A search for nearby galaxies in BATSE/IPN short GRB error boxes

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Abstract. Recent observations have revealed an apparent association between short duration gamma-ray bursts and a variety of host galaxies at moderate redshifts. However, observations of giant magnetar flares, as well as statistical analyses with a large sample of BATSE gamma-ray bursts indicate that at least some fraction of short GRBs originate in the local Universe. We have studied pre-Swift well-localized short GRBs to examine the possible association of these bursts with galaxies at low redshift. For the short bursts, we used BATSE and IPN localizations, and for the galaxies, we used the SDSS DR5 and PSCz surveys. We find no convincing association.

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INTRODUCTION

Recent Swift, HETE-2, Chandra and optical follow-up observations have revealed an apparent association between a few short GRBs and a variety of host galaxies at moderate redshifts [1, 2, 3]. The hosts are both elliptical and star-forming galaxies with redshifts z$\sim$0.2. This supports the model [4] in which short GRBs are produced in the merger of neutron star or black hole binaries. However, Tanvir et al.[5] have found a correlation between the locations of short GRBs and the positions of galaxies in the local Universe, indicating that 10 to 25 per cent of these bursts originate at redshifts $z < 0.025$. They used the sample of several hundred short GRBs detected by BATSE [6] and the IRAS Point Source Catalog (PSCz) of galaxies [7].

At the same time, the detection of the giant flare from the soft gamma repeater SGR1806-20 [8, 9] shows that a significant fraction of the short GRBs may come from extragalactic magnetars and may therefore be an entirely different phenomenon. Searches for this nearby subpopulation have been performed by various groups [10, 11, 12, 13]. The conclusion of [10], based on a search for short BATSE bursts from nearby star-forming galaxies, and [11], who examined the spectral properties of 76 short BATSE bursts, is that the fraction of SGR flares among short GRBs does not exceed a few per cent. The results of [12] and [13], who used the IPN GRB data, suggest $\sim$15% as the upper limit. [12] searched the error boxes of six IPN short bursts for nearby galaxies and found no host. [13] used a sample of a few dozen IPN short bursts to search for coincidences with 316 bright, star-forming galaxies, and found a single match which could, however, be a chance coincidence.

Here, we search for the hosts of individual short GRBs and for a population of bursts at low redshift using all the available pre-Swift BATSE and IPN data on well-localized short GRBs. We have used the Sloan Digital Sky Survey (SDSS DR5) and PSCz catalogs for our nearby galaxy surveys.

THE DATA SAMPLE AND THE DETAILS OF THE SEARCH

For the period 1990-2000, IPN[14, 15] data are available for 39 GRBs which were classified as "short". Most of the bursts in the sample were detected by BATSE. We take the BATSE 3σ error circles to have radii $r_{3\sigma} = 3\sqrt{\sigma_{stat}^2 + \sigma_{sys}^2}$, where σ_{sys} is the systematic error, 1.6^o, and σ_{stat} is the statistical error [6]. The IPN 3σ confidence annuli are centered at right ascension α, declination δ, with radii $R \pm \delta R$. 8 error boxes in our sample have areas less than 0. 003 deg^2, 5 have 0.003-0.1 deg^2, 20 have 0.1-1 deg^2, and 6 have 1-10 deg^2.

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We have used the SDSS DR5 [16] and the PSCz catalogs [7] as the galaxy surveys. The SDSS DR5 is the deeper survey with estimated redshifts up to $z \sim 0.5$ covering $\sim 1/4$ of the sky. The PSCz provides redshifts for galaxies up to $z \sim 0.1$ over 84% of the sky. The IRAS PSCz survey suffers less from incompleteness at low galactic latitudes than other nearby redshift surveys.

None of 39 GRB error boxes is fully covered by the SDSS DR5. Only 3 boxes have a coverage greater than 50%. Hence we cannot search for GRB hosts with the SDSS.

5 GRBs are not covered in the PSCz catalog, but we have searched for galaxies in the remaining 34 fully covered error boxes. We estimate the chance coincidence probability of a galaxy up to $z \sim 0.025$ appearing in an error box whose area is not larger than ~ 0.1 deg^2 to be $\leq 2 \times 10^{-3}$. For a closer galaxy the error box can be larger.

As a first step, we considered error boxes with sizes $S_{errorbox} \leq 0.1$ deg^2. 9 of the 13 boxes in this category are covered by the PSCz, but none of them reveals the presence of a galaxy. We then considered error boxes with sizes $S_{errorbox} \leq 1.0$ deg^2 and finally, the full sample of 34 GRBs. We found 3 and 10 PSCz galaxies respectively whereas the expected numbers in the case of a chance coincidence are 3.4 and 12.8, respectively.

We have estimated the probability P of a galaxy at given redshift appearing by chance in the error box. The probability is larger than 2×10^{-3} in all the cases. Therefore, we conclude that none of these galaxies can be considered to be a likely host.

If we nevertheless assume that the galaxies are indeed the hosts, we can estimate the GRB isotropic energy $E_{\gamma,iso}$: $E_{\gamma,iso} = (4\pi d_L^2 F)$, where d_L is the luminosity distance, and F is the fluence. We assumed $\Omega_L = 0.7$, $\Omega_M = 0.3$, $H = 70$ km/s/Mpc, and used the GRB fluence values (25-1000 keV) from the BATSE catalog [6]. In most cases the estimated $E_{\gamma,iso}$ are much larger than the measured values of Galactic and extragalactic SGR giant flares [8, 9, 17] This constitutes an additional argument that there are no likely SGR events in our sample. The estimated $E_{\gamma,iso}$ are in fact more typical of short GRBs [1, 2, 3], although we reiterate that given the chance coincidence probabilities we cannot make a strong case for them as the GRB hosts.

The total number of galaxies found in the error boxes is somewhat less than that expected. We estimate that the 90% confidence upper limit corresponds to 7% of GRBs originating in nearby galaxies in the PSCz catalog.

CONCLUSIONS

1) We have found no host galaxy candidate among the nearby PSCz galaxies in any of the 34 short GRB error boxes. 2) We have found no excess of nearby galaxies in the short GRB error boxes. The 90% confidence upper limit corresponds to 7% of them originating in the nearby galaxies in the PSCz catalog.

The questions "what fraction of short GRBs can be associated with SGR flares?" and "what fraction of short GRBs originates in nearby galaxies?" remain debatable. [18] have shown that only a dual population consisting of both SGR giant flares and NS-NS mergers can reproduce the likely local distribution of short GRBs as well as the overall number counts. A less conservative limit [5] is 25% of SGR flares in the short GRB sample. However, in all the searches for nearby hosts of well-localized pre-Swift short GRBs [19, 12, 13] no host has been found. Similarly, none of the Swift-era short GRBs with measured redshifts are nearby[1, 2, 3]. Therefore, more conservative estimates of the fraction of SGR flares and nearby GRBs in the short GRB samples (a few per cent - [10, 11] and this work) seem to be more realistic.

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