The sources of long GRBs: population inhomogeneity or possibility its using as standard candles

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Abstract. Large articles amount refers to GRBs (at least long ones) as standard candles and then concludes various cosmological consequences. But firstly long GRBs sources population homogeneity should be proved. Redshift distribution analysis should represent GRBs population homogeneity if its shape similar to one of objects with real uniform distribution in our Metagalaxy, such as SN1a (subsets of 42 and 53 ones used for its Ω and Λ definition). There are one maximum in each subset redshifts distributions. Typically considered short and long GRBs classes separated by t_{90}=2s. Moreover, registered event duration strongly depends on detector energy band and method used for temporal profile analysis and the same events could have different duration on various detectors data. GRBs mostly located at high redshifts and cosmological correction should be used in duration investigation. Redshift distribution for registered by Swift/BAT GRBs with t_{90}>1s (corrected to z) was analyzed with short GRBs exclusion. But its redshift distribution is sufficiently differs from ones for SN1a: bursts deficit occur at z~2, possibly caused by long GRBs population inhomogeneity. So, preliminary analyses results allow conclude long GRBs population inhomogeneity. Thus using GRBs as “standard candles” previously required events advanced classification completion and consideration only certain GRBs subsets.

1. Introduction: GRBs typical characteristics – short and long events.

Vela series satellites launched in middle of 1960th [1]. The first GRB with duration ~1s was observed on July 2, 1967 by detectors onboard Vela-4A in energy range 0.1 - 1 MeV [2]. GRBs characteristics vary in very large intervals. For example (see [3] and references therein), bursts duration lies in the interval 10^{-2} –10^{3} s, registered near the Earth fluencies varies in the range 10^{-8} –10^{-3} erg/(cm²×s). Several thousand GRBs were detected up to now (see, for example, [3]) by more than 30 instruments onboard various satellites in both hear-Earth and interplanetary space.

GRBs duration distribution was firstly analyzed using data of BATSE [4] (Burst and Transient Source Experiment) onboard the Compton Gamma Ray Observatory (CGRO). CGRO [5] was launched on April 5, 1991 and finished its functioning on June 4, 2000. BATSE registered GRBs temporal profiles in four energy bands (25 - 50 keV, 50 - 100 keV, 100 – 300 keV and > 300 keV) due 8 large area detectors (LAD) based on NaI(Tl) scintillation crystal 50.8 cm in diameter and 1.27 cm thick each also with SD detectors for spectroscopic measurements - see, for example, [4].

GRBs duration characterized by t_{90} and t_{50} accordingly to BATSE data analysis [4, 6]. These two parameters are the times of accumulation for 90% and 50% of burst statistics (i.e. duration of intervals where the integrated counts from the GRB raise from 5% to 95% and for 25% to 75%
correspondingly). The GRBs duration distribution analysis had shown two bursts classes existence: long and short GRBs separated by \( t_{90} \approx 2 \text{ s} \). But results of similar distributions for bursts observed by other detectors have shown shifting of boundary between short and long events from value of 2 s. For example, durations of 1 s more likely correspond to this separator point for Swift/BAT GRBs subset distribution [7]. During 4B current BATSE catalogue [9] analysis group of intermediate duration events located at 99% confidence level in duration interval of 0.8 s \( \leq t_{90} \leq 50 \text{ s} \) with \( <t_{90}> \approx 3 \text{ s} \) taking into account duration and duration-hardness distributions - see, for example, [8] and references there’re. Additional criterion of burst spectrum description was hardness \( H_{32} \), introduced using BATSE data analysis results. It was defined as the ratio of fluence in third and second energy channels. Taking into account duration-hardness distributions analysis the following criteria were obtained for short \( (t_{90} \leq 3 \text{ s}, <t_{90}> \approx 0.5 \text{ s}, H_{32} > 6.00) \) and long \( (t_{90} > 5 \text{ s}, <t_{90}> \approx 30 \text{ s}, H_{32} < 1.85) \) GRBs [10].

