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(NASA-CR-195191) [AN ANALYSIS OF GAMMA RAY BURST TIME HISTORIES] Final Report (Alabama Univ.) 4 p

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Final Progress Report for

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by

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Summary of scientific work:

Gamma-ray burst time histories, ranging in durations from milliseconds to thousands of seconds, are as varied as the number of bursts. They show a wide array of structures from those that are very smooth to those that contain a seemingly uncountable number of spikes riding on top of other spikes. These profiles have tantalized researchers for years – they obviously hold important information on the nature of GRB's, but to date no one has been successful in analyzing them.

For the past year I have been working on algorithms to analyze these data. I have followed two approaches in this investigation. The first is an attempt to quantify the amount of structure, or spikiness, in a profile. The second, involves applying the latest theorems on chaos and fractals with the aim of extracting useful information from what seems to be a random collection of shot noise.

Spikiness:

A parameter that accurately represents a profile's structure is important for two reasons. First, if we find such a parameter, S_p, then graphs of other burst characteristics versus S_p may reveal trends and groupings as did the H-R diagram in the early days of astronomy. If we can find such trends, then we may be able to put more effort into the GRB models that favor those trends. Second, histograms of structure for a large number of bursts may in itself reveal groupings, such as a bimodality, that could also be useful in leading future investigations. It is an interesting observation, that even after several years of data collection, no one has found a satisfactory classification scheme for GRB's (except the minor subset of a half dozen or so "soft gamma repeaters"). A time profile structure parameter would help in a classification scheme.

Lestrade et al. (1991) showed that a robust, quantitative measure of a profile's structure is prvided by a count of the number of occurrences of monotonic "runs", similar to the standard "run test" (Eadie et al., 1971). After trying several algorithms that relied on the difference in the *number* of counts between adjacent bins, we found that the wide variation in profile types complicated any conclusions that we drew. We then found that the run test gave more consistent results.

One of the first results to come out of this analysis is that the GRB time histories show a homogeneous distribution of structure. This implies (although, not in a rigorous sense) a single phenomenological source for the GRB population. If this result holds up under further analysis, it places a larger burden on those trying to explain the myriad of observations with models which combine two completely different sources.

One of the assumptions in this study (see attached paper), was that we needed to smooth the profiles with a 5-bin moving average before counting the number of spikes. While this does help separate highly-structured bursts from smooth ones and the latter from noise backgrounds, it greatly complicates the statistical analysis. It also removes smaller spikes.

Because of these shortcomings, we have recently turned our attention to building a reliable statistic that will measure the lengths and number of runs in *unsmoothed* profiles. This new technique holds great promise. The results were not ready for this report, but they will be in the paper submitted this summer to the Astrophysical Journal.

Chaos and Fractals:

It was heretofore believed that the evolution of a deterministic system was completely predictable once the mathematical equations that described the system were known. Examples of systems that did not fit this rule, such as weather or the stock market, were believed to be random systems with no significant deterministic elements. In these latter cases probability had to be invoked to predict the end states.

The discovery of "chaos" has revolutionized this simple classification scheme. In short, chaotic systems are deterministic systems which are unpredictable. Even though we may be able to write out the system equations in an analytical form containing no terms of probability, small differences in the initial conditions result in strongly different evolutionary paths and therefore unpredictability in final state (Krasner, 1990).

The benefit of recognizing when chaos exists in a particular case is that there are several powerful algoriths recently developed that permit the extraction of useful information from what seems like random data. In particular, time series data can be used to build the phase-space trajectory for the dynamical system. To do this requires a procedure called time-delayed imbedding. With this method, we may be able to calculate the number of degrees of freedom (dimension) of the underlying physical phenomenon (Lochner, 1989; Parker and Chua, 1989). This kind of information on the physics of GRB's can lead us onto the correct theoretical path.

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