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A new approach of Analyzing GRB light curves(*)

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Summary. — We estimated the T_{xx} quantiles of the cumulative GRB light curves using our recalculated background. The basic information of the light curves was extracted by multivariate statistical methods. The possible classes of the light curves are also briefly discussed.

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1. – Introduction

The light curve represents one of the most revealing information of a Gamma-ray Burst (GRB) (see, for example, [9], [12], [13] and references therein). In this work we make an attempt to classify the bursts by the light curves. We base this new approach on the BATSE Concatenated 64- ms burst database [15], which contains 2130 triggers. In order to be consistent with several other papers (*e.g.,* [2]) we used the same background and burst interval definitions as in [16] but we made our own independent parabolic background fits. We had background intervals for 2024 bursts [16] and we made parabolic fits using a χ^2 method in the 1024 ms scale data, summed up the four channels. Then we subtracted the estimated background from the BATSE cat64 ms data and calculated T_{90} [2,6,7]. Noisy bursts were excluded (where the χ^2 probability was less than 0.0005), therefore the final size of the sample was reduced to 1708. After fitting the background we calculated the times when the 5%, 10%, . . . , 95% of the photons were detected. For this purpose we calculated the cumulative light curves. After calculating the 19 time values we computed the differences of the neighboring values ($t10\% - t5\%$, $t15\% - t10\%$, $t20\% - t15\%$, etc.) and normalized them with T_{90}, therefore the duration of the bursts became uniformly one. This means that the duration information were removed form the data. These 18 variables were the base of our analysis.

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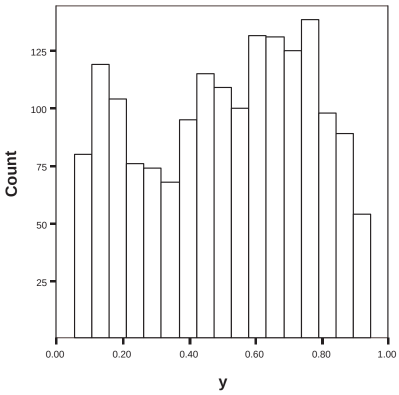

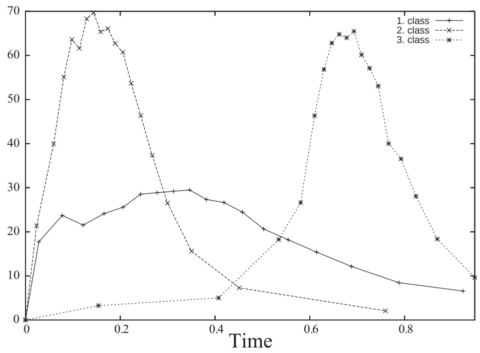

Fig. 1 Fig. 2

Fig. 1. – The histogram of the values where a vertical line near the maximal separation intersect the cumulative light curves.

Fig. 2. – The 3 light curves of the cluster centers.

2. – Calculations

We used the SPSS Statistical Analysis Software [14] to derive statistical information from our data set. For obtaining the possible classes we used the K-means clustering procedure (Quick cluster module in SPSS). This procedure assumes that data can be divided into a known K number of clusters (for GRB classification see [1, 3-5, 8, 10]). For each 1708 bursts we had 18 variables, which were the input for the K-means cluster analysis. The algorithm tried to separate the bursts which were points in a 18-dimensional space into the specified number of classes, therefore each burst falls closer to its own class center than to the other ones. The distance was specified by the usual Euclidean distance.

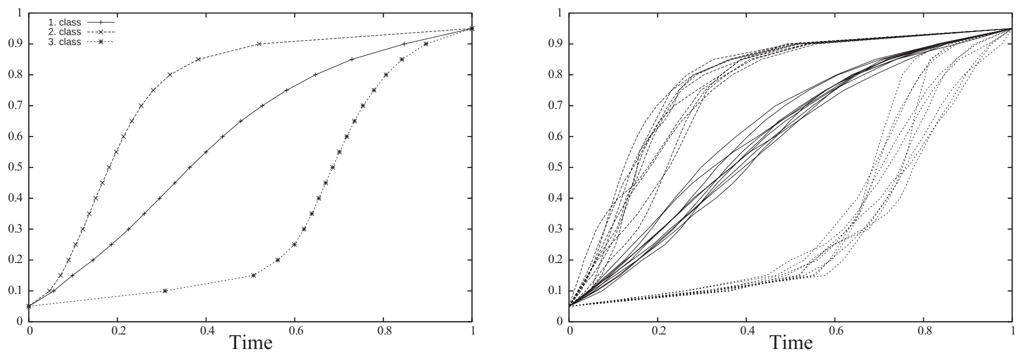

Fig. 3. – On the left side we displayed the cumulative light curve of the incoming photons, calculated from the cluster centers; on the right side 10 typical cumulative functions are selected from each class defined by the cluster analysis. (On the horizontal axis we displayed the relative time during the burst and on the vertical one the percentage of the detected photons.)