Also this type bursts presents in all BATSE catalogues (for example, 1B [9] and 3B [11]) in spite of it’s subsets volumes. Intermediate GRBs are more intensive than short and long events [7, 10] (such bursts were absent in catalogue of faint events separated by ground analysis [12, 13]). Figure 1 presents this subgroup appearance in BATSE data [7]. Similar subgroup presents are widely discussed – see, for instance, [14, 15].

However GRBs sources’ origins nature is cosmological – see redshift corresponding columns in catalogues. Therefore correction to cosmological dilation of GRBs duration should be consider because of real cosmological sources time properties should be investigated only taking into account its redshift.

2. **GRBs detection on Swift/BAT and Fermi/GBM data.**

The Burst Alert Telescope (BAT) onboard Swift satellite [16] is a highly sensitive coded aperture imaging instrument designed to provide GRBs observations with large field of view (1.4 steradian half coded) and 4-arcmin positions definition in energy bands 15-150 keV for imaging mode and up to 500 keV with a non-coded response. It was launched November 20, 2004 [14]. Three GRBs catalogues are published due to BAT data analysis. Now Swift/BAT catalogue contains ~ 1200 bursts and 358 ones with known redshift [17].

GBM (Gamma-ray Burst Monitor) consist of 12 NaI based low-energy detectors for burst temporal profile registration and two high-energy ones made on BGO provide event spectra analysis – see, for example, [18]). It installed onboard the Fermi Gamma-Ray Space Telescope (formerly GLAST) [19] was launched on June 11, 2008 and operates up to now. Characteristics of NaI and BGO detectors of GBM instrument are similar to ones of BATSE LAD and SD combination but cover a wider energy range despite of its smaller collection area. Four GRB catalogues are published based on GBM data analysis – see, for example, [20]. Current GBM catalogue listed in [21].
Figure 2. Difference in duration of GRB170405A (18:39:48 UT) in energy range 15-350 keV on Swift/BAT data ($t_{90}$=165 ± 32 s marked by arrow and filed light gray on the lower part of figure) and in energy band 50-300 keV on Fermi/GBM data ($t_{90}$= 78.593 ± 0.572 s marked by arrows on the upper part of figure).

Unfortunately, duration of registered event strongly depends on detector energy band and method used for temporal profile analysis. These reasons lead the same events could have different duration on data of various detectors. For example, GRB170405A (18:39:48 UT) had $t_{90}$=165 ± 32 s in energy range 15-350 keV on Swift/BAT data [17] but $t_{90}$= 78.593 ± 0.572 s in energy band 50-300 keV on Fermi/GBM data [21] – see figure 2. There are several peaks at this burst temporal profile and last peak was located at more than 50 s from main three-peaks episode. Moreover, it appears only at low energies. This peak is sufficiently slight than first episode: ten times smaller than first peak on Swift/BAT data in energy range 15-100 keV and is absent in energy band 100-350 keV. On Fermi/GBM data in energy band 10-44 keV, its intensity is only about 50 counts/s over background count rate 1200 counts/sec against ~2000 counts/s over background count rate ~1300 counts/s during first peak. And this peak separation cause difficulties just because of geomagnetic modulation of Fermi/GBM background. Thus Fermi/GBM burst table doesn't contain data about this episode of GRB170405A.

3. Duration cosmological correction
In addition, cosmological correction should be taken into account in event classes’ separation due to duration analysis because of sufficient amount of GRBs located at high redshift – see, for example, [22]. GRBs distribution on $t_{90}$ and corrected to cosmological extension $t_{90}$ is presented at Figure 3.

Thus, GRB110731A (11:09:30 UT) had $t_{90}$= 7.485±0.923 s in energy band 50-300 keV on Fermi/GBM data [21] but $t_{90}$= 38.8 ±32 s in energy range 15-350 keV on Swift/BAT ones [17]. After cosmological correction (its $z$= 2.83) $t_{90}$~10.1 s on Swift/BAT data (long burst accordingly standard classification) and $t_{90}$~1.95 s on Fermi/GBM data (short event accordingly standard classification).
Moreover, separation point between short and long GRBs shifted to \( \sim 1 \)s on preliminary results of analysis of Swift/BAT events with known \( z \) and duration (358 GRBs) and intermediate group of events occurs in range \( 1 < t_{90} < 10 \) s. The last facts can indicate inhomogeneity of long GRBs population. Unfortunately analogous Fermi/GBM subset is insufficient for statistical analysis. It contains only \(~50\) events because of more than 55\% of Fermi/GBM bursts has 1-sigma statistical uncertainty in the \( t_{90} \) duration bigger than 10\%.

