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The Rate Of Short Duration Gamma-Ray Bursts In The Local Universe

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The binary neutron star merger responsible for the gravitational wave event, GW170817, strengthened the merger association with short-duration gamma-ray bursts (SGRBs) following the detection of the SGRB counterpart, GRB 170817A. Here we consider the constraints on a population of local gamma-ray bursts with moderately short duration ($T_{90} < 4$ s) and within $d < 200$ Mpc, that may have originated from similar compact binary mergers. Using well localised gamma-ray bursts from ~ 14.5 years of *Swift*/Burst Alert Telescope monitoring, we find no events with high likelihood of being in this distance range, and place an upper limit for the all-sky rate of such events of $< 4\ y^{-1}$. For *Fermi*/Gamma-ray Burst Monitor (GBM) and *CGRO*/Burst And Transient Source Experiment (BATSE) detected bursts, where the localisation has considerably larger uncertainties, we cross-correlated with 2MASS Redshift Survey galaxies at $d < 100$ Mpc, obtaining a weaker constraint of $< 12\ y^{-1}$. A separate correlation search from the GBM and BATSE bursts for giant flares originating from soft gamma-ray repeaters in nearby galaxies ($d < 11$ Mpc) yields an upper limit of $< 3\ y^{-1}$.

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1. Overview

In light of GRB 170817A that accompanied a gravitational wave detection of a merging neutron star binary at d$\sim$ 40 Mpc, we consider the observational constraints on a nearby population of low-luminosity short-duration gamma-ray bursts (SGRBs), where we extend the definition to include bursts with $T_{90} < 4$ s.

Compact binaries consisting of a neutron star paired with either a black-hole or another neutron star may receive natal kicks from the supernovae during formation [1]. Sufficiently high kick velocities can eject a binary from its host galaxy. Thus, although the majority of SGRBs (including GRB 170817A) occur within the bodies of their host galaxies in projection [2], binaries of this nature may merge at large separation from their host and hence their distance from us will not be determined. We consider two approaches to identifying potential nearby host galaxies associated with catalogued SGRBs, allowing for the possibility of such kicks. In Section 2, we determine the number of detected Neil Gehrels Swift Observatory (*Swift*) bursts that have tentative nearby host galaxies that fulfil our criteria. In Section 3, we describe a cross-correlation of catalogued SGRBs with galaxies within 100 Mpc.

2. Using *Swift* to Localise Short-Duration Gamma-Ray Bursts

Swift is a dedicated detection and follow-up satellite designed to observe gamma-ray bursts using the on-board Burst Alert Telescope (BAT) and their afterglows with the X-Ray Telescope (XRT) and UV/Optical Telescope (UVOT) [3]. *Swift* provides excellent localisation of bursts ranging from a few arcminutes, if observed only by BAT, to $0.5-5$ arcseconds, if observed by XRT or UVOT.

We searched for *Swift* SGRBs that lie within an on-sky projection distance of 200 kpc (this distance corresponds to a long lived binary that has reasonable natal kick of $\sim 100\,\mathrm{kms}^{-1}$) to galaxies within $d = 200$ Mpc from the 2MASS Redshift Survey (2MRS) [4]. Table 1 lists the 10 bursts out of a total of ~ 150 *Swift* detected gamma-ray bursts with $T_{90} < 4$ s, that fulfill this criteria. None of these cases can be considered high confidence associations, and the total number is consistent with the expected rate of chance alignment of background bursts with foreground galaxies. We conclude an upper limit on the all-sky rate of local SGRBs to be $< 4\ y^{-1}$. Typical examples of bursts with either BAT or XRT error regions are shown in Figure 1.

3. Correlating *Fermi*/GBM and CGRO/BATSE Gamma-Ray Burst locations with 2MRS Galaxies

In comparison to *Swift*, the localisations from *CGRO*/BATSE and *Fermi*/GBM are considerably poorer but their fields of view are greater. As such, the joint BATSE+GBM population of observed gamma-ray bursts with $T_{90} < 4$ s is larger at ≈ 800. We performed a spatial cross-correlation between these bursts and 2MRS galaxies (as described in [5], see also [13]) for the purposes of constraining the fraction of bursts that arise in galaxies within 100 Mpc. This yields a maximum upper limit on the all-sky rate of $\lesssim 12\ y^{-1}$. An additional correlation using GBM and BATSE bursts with a $T_{90} < 1$ s to constrain the soft gamma-ray repeaters (SGRs) giant flare rate in nearby galaxies ($d < 11$ Mpc), yielded a rate of $< 3\ y^{-1}$.

