Testing Isotropic Universe Using Properties of Gamma-Ray Bursts Detected by *Fermi*/GBM, *CGRO*/BATSE and *Swift*/BAT

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Abstract

Previously we proposed a novel method to inspect the isotropy of the properties of GRBs such as their duration, fluences and peak fluxes at various energy bands and different time scales. The method was then applied on the Fermi GBM Burst Catalog containing 1591 GRBs and except one particular direction where we noticed some hints of violation from statistical isotropy, the rest of the data showed consistency with isotropy. In this work we apply our method with some minor modifications to the updated *Fermi*/GBM data sample containing 2266 GRBs (thus about 40 % larger). We also test other two major GRB catalogs, the BATSE Current GRB Catalog of the *CGRO* satellite containing about 2000 bursts and the *Swift*/BAT Gamma-Ray Burst Catalog containing about 1200 bursts. The new results show proper consistency with isotropy confirming our previous findings and discarding any statistically significant anisotropic feature in the data.

Introduction

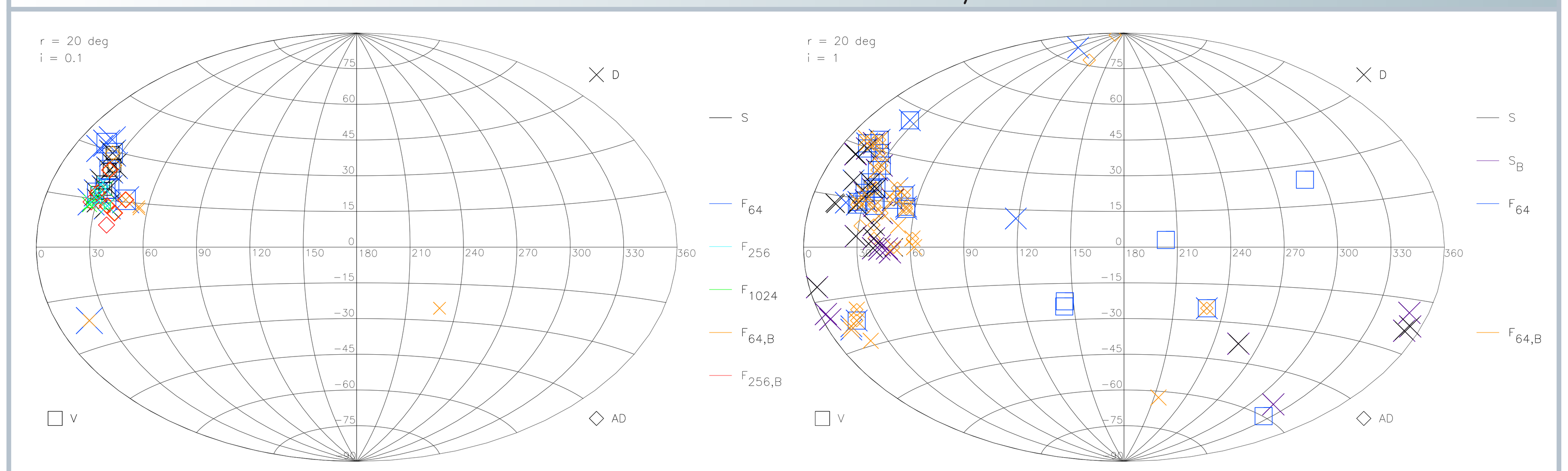
The distribution of Gamma-Ray Bursts (GRBs) on the sky had been initially claimed to be isotropic [1, 2, 3]. As more observational data were acquired the indication of some level of anisotropy appeared, e.g. see [4, 5, 6, 7]. Recently works [8, 9] claimed that there is a significant clustering of GRBs at redshift $1.6 < z \leq 2.1$ and size $\sim 2.0 - 3.0$ Gpc. However, another study [10] claimed that evidence of such significant clustering was not found. Also works [11, 12] reported an over-density of GRBs in the redshift range of $0.78 < z < 0.86$. All these GRB studies test the isotropy using the distribution of the number density. In our works [13, 14] we proposed a novel approach to test the isotropy through inspecting the observed properties of GRBs and applied this technique to the data samples of *CGRO*/BATSE, *Swift*/BAT, and *Fermi*/GBM.

Data Samples and Method

Durations T_{90}, fluxes F at various time scales and energy bands as well as fluences S at different energy bands were analyzed. Also the GRB positions contained in the catalogs were used.

We compare distributions of a given observed GRB property for a large number of randomly spread patches on the sky with a distribution of the same GRB property for the whole sky. We use four test statistics $\xi = \chi^2$ (two-sample Chi-square test), D (Kolmogorov-Smirnov test), V (Kuiper test), and AD (Anderson-Darling test). The obtained distributions of the test statistics for the measured data are compared with those for randomly shuffled data (*randomly shuffled observed GRB properties while keeping their positions fixed*) to infer the significance of potential anisotropies (for details see [13, 14]).

