

Galactic and Extragalactic components in Gamma ray bursts

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The origin of the Gamma ray bursts is still an unresolved issue even after 32 years since the discovery of the first event. From the recent data from the HETE satellite, it has become obvious that some of these events are definitely associated with Supernova explosions and some of these have cosmological distances. However, no simple classification scheme fit the data. We present an analysis of the $\log N - \log S$ distribution of the GRB's and argue that data suggest the presence of two components which may be associated with galactic and extragalactic origin.

Introduction

Gamma ray bursts are the most energetic explosions known in the Universe since the Big Bang. GRBs are unpredictable flashes of electromagnetic radiation in the X- and γ -ray energy region around 100 keV, coming from any directions with their time durations ranging from few millisecond up to seconds, and during the time they last, they outshine all other celestial sources combined. The mean rate of detected GRBs is around one per day; when the sky exposure time and the actual solid angle of the detectors are taken into account, this mean rate typically raises up to a few (2-3) per day.

Since its discovery in 1973, the gamma ray burst astronomy has gone through many revolutions. The first radical change was brought about by the BATSE detectors on board CGRO satellite which was launched on 1991. In its 9 years operation, the BATSE team cataloged 2704 events of different shapes, sizes and peak fluences. (see fig 1). Statistical studies show that about 80% of all GRB last less than one minute, and that there is a class of short-duration GRB which last less than a few seconds and that the distribution is well described by a bimodal function, with the two peaks around 0.3s and 30s, respectively. A breakthrough in understanding GRB came with the discovery of X-ray [1], optical[2], and radio [3] GRB afterglows. The detection of the host galaxies and the measurement of their redshift showed that the longduration GRB are events related to the final stage in the evolution of massive stars, taking place at cosmological distances. High Energy Explorer Satellite 2 (HETE-2) dramatically changed our understanding of GRB phenomena. Apart from the discovery of short-hard bursts, x-ray rich bursts, optical dark bursts, it confirmed the GRB -SN connection and that some of the long bursts are associated with Type 1c core collapse supernovae. It has provided evidence that the isotropic-equivalent energies and luminosities of GRBs are correlated with redshift, implying that GRBs and their progenitors evolve strongly with redshift. Both of these results have profound implications for the nature of GRB progenitors and for the use of GRBs as a probe of cosmology and the early universe [4]. However, 8 years after the discovery of the first afterglow, spectroscopic redshifts have been determined only for 40 bursts among 263 localized GRBs of which about 100 have an optical, x-ray or radio afterglow.

The spectral data too does not provide clue to the origin of gamma ray bursts. Although GRBs release their energy mostly in the 50-1000 keV band, photons down to a few keV and up to 18 GeV have been detected as well. The non-thermal spectra are well described by the Band law [5], that is a smoothed broken power law. This functional form fits the burst spectra satisfactorily in the energy range from 10 keV to 100 MeV and the break energy typically ranges from 100 keV up to some MeV.

Even the properties derived from the afterglow observations reveal only limited information about the distribution of GRB sources. Though the temporal nature of the afterglow can be explained globally, within the framework of the relativistic fireball models, first proposed by [6] [7] [8], the extreme characteristics of GRBs seem to lead to a paradox called “the compactness problem” and also the rebrightening of the afterglow is not yet understood. The gamma rays in a GRB are believed to be produced by internal shocks taking place in a collimated jet directed close to the line of sight, while the afterglow would result from the interaction of the jet with the surrounding medium. However, the energy release of about $10^{50} - 10^{54}$ ergs cm^{-2} , the time duration of 10^{-1} to 10^4 sec and temporal structures of millisecond duration within the time history, remain some of the nagging problems still to be resolved. The successful phenomenological models too, can only produce global picture and a composite understanding of all the observed parameters, the uniqueness and individual characteristics of each of these events depend on the nature of the sources and their distribution in the universe.

