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Hint of a galactic origin for a sub-population of extremely short and hard cosmic gamma-ray bursts

K. Shanthi[1], A. R. Rao[2], C. L. Bhat[1], M. N. Vahia[2]

[1] *Bhabha Atomic Research Centre, Nuclear Research Laboratory, Mumbai 400085, India*

[2] *Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400005, India*

Abstract. Gamma Ray Bursts (GRBs) belong to an exotic class of astronomical phenomena whose origin and nature continues to puzzle the astrophysical community. These enigmatic events are seen as intense outbursts of high-energy photon radiation (10's of keV to 10's of MeV), lasting from a few milliseconds to as long as several minutes. The understanding of gamma-ray bursts has to rely heavily on the statistical study of their properties. We have taken the BATSE 3B burst catalog for our analysis and have found a clear signature of a bimodality when bursts are classified on the basis of their time-duration and hardness-ratio. Two populations of events are suggested, one characterized by shorter bursts with harder spectra and the other by longer bursts with softer spectra. A subclass within the first group, comprising the hardest and the shortest bursts, indicate an association with some galactic feature/population.

1. Introduction

Gamma-Ray Bursts represent an enigmatic class of astronomical phenomena whose nature continues to defy a satisfactory explanation despite considerable attention that they have attracted from both, the experimentalist and the theorist, ever since their discovery in late sixties. Their overall angular distribution is isotropic, while their brightness distribution shows a reduced number of fainter events, and is compatible with a non homogenous spatial distribution. A new dimension to GRB puzzle was added with the recent launching of the Beppo-SAX, an Italian-Dutch satellite equipped with instruments (GRB monitor, two wide-field X-ray cameras and a set of four narrow-field X-ray telescopes) that enable fast and accurate localization of putative burst counterpart to a few minutes of arc within hours after the occurrence of a burst. In particular, the event of 8th May, 1997, GRB970508, detected by the BATSE and the Beppo-SAX, is reported to have an X-ray, optical (Bond, 1997) and radio counterpart (Frail and Kulkarni, 1997) and from the optical spectrum absorption lines (Metzger et al., 1997), it is estimated that the source is at a cosmological distance, corresponding to a redshift, $z \sim 0.835$. On the other hand, the optical counterpart of the GRB 970228, observed using the HST has an apparent proper motion (~ 2σ only), indicating a possible galactic origin for this burst (Sahu et al., 1997). We have attempted in this work to shed some further light on the so far unresolved origin-puzzle by using statistical methods.

2. Details of data analysis

Our analysis is based on the 3B catalog of BATSE and the parameters selected for investigations are : (1) Time duration T_{90}, the time during which the integral counting rate goes from 5% to 95% of the total; (2) The 'softness ratio' (SR) which is the ratio of the fluence recorded in the second energy channel (50-100keV) to the third energy channel (100-300keV). We have not considered the errors in T_{90} and SR as these intrinsic properties are independent of their positions and do not affect the anisotropic distribution. A biomodality is seen in the T_{90} distribution with broad peaks evident at T_{90} ~ 0.32s and ~ 31.6s, separated by a minimum at T_{90} ~ 2s. When the 3B catalog events are plotted on log(SR)=S vs log (T_{90}) = T plane (Fig. 1), moderately significant correlation is noted between S and T and two islands of populations are seen sitting along the best-fit regression line with coefficients a = 1.46 ± 0.06, b = 1.1 ± 0.1.

