Average Emissivity Curve of BATSE Gamma-Ray Bursts with Different Intensities

Igor G. Mitrofanov¹, Maxim L. Litvak¹

and

Michael S. Briggs², William S. Paciesas², Geoffrey N. Pendleton², Robert D. Preece²

and

Charles A. Meegan³

¹Space Research Institute, Profsojuznaya str. 84/32, 117810 Moscow, Russia

²Department of Physics, University of Alabama in Huntsville Huntsville, AL 35899

³NASA/Marshall Space Flight Center, Huntsville, AL 35812

Received ________________; accepted ________________
ABSTRACT

Six intensity groups with \( \sim 150 \) BATSE gamma-ray bursts each are compared using average emissivity curves. Time-stretch factors for each of the dimmer groups are estimated with respect to the brightest group, which serves as the reference, taking into account the systematics of counts-produced noise effects and choice statistics. A stretching/intensity anti-correlation is found with good statistical significance during the average back slopes of bursts. A stretch factor \( \sim 2 \) is found between the 150 dimmest bursts, with peak flux \(< 0.45 \text{ ph cm}^{-2} \text{ s}^{-1} \), and the 147 brightest bursts, with peak flux \( > 4.1 \text{ ph cm}^{-2} \text{ s}^{-1} \). On the other hand, while a trend of increasing stretching factor may exist for rise fronts for burst with decreasing peak flux from \( > 4.1 \text{ ph cm}^{-2} \text{ s}^{-1} \) down to \( 0.7 \text{ ph cm}^{-2} \text{ s}^{-1} \), the magnitude of the stretching factor is less than \( \sim 1.4 \) and is therefore inconsistent with stretching factor of back slope.
1. Introduction

Gamma-ray bursts are known to have very different intensities. The peak flux of bursts varies more than 2 orders of magnitude from the BATSE trigger threshold of about 0.3 ph cm$^{-2}$ s$^{-1}$ up to the highest measured values of about 50 ph cm$^{-2}$ s$^{-1}$ (Fishman and Meegan 1995). The rich statistics of the BATSE 4B Catalog (Paciesas et al. 1998) enables one to divide all detected bursts into several intensity groups with reasonably large numbers of events ($\sim 150$) in each of them. Although individual bursts have very different time profiles, a characteristic average temporal signature can be produced for each group. Using these average signatures, a comparison can be made between the duration of different brightness groups of gamma-ray bursts. The main goal of this comparison is to test the brightness-dependent stretching of gamma-ray bursts.

It is well-known that individual pulses from radio pulsars have quite variable emission time profiles, so that the characteristic periodic pulsar signal is hardly recognizable by examining a short interval of real-time data. The randomized time profile is transformed into the stable signature of a pulsar light curve by using the epoch folding technique, averaging the data over many periods. A similar signature has been proposed for cosmic gamma-ray bursts: averaging the time profiles of individual events by the normalized peak-alignment technique, where each time profile is normalized by the peak number of counts $C_{\text{max}}$, aligned at peak time bins $t_{\text{max}}$ and then averaged for all bins along the time scale (Mitrofanov et al. 1996, hereafter Paper I). This technique produces an Average Curve of Emissivity, or ACE, and the corresponding signature represents the averaging of observed time histories of bursts.

ACE curves have already been studied for different energy ranges and for different intensity groups of bursts, and they have been found to be rather convenient signatures to describe the basic properties of the slow temporal variation of bursts (Mitrofanov et al.}
1997). This signature averages out the fast variations of bursts in the sample and describes the general envelope of rising emission before the main peaks of bursts and the subsequent decaying tail. An analytic approximation to the ACE has been found, which results in a very acceptable fit to the observations. The ACE equivalent width parameter describes the mean time scale of the slow variation of GRBs.

The comparison of the generic time-dependent properties of gamma-ray bursts with different brightnesses has recently become an issue of common interest. Indeed, if the difference in intensities represents the difference in distances to the emitters, then the difference between the average time signatures of different brightness groups should manifest effects of cosmological time-dilation, where dimmer bursts are observed to be broader than brighter events because they were emitted at larger cosmological distances. The time-dilation test based on the comparison of the averaged temporal structures for dim and for bright sets has already been done by two groups, which have drawn two opposite conclusions: in the first case a large time-dilation effect $\sim 2$ was seen (Norris et al. 1994, Norris et al. 1997), in the other case none was observed (Mitrofanov et al. 1994 & Paper I).