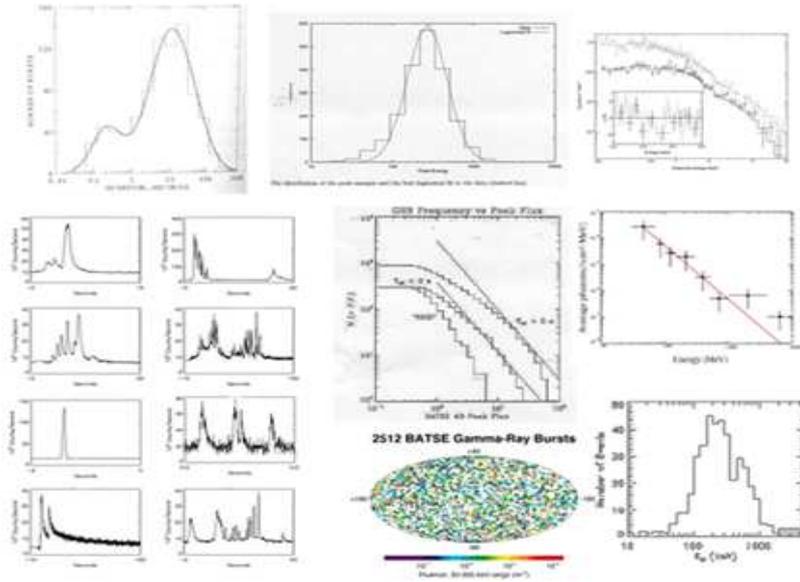


Figure 1. A collage of the spatial, Temporal and spectral properties of GRB, (*top*) time duration, fluence distribution, (*middle*) log N-log S for T90 events, energy spectrum, variety in pulse shapes and angular distribution

Source distribution of GRBs

The angular distribution of the 2704 bursts from BATSE catalog similar to that in Fig 1 suggests an apparent isotropic distribution[9], although earlier data did indicate concentration near the galactic plane [10] [11]. The observed dipole and quadrupole relative to the galaxy are perfectly consistent with null values, i.e. with an isotropic distribution; this property clearly supports an extragalactic origin or, at least, from an extended dark halo surrounding our Galaxy. However, in the BATSE GRB sample the number of faint bursts are fewer than expected for a homogeneous distribution in an euclidean space if one supposes that GRBs are standard candles. In the standard candle model within an Euclidean geometry, taking that all bursts have the same luminosity L and if S is the peak flux, V the volume of the sphere, whose radius R is the distance to the GRB source; then

for the minimum detectable flux S_{min} for a given detector, there is the maximum volume V_{max} , whose radius can be obtained from the $S_{min} = L / 4\pi R^2$ and under these assumptions,

$$V/V_{max} = (S_{min}/S)^{-3/2}$$

The ratio expressed by above equation can be used for testing the spatial distribution of a GRB events for a homogeneous distribution within an Euclidean space, the V/V_{max} distribution is uniform in the allowed range $0 \leq V/V_{max} \leq 1$ with a mean value $V/V_{max}=0.5$. In the case of BATSE bursts, however, the corresponding mean value is $V/V_{max}=0.33 \pm 0.01$ [12]. Similarly, the hypothesis for isotropic or a disk distribution of the GRB can be done with the LogN-LogS curve by considering the cumulative distribution $N(>S)$, representing the number of bursts, whose flux intensity is greater than (S), which in the case of a homogeneous distribution is characterized $N(>S) = S^{-3/2}$. The best fit parameters for a large sample of BATSE bursts, clearly show that the spatial distribution of GRBs is not consistent with the homogeneous case, since there are fewer faint bursts than expected on this hypothesis. However, the distribution of short duration burst is consistent with the homogenous distribution. The short bursts also show more symmetrical profiles than the long ones.

Similarly, the observed time durations of the burst events in the the BATSE sample there is some evidence for the existence of two classes. The T_{90} (calculated by taking the interval going from the time at which the total fluence is at 5% to the time at which it is at 95% of the overall burst fluence) distribution shows a bimodal behaviour i.e. short bursts with $T_{90} < 3$ s and long ones with $T_{90} > 30$ s [13].

