# Abstract

**Robert Chapman**

**Gamma-ray Bursts in the local Universe**

**University of Hertfordshire, 2008**

With energy outputs $\gtrsim 10^{51}$ erg in 0.1 - 1000 seconds, Gamma-ray Bursts (GRBs) are the most powerful events yet observed in the Universe. As such they are potential probes of the very early Universe, back to the era of re-ionisation and the first stars, but at the same time they have been observed to span a wide range in luminosity and redshift from the relatively local Universe ($z \sim 0.0085$) out to $z \sim 6.29$. GRBs divide into two classes based primarily on their duration as measured by $T_{90}$ (the time taken to observe 90% of the total burst fluence). Long bursts (L-GRBs) have $T_{90} \gtrsim 2$ seconds, and shorts (S-GRBs) $T_{90} \lesssim 2$ seconds.

Though much has been learned regarding long duration GRBs since the first afterglow discovery in 1997 (including their likely association with massive core collapse supernovae), much remains unknown regarding short duration GRBs. In this work, after a brief historical introduction and review, we present analyses of the angular cross-correlation on the sky of short GRBs from the BATSE catalogue with galaxies in the local Universe sampled from the PSCz Redshift Survey and the Third Reference Catalogue of Bright Galaxies (RC3). In particular we show that $20\% \pm 8\%$ ($1\sigma$) of all BATSE short duration bursts (localised to $10^\circ$ or better) show correlation with galaxy samples (morphological T-type $\leq 4$) within $\sim 112$ Mpc.

Our statistics thus provide evidence that a substantial fraction of BATSE short GRBs show a tendency to be associated with large scale structure on the sky traced by a variety of galaxy types. Short GRBs are believed to be produced in the final merger of compact object (neutron star–neutron star or neutron star–black hole)

binaries, though other possible progenitors are known to exist. The short initial spike of a giant flare from a Soft Gamma Repeater (SGR) such as the December 27th 2004 event from SGR1806-20 would have been detectable by BATSE as a short GRB if it occurred in a galaxy within $\sim 30 - 50$ Mpc (assuming a distance to SGR 1806-20 of 15 kpc). Using the observed luminosities and rates of Galactic SGR giant flares, as well as theoretical predictions for the rate of binary mergers, we investigate the ability of plausible Luminosity Functions (LF), singly and in combination, to reproduce our observed correlations and a cosmological S-GRB population. We find the correlations are best explained by a separate population of lower luminosity S-GRBs, with properties consistent with them being due to giant flares from extra-galactic SGRs. Overall predicted number counts are a good fit to the observed BATSE number counts, and furthermore, the wider redshift distribution is consistent with the early *Swift* S-GRB redshift distribution.

The three closest GRBs which have been observed to date were all long duration bursts, and we have therefore also searched for cross-correlation signals between the BATSE long GRBs and local galaxies. The three nearby bursts shared several similar properties such as being under-luminous, spectrally soft and of low variability. We have therefore also investigated a subset of L-GRBs with light curve properties similar to these known nearby bursts. The whole sample is found to exhibit a correlation level consistent with zero ($1\sigma$ upper limit = 10%, equivalent to 144 bursts) out to a radius of $\sim 155$ Mpc, but a spectrally soft, low observed fluence and low variability subset shows a correlation level of $28\% \pm 16\%$ ($\equiv 50 \pm 28$ bursts) within 155 Mpc. These results are consistent with low-luminosity, low-variability bursts being a separate sub-class of L-GRBs which may be much more prevalent in the local Universe than their high-luminosity, cosmologically distant counterparts. To investigate this further, we once again examined plausible luminosity functions for single and dual high and low luminosity populations, based on observed intrinsic

rates from the literature. The local population was once again found only to be produced to a sufficient level (while maintaining consistency with the observed overall number counts) by a separate low luminosity population with intrinsic rates several hundred times greater than their cosmological counterparts. Constraining the models via the *Swift* overall redshift distribution instead of threshold-adjusted BATSE number counts showed that the dual LF models were able to produce excellent fits to the entire redshift distribution while adequately reproducing a local population.

Finally, suggestions are made as to the direction future work may follow in order to build on these initial investigations, as well as to how observations with future missions and detectors such as *Fermi* (formerly *GLAST*), Advanced LIGO and LOFAR may shed further light on nearby GRBs.