Table 1: Compilation of *Swift* detected bursts that have candidate host galaxies within 200 Mpc from the 2MASS Redshift Survey (2MRS). For other potential SGRB events that have tentative galactic hosts that are not present in 2MRS but have been discussed in literature are listed below the table break [5].

GRB	T_{90} **(s)**	**Angular Separation (arcmin)**	**Closest Galaxy**	**Galaxy Type**	**Optical Bands (B/R) (mag)**	**J-Band (mag)**	d **(Mpc)**	**Impact Parameter (kpc)**	$E_{\rm iso}$ **(10^{46} ergs)**
050906	0.26	2.0	IC 0328	Sc	14.0 (B)	12.2	132 [6]	77 ± 109	1.9
100213A	2.40	5.4	PGC 3087784	S0-a	14.7 (B)	11.3	78 [6]	123	39.9
111210A	2.52	6.0	NGC 4671	E	13.4 (B)	10.1	43 [6]	76	7.5
120403A	1.25	4.9	PGC 010703	Sc	14.4 (B)	12.1	133 [6]	192 ± 90	38.2
130515A	0.29	8.5	PGC 420380	S0-a	16.0 (B)	12.3	73 [7]	180	28.4
160801A	2.85	6.7	PGC 050620	Sa	15.2 (B)	12.4	59[6]	115	10.7
181126A	2.09	39.8	NGC 3125	E	13.00 (B)	11.3	14.9[8]	173	1.9
070809	1.30	2.0	PGC 3082279 [9]	Sa	16.3 (B)	13.5	180 [10]	105	64.4
090417A	0.07	4.4	PGC 1022875 [11]	S0-a	15.9 (B)	13.4	360 [10]	461 ± 292	24.5
111020A	0.40	2.3	FAIRALL 1160	Sa	~ 14 (R)	11.7	81 [12]	54	9.4

4. In the Era of LV-O3

So far, during the third LIGO/Virgo science run (LV-O3) there has been one detection (S190425z) with a high probability of originating from a neutron star binary merger within 200 Mpc. There were no detections of an accompanying gamma-ray transient reported, despite the localised field being observable by *Fermi* [14], and *Integral* [15].

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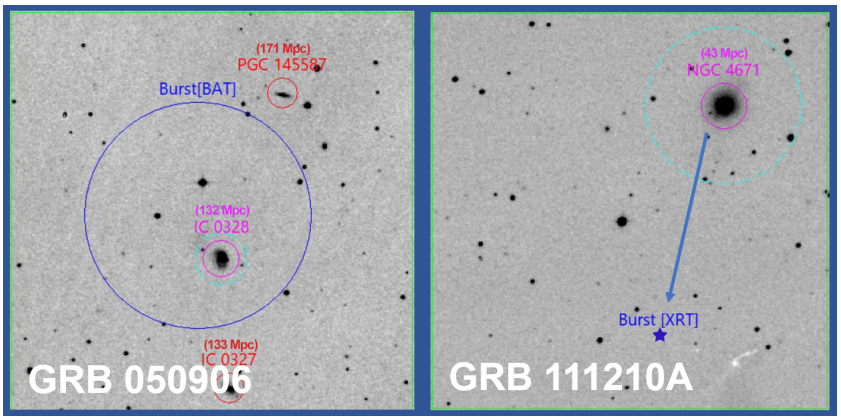

Figure 1: Potential galactic hosts to SGRB events that are within a projected distance of 200 kpc from the burst's location. [Left panel] An example case using GRB 050906, where a potential host, IC 0328, appears within the BAT uncertainty region. For this example, no X-ray or optical counterpart was identified. [Right panel] An example case of GRB 111210A, where a potential host galaxy (NGC 4671) is found at a displaced distance from the XRT localisation of the burst. In each case, the dashed cyan circle corresponds to a 25 kpc offset from the candidate host [5].