The effect of cosmological time-dilation should also be accompanied by the effect of photon energy red-shift, which could influence the time-stretching value (Fenimore & Bloom 1995a, Mitrofanov et al. 1997). On the other hand, sources of bright and dim gamma-ray bursts could be non-standard candles with intrinsic luminosity-based correlations (Brainerd 1997). In this case, the observed time-stretching of dim bursts could result from the fact that shorter outbursts correlate with smaller intrinsic luminosity of their sources. Also, one should take into account possible distance-related evolution of bursts emitters: in the co-moving reference frames, more distant sources could have shorter time profiles than nearer sources. These intrinsic effects could interfere with the cosmological effects.
Therefore, in order to make conclusive statements about generic time-dependent properties of gamma-ray bursts, one should distinguish between the physical effect of time-dilation, which results from the expansion of the Universe, and the phenomenological effect of time-stretching, which is found by the comparison of bursts with different intensities. We think that the first logical step should be the investigation of the stretching/intensity phenomenon by comparing time profiles for different intensity groups of bursts. If a significant time-stretching effect is found between different intensity groups, then the next logical step can be made. This step should be the physical interpretation of the observed stretching, according to predictions of a cosmological model, taking into account the geometrical effects of time-dilation and red-shift, the physical effects of time-energy dependence of emission, the effects of a broad luminosity distribution of emitters, and finally, the effects of distance-related evolution. In this paper, we restrict ourself to purely phenomenological studies of the stretching/intensity correlation of bursts, using the average emissivity curves for different brightness groups of bursts as the tool for measuring the stretching.

A total set of 887 bursts with $t_{90} > 2$ s from the BATSE 4B Catalog (Meegan et al. 1994, Paciesas et al. 1998) have data available on the 1024 ms timescale. We have divided these into 6 intensity groups (Table 1), using the peak flux parameter $F_{\text{max}}^{(1024)}$ as the selection criterion. For each of these groups, an ACE profile is produced using counts observed in the broad energy range 50-300 keV. The technique used to produce ACE profiles is described in Paper I. Below, the stretching/intensity effect is investigated and stretching factors are evaluated between each ACE$_i$ for the dimmer groups ($i = 2 - 6$) and the reference group (ACE$_1$). We have done this analysis for the total profile as well as for the rise fronts and the back slopes separately.
2. Analytical approximation of ACE profiles

We have previously determined that there is a simple analytical form that fits the ACE profiles of all burst intensity groups in several different spectral ranges quite well (Mitrofanov et al. 1997). For each selected group \( i \) of bursts, the analytical approximation to the ACE is

\[
f^{(i)}(t) = \left( \frac{\Delta t^{(i)}}{\Delta t^{(i)} + |t - t^{\text{max}}|} \right)^{a^{(i)}_{\text{RF}} - a^{(i)}_{\text{BS}}},
\]

with different power indices \( a^{(i)}_{\text{RF}}, a^{(i)}_{\text{BS}} \) at the rise front (RF, with \( t < t^{\text{max}} \)) and at the back slope (BS, with \( t > t^{\text{max}} \)), respectively.

Another approximation for ACE-like profiles with exponential wings has been suggested by Stern et al. 1996. A direct comparison between these two approximations has shown that a power law (eq. 1) fits the 1024 ms time scale ACE profiles over the range of 20 time bins before and after the peak much better than the exponential model. For example, with intensity group 1 (Table 1) we found a reduced \( \chi^2 = 1.51 \) for an exponential-type law, while Eq. 1 provided a better fit, with reduced \( \chi^2 = 0.88 \). For this reason, we use Eq. 1 to model ACE profiles in this paper.

3. Two procedures to estimate stretch factors between ACE curves of different intensity groups

When cosmological models were first suggested for GRBs, the observational tests for cosmological signatures were expected be quite obvious; for the case of ACE stretching coefficients, a factor of at least 2 should be observed between the brightest and dimmest burst intensity groups. Therefore, a simple procedure was devised to look for evidence for this stretching (see Paper I). However, a stretching factor of the expected magnitude was not found; indeed, recently-developed cosmological models for bursts predict much smaller
average stretching, despite the fact that some emitters should exist at large cosmological red-shifts (see e.g. Brainerd 1997). In order to make further progress, a more sensitive comparison method between different ACE profiles has been developed, allowing the measurement of weak-signature stretching factors (less than 1.5). To be successful, this method must take into account several statistical biases associated with the limited number of bursts in different intensity group samples and with the poor counts statistics of weak events.

