SEARCHING FOR GALACTIC SOURCES IN THE *SWIFT* GRB CATALOG

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Abstract. Since the early 90s Gamma Ray Bursts have been accepted to be of extra-galactic origin thanks to the isotropic distribution observed by BATSE and the redshifts observed in some of their optical or infrared counterparts. Nevertheless, there have been a few cases that upon further examination have turned out to be of galactic origin. Several of these galactic sources have presented a Fast Rise, Exponential Decay structure which leads us to believe that there could be an underlying correlation. In this work we do several statistical analyses to determine the degree of contamination by galactic sources that certain subsample of known FREDs have. And find that certain subsamples have a most probable contamination between 27% and 34%.

1 Introduction

Gamma Ray Bursts (GRB) afterglows fade within a few hours, and as a consequence, the redshift of most GRBs are unknown. In the past several studies have been carried out to indirectly determine the Galactic or extra-Galactic nature of the bursts by analyzing their spatial distribution in the sky Balazs *et al.* (1998), Mazets *et al.* (1981), Meegan *et al.* (1992), and historically it served as a strong argument against the Galactic origin of GRBs Paciesas *et al.* (1999). This technique has also been used to suggest a more local nature of long-lag bursts

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Table 1. Dipolar and quadrupolar moments as an indicator of the degree of isotropy in the samples.

Sample	$\langle \cos b \rangle$	$\langle \sin^2 b \rangle$
#1	0.7883	0.3397
#2	0.8221	0.2860
#3	0.8184	0.2909
#4	0.8344	0.2673
#5	0.8397	0.2622

by showing that they may be related to the super-Galactic structure Foley *et al.* (2008), Norris (2002). The observed light curve of each GRB varies from burst to burst, particularly during in the prompt phase when the gamma ray emission is emitted, where one or multiple peaks with a variety of shapes are observed. However, some of them present a fast rise and exponential decay (FRED hereafter) behavior. These have been correlated with other properties of the bursts Bhat *et al.* (1994), suggesting that they may be of a different nature than other GRBs.

There has been at least one reported GRB that upon closer examination has resulted to be a phenomenon from within the Milky Way Castro-Tirado *et al.* (2008), Stefanescu *et al.* (2008). This source displayed a FRED structure, which leads us to believe that there could be others like it. We aim to estimate the most probable degree of contamination by Galactic sources that certain samples of FREDs have.

2 Sample selection

To achieve a homogeneous distribution, only *Swift*-detected GRBs were taken into account. From the catalog of 596 GRBs detected by *Swift* before March 2011, 111 GRBs were selected because they had a FRED structure reported in a GCN. Using the information available in peer-reviewed papers⁸ and other GCN circulars related to the 111 FRED GRBs, the following subsamples were selected⁹: **Sample 1:** All 111 FREDs detected by *Swift* until February 2011. **Sample 2:** 77 Bursts from Sample 1 discarding those that have a measured redshift. **Sample 3:** 71 FREDs from Sample 2, discarding those that have a stated high-redshift criteria in GCNs. **Sample 4:** 59 FREDs from Sample 2, discarding those with any type of indirect redshift indication. **Sample 5:** 49 FREDs from Sample 4 discarding those with multiple peaks. It is important to note that only sample 5 included solely those bursts that consisted of one pure FRED peak.

⁸Only two peer-reviewed papers were relevant for the sample selection Clemens *et al.* (2011), Perley *et al.* (2009).

⁹For a list of specific selected bursts see Tello *et al.* (2012).

Fig. 1. Swift exposure map in Galactic coordinates derived for this study. Colors represent the exposure time (in seconds).

3 Anisotropy quantification

It has been proven Hartmann & Epstein (1989) that the mean dipolar and quadripolar moments of the Galactic coordinates ($\cos b$ and $\sin^2 b$, where b is the Galactic latitude) are good tools to quantify the isotropy with respect to the Galactic plane Castro Tirado (1994). The degree of isotropy of each sample was calculated using the coordinates available from the gamma-ray burst coordinate network (GCN) circulars for each burst. The results are shown in Table.