Results for *Fermi*/GBM

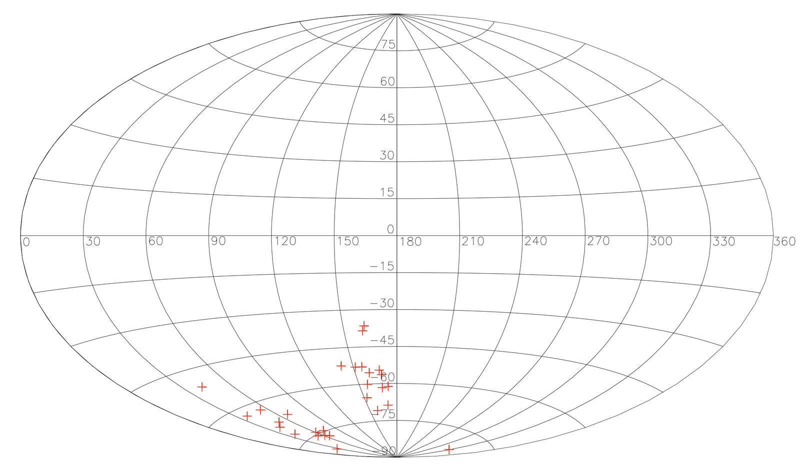


Figures show results for *Fermi*/GBM with 1591 GRBs from [13]. Plotted are the patch centers (Galactic Coordinates), for which the statistical properties of GRBs are mostly deviated from randomness. That is the patches for which a given statistic ξ^m, for the measured data, is higher than a limiting value ξ_i^s and the significance $P_i^N \leq 5\,\%$. Despite this feature in the data the result is consistent with isotropy which was confirmed on about 40 % larger data sample in our work [14].

Table compares results of several tests performed on the older sample in [13] and on the new updated sample in [14] for statistic D and patch radii $r = 20°$ demonstrating how the signal of a feature found in [13] vanished with larger data sample. N_i^m are number of patches in the measured data for which statistic D is higher than a limiting value ξ_i^s following from randomly shuffled data.

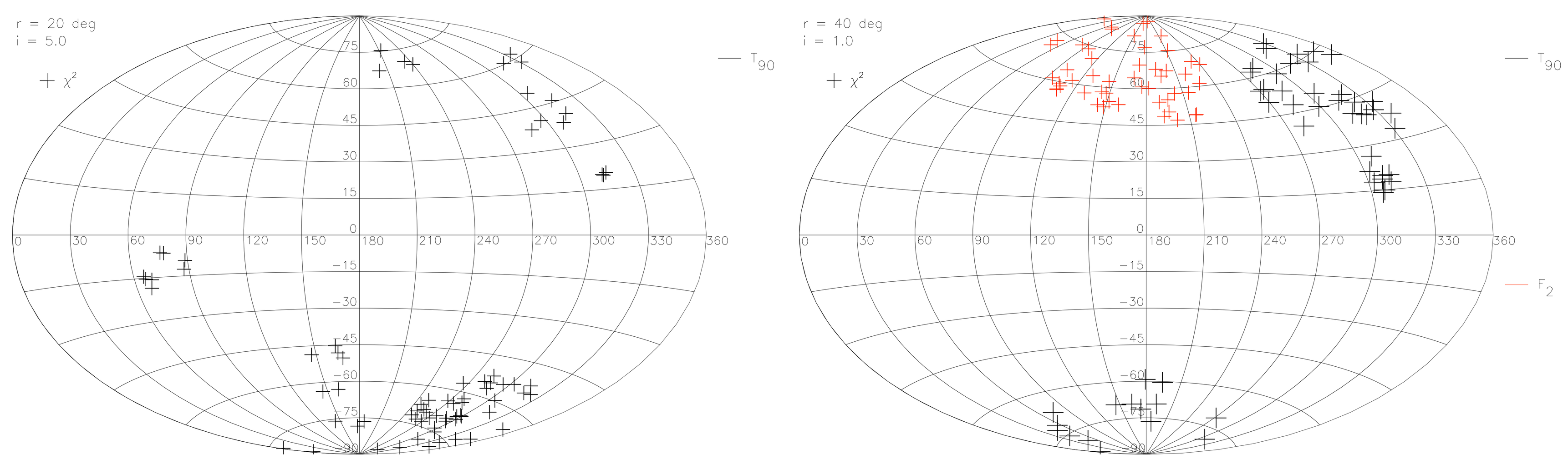
	old sample [13]				new sample [14]			
	N_5^m	P_5^N (%)	N_1^m	P_1^N (%)	N_5^m	P_5^N (%)	N_1^m	P_1^N (%)
F_{64}	87	3.4	30	1.5	55	36.8	10	44.6
S	72	13.1	30	2.2	57	32.2	17	17.1
S_B	74	11.5	31	1.4	52	43.7	17	17.9

Results for *CGRO*/BATSE



Plotted are the patch centers on the sky (Galactic Coordinates), for which the $\chi^{2\,m}$ statistic, for the measured data, is higher than $\chi_1^{2\,s}$ obtained from the randomly shuffled data and the significance P_1^N is below 5 %. The tested GRB property is fluences S_1 and the patch radii are $r = 20°$. This is the only case in the *CGRO*/BATSE sample, for which the significance P_i^N is below 5 %.

Results for *Swift*/BAT



Plotted are examples of the patch centers on the sky (Galactic Coordinates), for which the statistical properties of GRBs are mostly deviated from the randomness. The markers denote the centers of the patches for which a given statistic ξ^m (in this plot χ^2), for the measured data, is higher than ξ_i^s obtained from the randomly shuffled data and the significance $P_i^N \leq 5\,\%$, where i=5 or 1. The size of the markers is inverse proportional to the probability P_i^N. Different colors mean different properties of GRBs being tested. In different panels the results are plotted separately for different patch radii r and for different thresholds i. For details see article [14].

Conclusions

- The signal of a feature found in work [13] washed away with larger updated *Fermi*/GBM data sample used in work [14] and the results are consistent with isotropy confirming our previous conclusions.
- The method was also applied to the dataset of *CGRO*/BATSE instrument. The results are fully consistent with isotropy.
- The last investigated GRB data sample is from *Swift*/BAT instrument and our method together with Monte Carlo simulations show that results are consistent with isotropy as well.

References and Acknowledgements

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