We have developed two such procedures to make a robust comparison of ACE profiles between different brightness groups of bursts. Procedure (a), which is relatively time-consuming, requires the following steps to compare intensity groups $i = 2 - 6$ with the reference group $i = 1$:

(a1) An arbitrary stretching coefficient $Y$ is selected, and each burst of the reference group 1 is stretched by the factor $Y$.

(a2) An artificially-dimmed reference group, which has the same signal-to-noise ratio as group $i$, is created from bursts of the stretched reference group (see Section 5).

(a3) ACE profiles are produced for the stretched and dimmed version of the reference group and for the original group $i$. The value of $\chi^2$ is used to measure the difference between them. To find the best fit stretching coefficient $Y_i$, the value of the stretching coefficient $Y$ is changed, and the cycle (a1)-(a3) is performed again to minimize $\chi^2$.

The time-efficient procedure (b) is more simple and straight-forward than the first one. It consists of the following steps:

(b1) An artificially-dimmed reference group that has equal signal-to-noise ratio to the the group $i$ is created from the reference group (see Section 5).

(b2) An ACE profile is produced for the artificially-dimmed reference group, and the
parameters of the best-fit analytical model (Eq. 1) are computed.

(b3) The stretching parameter $Y$ for the time constant $\Delta t^{(1)}$ is introduced into the analytical model (Eq. 1) for the artificially dimmed reference group 1:

$$f^{(i)}_{dim}(t) = \left( \frac{Y_i \cdot \Delta t^{(1)}}{Y_i \cdot \Delta t^{(1)} + |t - t_{max}|} \right)^{a_{RF}^{(1)} a_{BS}^{(1)}}.$$  \hspace{1cm} (2)

Fixing all other parameters, the best fit value for $Y_i$ as a free parameter, is found for the ACE of each group $i = 2 - 6$. This value is taken to be the stretch coefficient $Y_i$ between the group $i$ and the reference group.

A direct comparison of these two procedures has been performed for the back slopes (time bins after the peak in the ACE) of bursts using the 3B Catalog data base (Litvak et al. 1997a). Excellent agreement between the best-fit stretch factors ($Y$) estimated from both procedures was found. The difference between them is much less than 1σ for choice statistics (see Section 4). Therefore, the computationally time-efficient procedure, (b), is used below in studies of ACE stretching.

4. Choice statistics and the related errors of the stretching coefficients

The proposed method suggests that we may use the ACE as the signature representing the slow variability of a selected sample of gamma-ray bursts. Individual bursts have very different time profiles, and one must use a very large number of individual events to build up a representative ACE that will be the same for different samples of bursts with similar brightnesses.

The errors associated with ACE curves may be estimated from the sample variance for the selected groups of bursts. ACE profiles for two independent groups are statistically
indistinguishable, provided the difference between them is within these errors. The direct comparison of ACE profiles for different groups has shown that they are much more different than might expected from the variance within each sample only. This means that these groups are not representative samples, and a random selection of bursts within these groups does not ensure well-weighted contributions from all kinds of possible profiles.

To study the random choice statistics of bursts, a Monte Carlo test has been performed using the total set of 603 bursts from the 3B Catalog (Meegan et al. 1997) that have catalog values of peak flux and durations $T_{90} > 2$ s (Litvak et al. 1997b). Different numbers of bursts, $N = 100, 150, 200, 250, 300$, were assumed. We randomly selected $10^4$ times, two testing groups of $N$ events each from the total set of bursts, produced ACEs for these groups, and then determined the best-fit stretch factor $Y_{\text{choice}}$ between them. The distributions of $Y_{\text{choice}}$ for two different values for $N$ are presented in Fig. 1.

The spread of stretching coefficients $Y_{\text{choice}}$ due to random choice statistics is found to be much broader than would be expected from the sample variance for each individual group. Of course, the distribution of $Y_{\text{choice}}$ becomes narrower for larger $N$, but even for the largest value, $N = 300$, it is still quite broad.