4. GRBs distribution on duration and \( t_{90} \)

As was mentioned above, the volume of Fermi/GBM bursts subset with known redshift and duration is insufficient for analysis because of big 1-sigma statistical uncertainty in the \( t_{90} \) duration. Thus redshift distribution for subset of registered by Swift/BAT GRBs (corrected to \( z \)) was analyzed. Figure 4 presents redshift (a) and redshift-duration (b) distributions for total Swift/BAT GRBs population taking into account cosmological extension. Short bursts with \( t_{90} < 1 \) s mostly located at \( z < 2 \), but additional 9 events with longer duration should be included to this group due preliminary results of population analysis. There is deficit of events with \( z \sim 2 \) and shape of distribution differ than one of objects with real uniform allocation in our Metagalaxy, such as SN1a – see, for example, [10].

Than Swift/BAT GRBs subset was investigated but mentioned at figure 4 short bursts are excluded – see figure 5. But its redshift distribution is sufficiently differs from ones for SN1a too: deficit of bursts also occur at \( z \sim 2 \). It can be caused by long GRBs population inhomogeneity and presence of intermediate duration group of bursts (marked triangles at figure 5b).

Also there are several differences of magnitude dependence on redshift for GRBs, usually used as standard candles SN1a and SN1c (especially connected with GRBs) types supernovae. The preliminary analysis results of Latest supernovae project data [23] (samples of 5918 SN1a and 374 SN1c) presented at Figure 6.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure3.png}
\caption{GRBs distribution on \( t_{90} \) and corrected to cosmological extension \( t_{90} \). Vertical and horizontal lines illustrates location of point with \( z < 0.1 \) and \( t_{90} \sim 2 \) sec, i.e. separation point between short and long events not shifted after taking into account cosmological extension only for low redshift bursts.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure4.png}
\caption{Redshift (a) and redshift-duration (b) distributions for total Swift/BAT GRBs population with correction to cosmological extension. Stars shows short bursts.}
\end{figure}
Figure 5. Redshift (a) and redshift-duration (b) distribution for Swift/BAT GRBs subset with removed marked by stars at figure 4b short events. GRBs marked triangles at panel (b) possible correspond intermediate bursts.

Figure 6. Magnitude dependence on redshift for Swift/BAT GRBs, SNIa and SNIc. Twelve connected SNIc with GRBs ones marked stars at panel (c), eight bursts associated with SNIc marked as stars at panel (a).

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Conclusion
In discussion of possibility using of any sources as “standard candles” firstly redshift distribution analysis should be made. If redshift distribution shape of analysed subset is similar to one of objects with real uniform distribution in our Metagalaxy than we could use sources of this subset as “standard candles”. Usually SN1a consider as standard candles (for example, subsets of 42 and 53 ones used by group of S. Perlmutter for definition of $\Omega$ and $\Lambda$ for our Metagalaxy [24]). Investigation of these subsets redshifts distributions shows one maximum each.
Redshift distribution of subgroup of Swift/BAT GRBs with known $z$ and duration have been analysed. But its redshift distribution is sufficiently differs from ones for SN1a both for total subset and one with excluded short GRBs: there is deficit of bursts at $z \approx 2$. It can be caused by long GRBs population inhomogeneity because of all selection effects should be appear in results of analysis of subgroups of other sources too. Also, there are several variations of magnitude dependence on redshift for GRBs, SNIa and SNIc, moreover, sample of usual SNIc differ from one associated with GRBs.

So, results of preliminary analysis allow make conclusion about inhomogeneity of long gamma-ray bursts population. Thus using GRBs as “standard candles” previously required completion of events advanced classification and then taking into account only certain GRBs subsets. Inhomogeneities of long GRBs population also require new theoretical implications of its sources models.

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