New uniform catalog of Gamma Ray Bursts found in the archive BATSE data: the test for isotropy and the constraints on the halo subpopulation

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We have performed an angular analysis of the new uniform GRB catalog of Stern &Tikhomirova. The catalog includes 3907 bursts with peak fluxes down to 0.1 ph cm^{-2} s^{-1} found in the BATSE 1024 ms continuous records. We confirm the isotropy and constrain the possible fraction of GRBs from an extended galactic halo subpopulation by 60% and of an Euclidean component by 23% in that GRB sample.

1 Introduction

The evidence that a number of observed Gamma-Ray Bursts (GRBs) has a cosmological origin is ultimately convincing (Djorgovski et al.[1]). However GRBs are not necessarily a uniform phenomenon. One can still admit that some fraction of GRBs originate from a non-cosmological (i.e. local galactic, galactic halo, or low redshift extragalactic) population of sources. Here we constrain such local subpopulation with new statistical GRB data.

Previous attempts to constrain Galactic GRB scenaria (see, for example, Hakkila et al.[2], Loredo & Wasserman[3]) showed that the least constrained local model is an extended galactic halo of bursters. It is interesting to recalculate the allowed fraction of halo GRBs and the Euclidean component in the observed GRBs sample.

The richest statistics of GRBs was provided by Burst And Transient Source Experiment (BATSE) (1991-2000) (Fishman et al.[4]) due to its unique sensitivity and long duration of the mission. The completed electronic BATSE catalog (at http://gammaray.msfc.nasa.gov/batse/) of triggered GRBs contains 2702 events.

The extention of BATSE GRBs statistics has been done by the search for non-triggered GRBs of Stern et al.[5,6]. Their new uniform catalog of GRBs (Stern & Tikhomirova[7]) found in the BATSE daily records for the whole period of the observations includes 3907 (2068 triggered

Table 1: The results of the tests for a large scale isotropy of GRB sky distribution.

statistics	exp.for isotropy	4Br catal. (1637)*	UC test bursts (5345)	UC all bursts (3907)	UC non-trig. (1839)
$\|\vec{R}\|$	0.018	0.029±0.025	0.026±0.014	0.021±0.016	0.030±0.023
$< \cos(\theta) >$	−0.009	−0.025±0.014	−0.012±0.008	−0.016±0.009	−0.019±0.013
$< \sin^2(b) - 1/3 >$	−0.004	−0.001±0.007	0.001±0.004	−0.007±0.005	−0.006±0.007
$< \sin(\delta) >$	0.018	0.024±0.014	0.003±0.008	0.010±0.009	−0.000±0.013
$< \sin^2(\delta) - 1/3 >$	0.024	0.025±0.007	0.022±0.004	0.025±0.005	0.026±0.007

* Paciesas et al.[10]

and 1839 non-triggered) events. Non-triggered bursts extend the statistics of known bursts down to fluxes F $\approx$ 0.1 photons cm^{-2} s^{-1} (a factor 2 lower than the BATSE trigger threshold) and give a chance to study more distant GRB sources without new more sensitive experiment. We use the new catalog as the largest and deepest GRBs sample.

Note, that all bursts of the UC were extracted from the DISCLA BATSE data of 1 s time resolution so **the constraints will be done mainly for the class of "long" bursts** (>2 s).

2 Test for isotropy

The sky distribution of GRBs from the UC seems isotropic visually. We use the following statictics for the large scale isotropy test:
1) dipole vector $\vec{R}$ in the independent coordinate system,
2) $< \cos(\theta) >$, where θ is the angle between the Galactic center and a GRB,
3) $< \sin^2(b) - 1/3 >$, where b is the Galactic latitute of a burst,
4) $< \sin(\delta) >$, where δ is the declination of burst and
5) $< \sin^2(\delta) - 1/3 >$.

About statistical errors for these tests see in Hartmann, Epstein[8] and in Briggs[9]. The total error has an additional component associated with the location errors of individual GRBs. The Monte Carlo simulations showed that this component is smaller by an order of magnitude than the statistical one.

The results of the tests are listed in Table 1. The values expected for isotropy and corrected for the non-uniform BATSE sky exposure (Paciesas et al.[10]) are given in the first column. In the BATSE catalogs these value are usually used as expected (see Paciesas et al.[10]). However, other systematic effects could appear as the result of a non-uniform burst selection. Such effects can be revealed by the test bursts used in the scan of Stern et al.[5,6]. Test bursts are initially isotropic and are subjected to the same systematic effects as real bursts. The results for test bursts are given in the column 4.

Table 1 represents the results for all bursts (the column 5) and for only non-triggered bursts (the column 6) from the UC. All deviations from the expected values for isotropy are within 1.5σ. The results of tests for the 4BATSE catalog are given in the column 2 for comparison.