Therefore, we conclude that for any two intensity groups, with $N$ bursts each, the estimated stretching coefficient must be compared with standard deviations from the random choice distribution, evaluated for $N$ events. For $N = 150$, the level of $1\sigma$ significance corresponds to the stretching coefficient $\sim 1.10$. Therefore, for $Y \sim 1$, one should use the errors $\delta Y \sim 0.10$ for the $1\sigma$ errors of the stretching coefficients. In the arbitrary case where $N \geq 100$, one can use following for estimations of errors:

\[
\frac{\delta Y}{Y} = 0.10 \cdot \sqrt{\frac{150}{N}}.
\] (3)

Below, these errors were used to estimate the significance of stretching between selected brightness groups (Tables 2 and 3).
5. Count-noise produced effects on the ACE

The procedure to create each ACE includes the selection of the highest peak of each burst, with counting rate $C_{\text{max}}$, and the normalization of the time profile by the $C_{\text{max}}$ value. Therefore, the ACE is sensitive to a bias where positive fluctuations of counts $(C + \delta C)$ dominate the selection of $C_{\text{max}}$. When the normalization is performed, a profile is lowered $(C_{\text{max}} + \delta C)/C_{\text{max}}$ times. The effect should be larger for dimmer bursts, where the ratio of $(C_{\text{max}} + \delta C)/C_{\text{max}}$ is larger.

To evaluate the effect, the reference group 1 (Table 1) has been transformed by the procedure of Monte Carlo noisification into 5 artificial reference groups, which have peak flux distributions similar to the corresponding distributions for the 5 observed dim intensity groups, $i=2-6$ (Table 1). The Monte Carlo transformation procedure includes the following steps:

a) For each original burst of the reference group (1), some counterpart event is randomly selected inside the testing group $i$.

b) The ratio of peak fluxes $f = F_{\text{max}}^{(1)}/F_{\text{max}}^{(i)}$ is estimated between the peak fluxes of the original burst and its weaker counterpart.

c) The time profile of the original bright burst is divided by the factor $f$, and counts for an artificially-dimmed version of the original burst are simulated using Poisson statistics:

$$D_j = \frac{C_{S,j}}{f} + C_{B,j},$$

(4)

where $C_{S,j}$, $C_{B,j}$ are the signal and background counts accumulated during the $j$th time bin for a burst from the reference group.

Using equation (2), stretching coefficients $Y_{\text{noise}}$ have been estimated between the ACE$_1$ for the original reference group and ACE$_i^{\text{art}}$ for the artificial reference groups ($i = 2-6$).
One can see the largest effect is that the \( \text{ACE}_{6}^{\text{art}} \) for the dimmest group \((i = 6)\) must be broadened by a factor of 1.22 to equal the width of the \( \text{ACE}_{1} \) for the original reference group. Therefore, if the observed stretching factor between ACEs for the actual observed dim group and the reference group is equal to 1, it should be interpreted as evidence for real stretching on the order of \( Y_{\text{noise}} \) between the dim and reference groups, because the ACE for the dim group is known to be narrowed systematically due to larger relative Poisson noise. This effect could be ignored when testing for much larger stretching coefficients above 2.0 (Paper I), but it should certainly be taken into account when the expected stretching might be as small as the noise-produced effect (see below). Both procedures (a) and (b) (Section 3) take this effect into account.

6. Stretching factors between the ACE for different intensity groups

6.1. Stretching with respect to the reference group

Using procedure (b) to compare between ACEs, stretching coefficients were estimated for each intensity group (Figure 2 and Table 2). The group of brightest events (1) is used as a reference and the corresponding stretching coefficient for this group was defined to be 1. For each group, the stretching factors \( Y_{\text{RF}}^{(1)}, Y_{\text{BS}}^{(1)} \) and \( Y_{\text{TOT}}^{(1)} \) were estimated with respect to group 1 for the RF and BS wings and for the total ACE profiles, respectively (Figure 2 and Table 2).