3.1 Exposure map

Owing to the nature of its instruments, orbit, and mission, *Swift*'s pointing toward the sky is not homogeneous. It is of particular relevance to note that there has been less integrated exposure time toward the Milky Way's disk than toward the Galactic poles. This fact would represent a bias for the nature of the study carried out for this publication if left unaccounted, therefore we created a map by integrating the exposure mask function for the BAT instrument, multiplied by the exposure times of all observations carried out between April 16, 2005 and February 1, 2011, taking into account the pointing and rotation of the BAT instrument¹⁰.

3.2 Monte Carlo simulations

Monte Carlo simulations were carried out to determine the probability mass function (PMF) of the average dipolar and quadripolar moments of random GRB distributions. Therefore random coordinates were generated, taking care that they had a homogeneous distribution on an spherical surface.

These random points were then used to determine if the observed samples' dipolar moments deviated from those of a completely isotropically generated sample. To do this we generated an equal number of random points to that of each sample, recording the value of the mean dipolar and quadripolar moment and iterating a

¹⁰The method used to derive the exposure map is the same as the one detailed in Veres *et al.* (2010).

statistically significant number of times ($\approx 10^6 - 10^9$ iterations). The histogram of the recorded values was then used to determine the values for standard deviations ($\sigma, 2\sigma, 3\sigma$).

3.3 Metropolis-Hastings algorithm

To account for the anisotropy of *Swift*'s exposure of the night sky, it was necessary to factor in the probability that a particular random source was detected by *Swift*. We used the Metropolis-Hastings algorithm for this, which will effectively generate random sources that are more likely to appear where the exposure is higher.

3.4 Contamination by Galactic sources

Considering that i) the density of matter of the Milky Way is roughly correlated with the amount of interstellar dust, and by consequence so is the amount of stellar sources, and ii) the transparency of gamma-rays to interstellar dust, we used maps of dust IR emission Schlegel *et al.* (1998) as a weighting mask for the Metropolis-Hastings algorithm to generate random Galactic sources.

The isotropically generated samples were contaminated by increasing the number of Galactically generated random sources (N) to observe how this affected the PMF of their dipolar and quadripolar moment. We considered all possible combinations for the number of GRBs in the different samples and took into account the *Swift* exposure map for each generated source.

4 Results

The Monte Carlo simulations of the isotropically generated random samples (weighted by the *Swift* exposure map) showed that the dipolar and quadripolar moments from the real samples consistently deviated from the average: with the exception of the first sample, all samples have dipolar and quadripolar moments located outside two standard deviations.

The probability distribution of samples that contained both isotropically and Galactically generated sources allowed us to compare how the contamination by Galactic sources affected the likelihood of obtaining certain momentum values. This technique is similar to the one used in the past for studying the degree of contamination by Galactic repeater gamma-ray sources present in two GRB catalogs Gorosabel *et al.* (1998).

By observing the probability of the observed values in each one of the curves that resulted from the simulations, we determined the relative probability that each one of those combinations of isotropically and Galactically generated sources would yield the observed momentums. Figure 2 shows the probability as a function of the amount of Galactic sources introduced in each sample.

Fig. 2. Relative probability of obtaining the dipolar (*top*) and quadrupolar (*bottom*) moments ± 0.002 measured in each samples for different amounts of simulated galactic sources.

5 Conclusions

With the exception of the first sample, all observed samples show dipolar and quadrupolar moments outside two standard deviations from the mean of an isotropically generated distribution. Although this result is not conclusive, there is a high probability that the samples are not of a purely Extra-Galactic nature.

The amount of Galactic sources that are most probably contaminating the *Swift* GRB catalog is between 16 and 22. This value represents approximately 3% of the complete GRB *Swift* catalog. Sample 5 has been narrowed down so that it is likely that one out of every three is in fact a Galactic source.

The high Galactic extinction normally discourages optical ground-based spectroscopy of most low Galactic latitude GRBs. We showed that a large part of those abandoned follow-ups could reveal a missing population of Galactic events. So We encourage ground observers to follow-up those events, since it might lead to the discovery of unknown high-energy phenomena in our Galaxy.

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