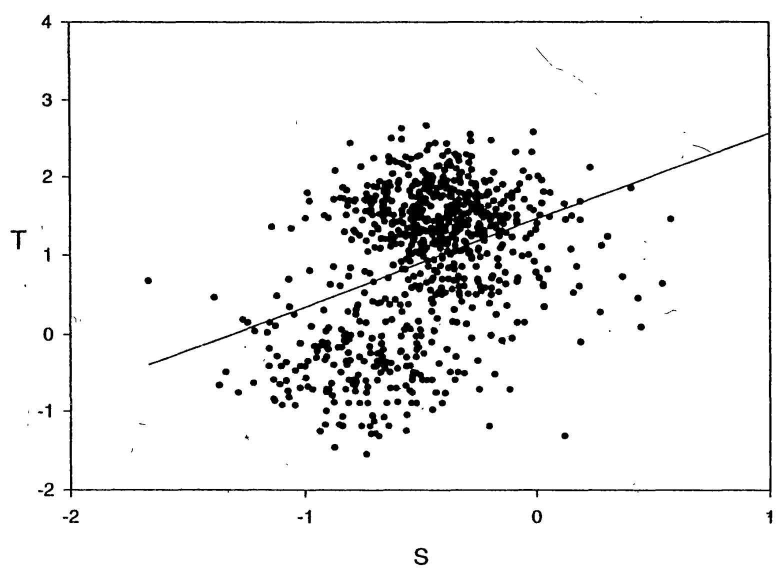

Figure 1. GRB distribution in $S - T$ plane where S is related to the burst softness ratio and T, to its time duration.

With a view to consolidate the above-referred picture of two GRB populations, we make use of the apparent correlation between S and T and define a length parameter (L) which represents the geometrical distance between the burst position on the (S,T) plane from a fixed point (S_o, T_o) located on the fitted regression line. For every point (S_i, T_i) representing a GRB, the distance to this fixed point, called the length L, can be calculated as $L = \sqrt{(S_i - S_o)^2 + (T_i - T_o)^2}$. In order that there is no ambiguity, the reference point (S_o, T_o) should be sufficiently far away from the data points and on the fitted line. Here we have chosen the reference point (S_o, T_o) to be twice the distance from the mid-point on the fitted line. Defined this way, smaller L means bursts with shorter duration and harder spectra (both T and S small), while larger L implies bursts with larger durations with softer spectra (both T and S large). The resulting frequency distribution of the events, as a function of L, shows a clearer biomodality (Fig. 2), further consolidating the two-GRB population picture : Type I with shorter duration and harder spectra (~ 197 events) and Type II, with relatively longer duration and softer spectra (~ 588 events). After binning the events in smaller intervals of length L, we have searched for any significant anisotropies by calculating, for each event sub-group, the dipole moment to the galactic centre, d =< cos θ > and the quadrupole moment about the galactic plane, q =< $\sin^2$ b–1/3 >, where θ is the angle between the burst location and the galactic centre and b is the galactic latitude of burst location.