The rise front portions of bursts do not manifest any significant increase of stretching with decreasing intensity of bursts. The stretch factor for the rise front of group 5 with respect to the reference group is the only one that is above the \( 3\sigma \) level (in this case, \( 3\sigma = 1.34 \)). On the other hand, at the back slopes the stretching factors \( Y_{\text{BS}}^{(1)} \) are larger than \( 3\sigma \) already between groups 2 and 1, and increase up to \( \sim 2 \) with decreasing brightness...
(Table 2). The noise-produced systematic narrowing of the ACE is taken into account for these values, because the test groups \(i = 2 - 6\) are compared with the correspondingly noisified reference groups. In the case of the comparison with the original reference group (1), the stretching would be less. The lack of stretching during the rising portion of the ACE of the dimmest group (6) may be an instrumental effect, resulting from the deficit of slow-rising events near the trigger threshold (e.g. Higdon & Lingenfelter, 1996). We know from the non-triggered burst sample of Kommers et al. (1997) that the threshold effect may change the estimate for the rise-front stretching factor only for the dimmest group 6 in our sample.

When the total ACE profiles are compared, the stretching factors have intermediate values between the corresponding factors for rise fronts and back slopes. One can see that the back slope stretching factors for dimmer groups \(i = 3-5\) are \(\sim 2\sigma\) larger than those associated with the rise front (Table 2). That is why one should study the stretching phenomena of bursts separately for the rise front and back slopes.

### 6.2. Stretching with respect to the second brightest group

With decreasing burst intensities, the largest increase of stretching between successive intensity groups happens between the brightest and the second brightest groups (Table 2 and Figure 1). Of course, this could result from a random choice fluctuation: the number of bursts in each group is still not large enough to exclude this possibility. Larger burst samples from subsequent BATSE catalogs should be used to check the jump of stretching for the two intensity groups bounded by the flux of \(\sim 4.1 \text{ ph cm}^{-2} \text{ s}^{-1}\). The jump may completely disappear for larger statistics; or, more interestingly, it could be confirmed as a real phenomenological effect.
However, one has to be sure that this jump-like effect between the test group \((i = 2)\) and the reference \((i = 1)\) does not result from some systematic effect in the comparison procedure. Indeed, the reference group has been transformed by adding noise in order to be compared with dimmer groups, and some unknown systematics in this procedure could result in a jump of stretching between the reference group and dimmer groups.

To check this possibility, the same procedure used for the estimations of stretching factors has been reproduced; however, this time assuming the second bright group \((2)\) to be the reference (Table 3). The stretching factors \(Y^{(2)}_{RF}\) and \(Y^{(2)}_{BS}\) for group 2 have been defined as 1.0 in this case. To facilitate comparison between stretching coefficients based on group 1 and group 2, the re-normalized factors \(1.19 \cdot Y^{(2)}_{RF}\) and \(1.35 \cdot Y^{(2)}_{BS}\) are also presented in Table 3. There is very good agreement between stretching factors \(Y^{(1)}\) (Table 2) and \(Y^{(2)}\) (Table 3), based on the reference groups 1 and 2, respectively.

Therefore, one can exclude the possibility that some systematic effect takes place when the reference group is compared with dimmer ones. One may conclude that in the 4B catalog data set a large stretching factor of about 1.35 really exists between the back slopes of bursts of intensity groups 1 and 2, separated by a flux \(\sim 4.1\) ph cm\(^{-2}\) s\(^{-1}\).

6.3. Consistency between stretching factors for intensity groups of the 2B and 4B database

A comparison between ACE profiles was done previously (Paper I) using the database of 338 events from the BATSE 2B catalog (Meegan et al. 1994), with durations \(T_{90} > 1\) s. These were divided at the peak flux value \(\sim 1\) ph cm\(^{-2}\) s\(^{-1}\) into two intensity groups with 143 bright bursts and 179 dim bursts. The estimated equivalent time widths \(t_{ETW}\) (see Paper I) of ACE rise fronts, back slopes and total profiles for these old samples are
presented in Table 4. The values labeled “Old samples” are taken from Paper I but the errors are estimated according to random choice statistics as described above (Section 4). No significant stretching is seen between the ACE for these groups.

The 4B catalog allows us to do a similar analysis for new samples with as many as 480 bright bursts and 464 dim events, and to check the consistency between the estimations of equivalent time widths for the old and new samples. One concludes from Table 4 that the “old” and “new” results are consistent for intensity groups divided by the same peak flux value $\sim 1$ ph cm$^{-2}$ s$^{-1}$. There is no evidence for stretching for the “old” groups with 143 bright and 179 dim events either during the rise front or the back slope. Using the much better statistics available with the “new” intensity groups, there still is no significant stretching during the rise fronts, but there is some effect when $t_{ETW}^{(BS)}$ are compared.