The significant deviation from the homogenous distribution of sources therefore requires fresh look to explain the observed data. The fundamental questions to be answered are whether, the present sensitivity of the instruments have been sufficient to detect a true GRB frequency and if there is class of events which have defied detection. For example, some of the weak burst event reported in literature have no correspondance to the BATSE data. Second, whether observed transient events are a mixture of completely independent phenomena only related in their transient nature or third, if the observed lon-logS curve consists of a mixture of different populations having different spatial distribution.

Two component model

We propose that GRB sample indeed consists of two populations namely, extragalactic and galactic. The contribution from the galactic component is small, such that observed angular distribution has an apparent isotropy. In the figure 2, I have plotted the GRB frequency distribution for the peak fluxes for the events published in 4B BATSE catalog. It is seen from the figure that a simple 3/2 scaling law does not fit the data. The solid line in the figure is the best fit for a mixture of two populations one of which follows a 3/2 scaling and the second, a gaussian distribution with a maximum at 2.8 counts and a amplitude of about 7.5% of the first component given by

$$N(> S) = 950 S^{-1.5} + 70 e^{-[(S-2.8)/1.9]^2}$$

It is seen Fig. 2 that a mixed population functional form fits the data better quite well. A gaussian distribution of the galactic component simply reflects the radial distribution of the matter in the galaxy and is similar to the distribution of the galactic supernovae. In addition a small spread in the absolute luminosity of the GRB events will further broaden the gaussian function [14]. Assuming that second population is galactic in nature, it is instructive to assign a calibration marker of 10^{51} ergs to the gaussian peak which then leads to the absolute scale for the peak fluxes of the observed gamma ray bursts to be between $\sim 3 \times 10^{49}$ to $\sim 3 \times 10^{52}$ ergs.

In conclusion, irrespective of the fact that some the long burst are associated with the supernovae in other galaxies and may be at cosmological distance, the statistical analysis of the observed burst parameters clearly suggest that the observed sample consists of both the galactic and extragalactic component.

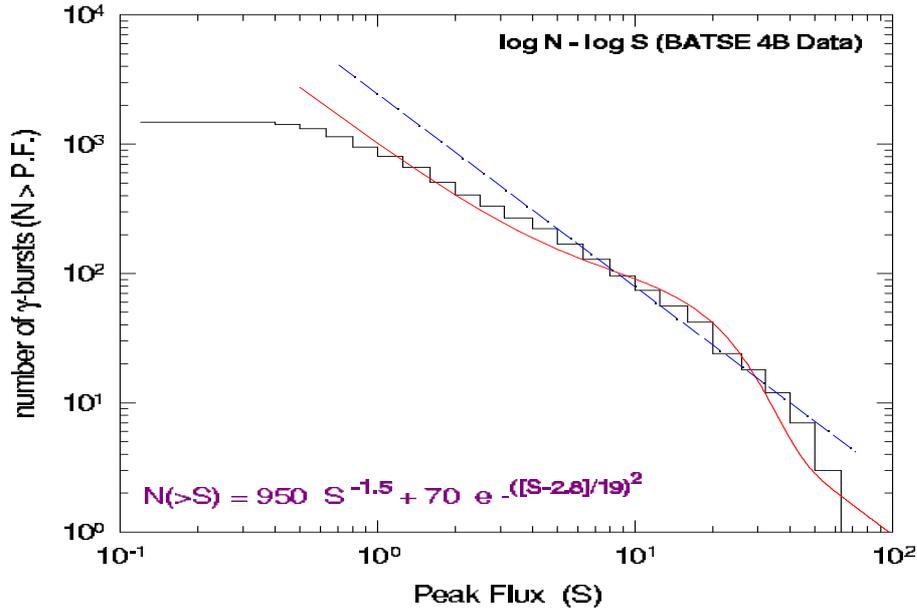


Figure 2. LogN-Log S curve for the gamma ray bursts

1. Acknowledgements

It is a pleasure to thank BATSE team for making the archival data available on the WEB. I also thank the members of the SIX team who provide a continuous support for research activities.

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