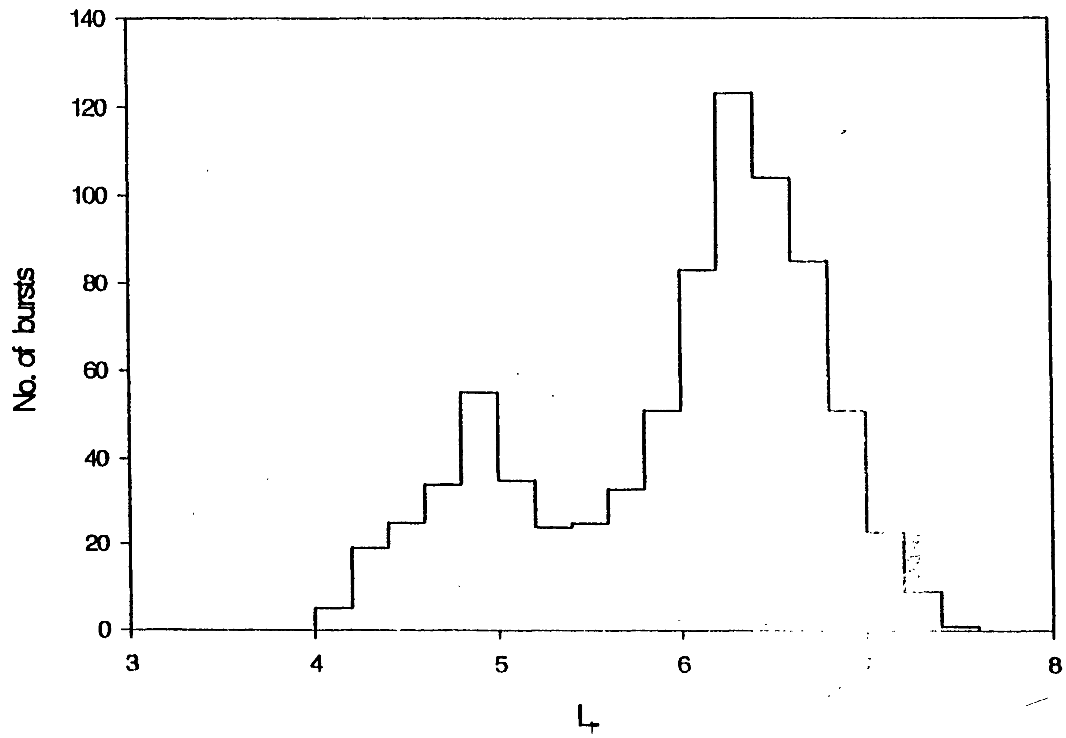

Figure 2. Burst 'length' L distribution for 785 GRBs showing a bimodal distribution. Here L is the 'length' which is the distance of a GRB from an arbitrary point on the fitted line in the $S - T$ plane. Shorter lengths correspond to bursts of shorter duration and harder spectra while larger lengths corresponds to comparatively longer duration and softer spectra.

3. Results and Conclusions

A clear biomodality in L distribution suggests the possibility of two populations of the GRB events : Type I, consisting of shorter and harder bursts and Type II, consisting of relatively longer and softer bursts. A similar picture of dichotomic behaviour of the GRB has resulted from the recent work of Belli (1997). Interestingly, from our analysis, the sub-group of the shortest and hardest events in Type-I, (37 events with $L < 4.5$), shows a non-zero quadrupole moment with a statistical significance of ~ 3σ and a non-zero dipole moment with a marginal significance of ~ 1.5σ (Fig. 3), suggesting that this sub-class may belong to a galactic population. This viewpoint receives a measure of support when it is noted that this subclass is largely clustered in the galactic longitude range 90° – 180° and the galactic latitude interval $-10° < b^{II} < 30°$. The other events do not show any deviation from isotropy, hinting at their possible cosmological origin. A galactic-arm association for this subclass of bursts is being investigated.

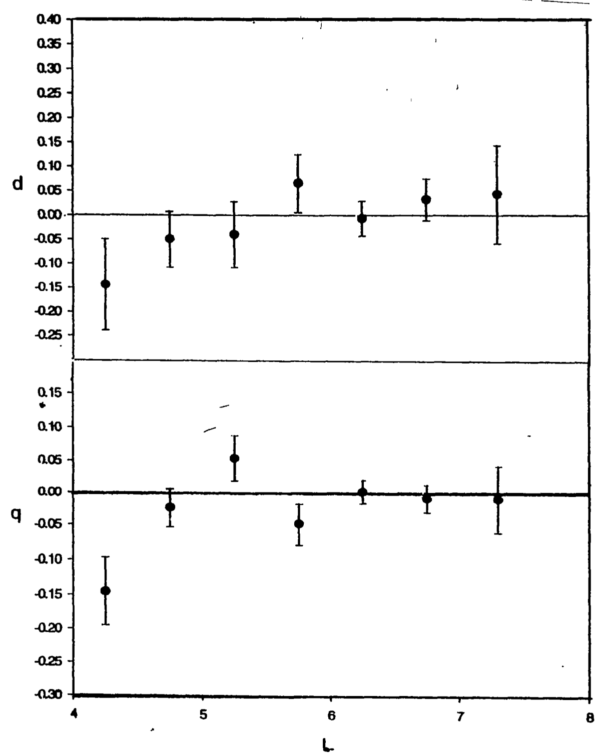

Figure 3. The GRB dipole moment d and the quadrupole moment q plotted as a function of the GRB length L (see text for details).

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