The separation of all bursts into bright and dim groups by the peak flux $\sim 1$ ph cm$^{-2}$ s$^{-1}$ was appropriate when the goal was to test for an obvious signal of stretching by factors large as $\sim 2$. On the other hand, the 2B catalog sample was too small for more accurate sampling. Now, with much better statistics, more subtle stretching effects can be seen for several intensity groups (Table 2), in particular at the back slope of ACE profiles. In the half-to-half separation, a stretching effect of $\sim 2\sigma$ is also seen at the back slope (Table 4).

7. Conclusions

Six burst intensity groups with $\sim 150$ events each have been compared to determine a stretching effect between the ACE profiles for dim and bright groups. To study the stretching, a separate comparison is preferable for the average rise fronts and back slopes. The Pearson $\chi^2$ statistic between the reference and the stretched dimmer groups allows us to find the most probable stretching factors for the ACE of different intensity groups.
(Table 2), and the resulting reduced $\chi^2$ values are significantly smaller when the rise fronts and back slopes are each compared separately. There is a significant difference between the corresponding stretching factors for the rise fronts and back slopes in different intensity groups. During the rise front a stretch factor of $1.39 \pm 0.14$ is found between intensity groups 5 and 1, which seems to be marginally significant. The other factors determined for the rise fronts, taken together, also indicate some stretching effect, but not significantly.

This study is based on BATSE 1 s resolution discriminator data. Higher temporal resolution datatypes begin either at the trigger time or 2 s before. Our choice of the continuously available 1 s data avoids possible systematic effects in the rise front due to mixing datatypes of differing temporal resolutions.

There may be an instrumental triggering bias that selects against those dim bursts that rise more slowly on the average. This has been corroborated in the study of non-triggered bursts by Kommers et al. (1997), who found that only some of the dimmest bursts failed to trigger due to slow rise times. The intensities of these events correspond to our dimmest intensity group 6. Since only group 6 is incomplete due to missing slow risers, and since this incompleteness affects only the rise front results, we base our conclusions on rise front stretching on groups 1 to 5. Therefore, omitting the dimmest group, there is the indication of a trend for the rise-front stretching factors (Figure 3).

At the back slopes the estimated stretch factors are quite significant for all dimmer groups ($i = 2 \rightarrow 6$) with respect to the brightest one ($i = 1$), and the largest factor between the ACE profiles of dimmest 150 bursts and the brightest 147 bursts is about $2.1 \pm 0.2$. The non-stretching hypothesis may be significantly rejected for the back slopes of bursts. Our results are in qualitative agreement with recent estimations of time-stretching by Norris et al. 1994, where a different energy range was used for burst averaging and a different time scale was applied for burst selection.
We conclude that models of gamma-ray bursts should explain two phenomenological results:

1) Back slopes for the 150 dimmest bursts, with peak fluxes $< 0.45 \text{ ph cm}^{-2} \text{ s}^{-1}$, are on the average $\sim 2$ times longer in duration than the 150 brightest bursts, with peak fluxes $> 4.1 \text{ ph cm}^{-2} \text{ s}^{-1}$.

2) While a trend of increasing stretching factor, relative to group 1, may exist for rise fronts for groups 2 to 5, the magnitude of the stretching factor is less than $\sim 1.4$ and is therefore inconsistent with the stretching factor of the back slope.

3) Finally, there is definitely no full-profile stretching between dim and bright bursts as large as $\sim 2$ or more. Whatever stretching exists is weak and so the correct determination of the stretching factor will require careful treatment of statistical and systematic effects that are comparable with the physical effect of stretching that we are looking for. Using the 4B data, we conclude that a significant stretching by a factor of $\sim 2$ between the different brightness groups may only be resolved for the back slopes of the average light curves of GRB time profiles.