3 Test for a GRB halo subpopulation

We represented the whole sample of GRBs as $(\xi - 1)S_0 + \xi S_h$ where S_0 is an isotropic cosmological subsample with unknown log N - log P distribution, S_h is the model halo (our Galaxy+M31)subsample, and find the value of ξ at which four criteria can be satisfied:

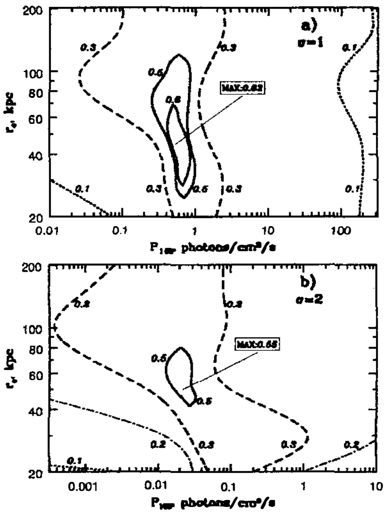

Figure 1: The maps of constant levels of allowed fraction ξ of halo subpopulation in the whole sample of UC: a) at $\sigma = 1$, b) at $\sigma = 2$. r_c is the halo core radius, P_{100} is the GRB peak count rate at the distance 100 kpc.

1) The dipole towards the Galactic center should be within observed 2σ upper limit,
2),3) The fraction of bursts with locations within 25^o and 18^o from M31 location, should not exceed observed 2σ upper limit,
4) The log N - log P: the sum of the diagrams for S_0 and S_h should give observed one of UC; the S_0 diagram should be bend down not steeper than $dN/d(logP) \propto P^{+0.5}$ at the low brightness, and the difference between neighbouring points of the S_0 diagram should not exceed 3σ.

The model of halo was traditional (see, for example, Hakkila et al.[2]):

$$N(r) = N_o r_c^2/(r_c^2 + r^2) \tag{1}$$

where $N(r)$ is the burster density per unit of volume, N_o is the density in the center, r is the distance from the center of Galaxy, r_c - the core size, with cutoff at 800 kps for both galaxies. The GRB luminosity function was assumed to be a lognormal distribution.

Monte-Carlo simulations showed that the allowed maximum fraction ξ is 0.63 at $\sigma = 1$ and 0.56 at $\sigma = 2$. However, as you can see in fig1, the brightness intervals where the fraction of galactic subpopulation can exceed 0.5 are only: $(1. - 3.3)\cdot 10^{41}$ erg/s and $(1.8 - 4.5)\cdot 10^{40}$ erg/s respectively. Fig2 represents the simulated logN-logP diagrams and the sky maps in the case of maximum fraction ξ of GRBs in the UC. The surprisingly high ξ is caused by the the absence of turnover of the logN-logP diagram at low brightnesses according new data of Stern et al.[6].

4 The constraints on Euclidean component

We used the same logic as in section 3. The calculated upper limit on a Euclidean component is **0.23** for the whole sample and about 0.14 for the sample with peak fluxes down to the BATSE trigger threshold from the UC (≈ 0.2 ph cm^{-2} s^{-1}) (which is slightly higher than that of Kommers et al.[11]

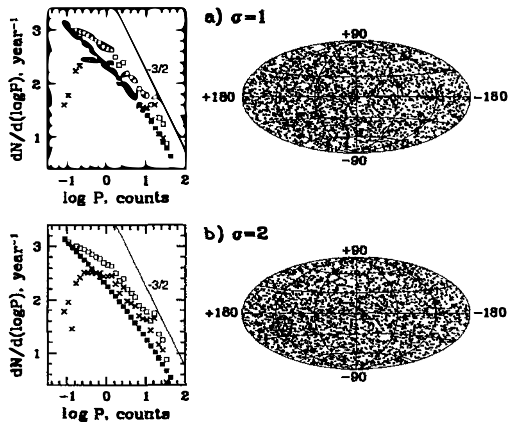

Figure 2: Simulated GRB logN-logP diagrams and sky distribution on an Aitoff-Hammer projection in Galactic coordinates in the case of maximum fraction of ξ in the UC: a) at $\sigma = 1$, b) at $\sigma = 2$. LogN-logP: crosses – cosmological population filled squares – halo population, empty squares – observed diagram. Sky maps: the whole sample (cosmological + halo), the halo of M31 is visible only at $\sigma = 2$ (M31 location: $l \approx 122^o$, $b \approx -21^o$).

5 Conclusions

For 3907 BATSE GRBs with peak fluxes down to ≈ 0.1 photons cm^{-2} s^{-1}:
-The large scale isotropy of the GRB sky distribution is confirmed.
-The maximum fraction of an extended galactic halo GRBs is about 0.6.
-The upper limit on Euclidean component is about 0.23.

Acknowledgments

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