the peak. The higher energy features fluctuate more rapidly than the lower, thus indicating a spectral softening with time per increase. Finally, the spectra of complex intensity variations are not like those at single-peak intensity rise or decay. All this supports the picture suggested here, that intensity fluctuations might be a superposition of prototypes, each with approximately the same shape and, most likely, with similar spectral evolution.

5. Discussion. Given the reasonability of the hypothesis that a complex burst event is made of a clustering of prototypes, the question of the similarity of the (event-peculiar) prototypes remains. Figure 1 illustrates the narrowest and most intense single fluctuations that had been selected for interplanetary timing purposes from the complex time history of the 1978 November 19 event (9). In all, the results from 7 different instruments are consistent, within statistics, with similar temporal behavior. Since these ≈ 0.12 second wide peaks are the fastest clearly resolved fluctuations in that 20-second event, one can speculate that this shape can be identified as prototypical for that event. The 1978 November 19 burst, however, is one of the very most intense on record. Presently collected data probably do not permit the identification of event-peculiar prototype shapes for very many complex events. A detailed exploration of the utility of this concept may require observations of the quality that will not exist before the launch of the Gamma Ray Observatory (10,11).

6. Conclusion. It is speculated that any gamma ray burst can be usefully pictured as having a temporal structure that is made of superpositions of simple increases of a prototypical shape; these peaks have similar rise times, decay times, and spectral evolution within that event. The family of prototypical shape parameters may continue on to the existing (5), single-peak parameter plot. The concept suggested here may assist in the modelling of burst processes. This phenomenology, if borne out in future data analyses, may also provide some way to delineate burst populations. Finally, it may be possible to statistically define the peak prototypical intensity in each complex event, thus replacing the measured peak intensity as a parameter for size spectral analyses.

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