Our primary concern has been assessing the observational evidence for time stretching in the average profiles of GRBs. The observation of stretching in the back slopes but not in the rise fronts of GRBs cannot be solely caused by cosmological effects – at least one of these phenomena seems to be intrinsic to GRBs, perhaps indicating a slope correlation with absolute intensity or the existence of source evolution. Whatever the explanation, determining the distance scale of GRBs using cosmological tests is proving to be more difficult than had been hoped.
8. Acknowledgments

The work in USA was supported by NASA grant CRO-96-173. The work in Russia was supported by RFBR grant 96-02-18825.
REFERENCES


This manuscript was prepared with the AAS \LaTeX{} macros v4.0.
Fig. 1.— The $Y_{\text{choice}}$ distribution for $N=150$ events is shown by a thick line, while the distribution for $N=300$ events is shown by a thin line.

Fig. 2.— The ACE for the reference group (*thick line*) is compared with the ACE for dim groups (*thin lines*).

Fig. 3.— The best-fit stretching factors for the average back slopes (*solid*) and rise fronts (*dashed*) relative to the brightest group (*solid arrow*) as a function of peak flux. The value for the rise front for the dimmest group 6 may be altered by missing “slow riser” triggers – see text.
Table 1.

<table>
<thead>
<tr>
<th>Intensity group</th>
<th>Peak flux (ph cm$^{-2}$ s$^{-1}$)</th>
<th>Number of bursts</th>
<th>$Y_{\text{noise}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$&gt;4.10$</td>
<td>147</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>1.76-4.10</td>
<td>153</td>
<td>1.08</td>
</tr>
<tr>
<td>3</td>
<td>1.05-1.76</td>
<td>148</td>
<td>1.11</td>
</tr>
<tr>
<td>4</td>
<td>0.67-1.05</td>
<td>148</td>
<td>1.15</td>
</tr>
<tr>
<td>5</td>
<td>0.45-0.67</td>
<td>148</td>
<td>1.19</td>
</tr>
<tr>
<td>6</td>
<td>$&lt;0.45$</td>
<td>150</td>
<td>1.22</td>
</tr>
</tbody>
</table>

Table 2.

<table>
<thead>
<tr>
<th>Intensity group</th>
<th>Relative Stretching coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$Y_{RF}^{(1)}$</td>
</tr>
<tr>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>1.19±0.12</td>
</tr>
<tr>
<td>3</td>
<td>1.23±0.12</td>
</tr>
<tr>
<td>4</td>
<td>1.22±0.12</td>
</tr>
<tr>
<td>5</td>
<td>1.39±0.14</td>
</tr>
<tr>
<td>6</td>
<td>1.07±0.11</td>
</tr>
</tbody>
</table>
Table 3.

<table>
<thead>
<tr>
<th>Intensity group</th>
<th>$Y_{RF}^{(2)}$</th>
<th>$Y_{RF}^{(2)} \cdot 1.19$</th>
<th>$Y_{BS}^{(2)}$</th>
<th>$Y_{BS}^{(2)} \cdot 1.35$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.00</td>
<td>1.19</td>
<td>1.00</td>
<td>1.35</td>
</tr>
<tr>
<td>3</td>
<td>1.06±0.11</td>
<td>1.26</td>
<td>1.16±0.12</td>
<td>1.57</td>
</tr>
<tr>
<td>4</td>
<td>1.01±0.10</td>
<td>1.20</td>
<td>1.11±0.11</td>
<td>1.50</td>
</tr>
<tr>
<td>5</td>
<td>1.12±0.11</td>
<td>1.33</td>
<td>1.30±0.13</td>
<td>1.76</td>
</tr>
<tr>
<td>6</td>
<td>0.85±0.09</td>
<td>1.01</td>
<td>1.52±0.15</td>
<td>2.01</td>
</tr>
</tbody>
</table>

Table 4.

<table>
<thead>
<tr>
<th>Parameters to compare</th>
<th>Old samples</th>
<th>New samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t^{(RF)}_{ETW}$ for bright groups</td>
<td>2.47±0.27</td>
<td>2.48±0.15</td>
</tr>
<tr>
<td>$t^{(RF)}_{ETW}$ for dim groups</td>
<td>2.25±0.29</td>
<td>2.35±0.14</td>
</tr>
<tr>
<td>$t^{(BS)}_{ETW}$ for bright groups</td>
<td>4.16±0.46</td>
<td>3.62±0.21</td>
</tr>
<tr>
<td>$t^{(BS)}_{ETW}$ for dim groups</td>
<td>4.32±0.48</td>
<td>4.27±0.26</td>
</tr>
</tbody>
</table>