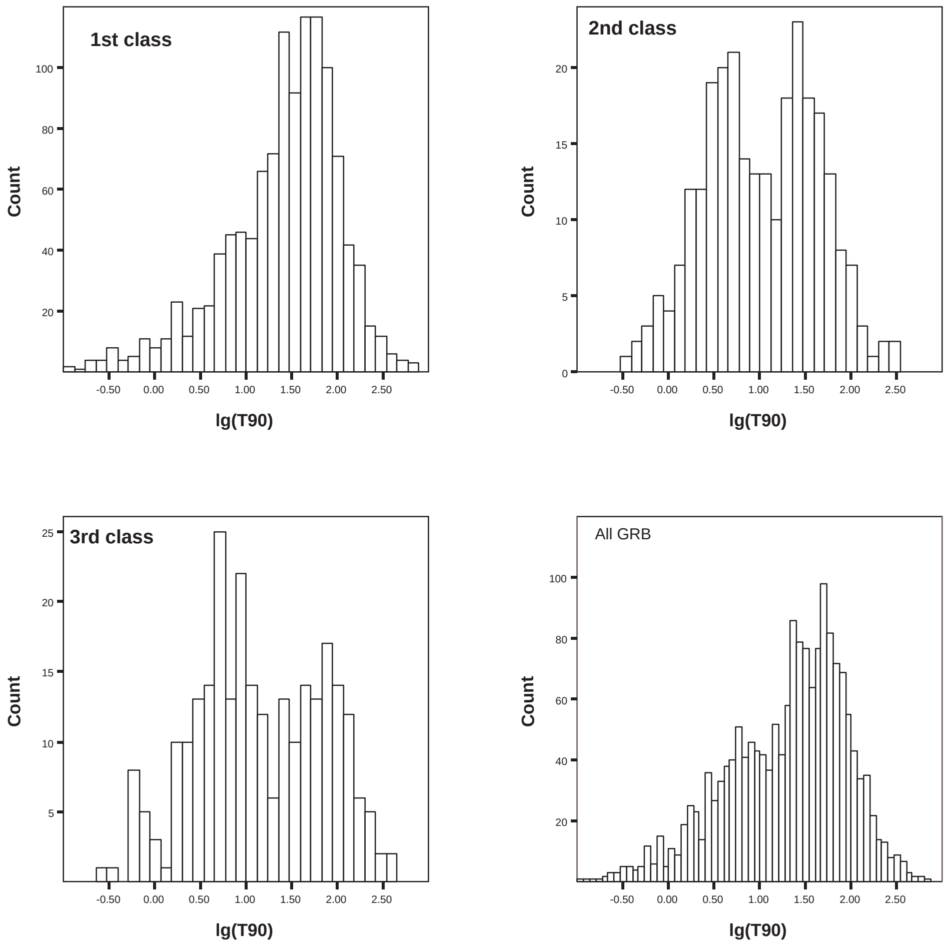

Fig. 4. – Histograms of logarithmic T_{90} durations. 1st class on the top left, 2nd class on the top right, 3rd class on the bottom left and the all GRB on the bottom right corner.

The K value is an input parameter of the algorithm. After making a vertical cut on the whole set of the cumulative light curves near the maximal separation we recognized three clumps so we accepted $K = 3$ (see fig. 1). This algorithm is sensitive to the initial setting of cluster centers, so we started the iteration from several different positions to make sure that the class centers obtained are stable. The 1st group contained 1174, the 2nd group 268, and 3rd group 266 bursts. This procedure also gave the Euclidean distances of each GRB from the center of the classes. In fig. 3 we displayed the cumulative light curves calculated from the coordinates of the cluster centers, along with 10 typical (the nearest ten to the center) cumulative curves from each classes. From our data set we easily calculated the light curves that we show in fig. 2. In this picture we can see that the classification of the bursts in this 18-dimensional space happens according to the distribution of arrival times of the photons. In the case of the first class the photons were distributed almost smoothly in the whole duration, in the second class most of the photons detected at the beginning of the burst, and in the third one at the end. After assigning the bursts to classes we compared the real light curves with those of the cluster centers, and we found them to be similar.

The next step was the analysis of the classes. We examined the distribution of the logarithmic T_{90} durations within each class, and found that the distributions in 3 different classes have different numbers of maxima, and have them at different durations. The first class, which is the most populated, and has got the smoothest cumulative function, has one maximum at 50 s, while the 2nd and 3rd groups have two maxima at 15 s, 5 s and 80 s and 5.6 s (the histograms can be seen in fig. 4). This is not obvious because the duration information was excluded from the data set, by normalization. We also calculated the average duration for each class. The first, second and third classes have 51.97 s, 25.15 s, 40.65 s average duration, respectively. This means that these three classes are different in the mean duration.

All of the results are available on the World Wide Web [17], specially the class membership of the analyzed GRBs.

3. – Conclusion

We calculated new T_{xx} quantiles of the cumulative GRB light curves. Making use the Quick cluster module of the SPSS statistical package we performed K-means clustering and identified 3 classes in our sample. The general form of the light curve differs between the classes. Comparing the frequency distribution of the newly determined T_{90} durations we recognized that the diagram of the 1st class peaks at long T_{90} value, the 2nd has two and the 3rd maybe three maxima. These new results may give a new insight into the physical classification of GRBs.

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REFERENCES

[1] Bagoly Z. *et al.*, *ApJ*, **498** (1998) 342.
[2] Bonnell J. T. *et al.*, *ApJ*, **490** (1997) 79.
[3] Hakkila J. *et al.*, *ApJ*, **538** (2000) 165.
[4] Horváth I., *ApJ*, **508** (1998) 757.
[5] Horváth I., *A&A*, **392** (2002) 791.
[6] Koshut T. M. *et al.*, *ApJ*, **463** (1996) 570.
[7] Meegan C. A. *et al.*, *Current BATSE Gamma-Ray Burst Catalog* (2001) http://www.batse.msfc.nasa.gov/data
[8] Mészáros A., Bagoly Z. and Vavrek R., *A&A*, **354** (2000) 1.
[9] Mészáros P., *Science*, **291** (2001) 79.
[10] Mukherjee *et al.*, *ApJ*, **508** (1998) 314.
[11] Press W. H. Flannery B. P. Teukolsky S. A. and Vetterling W. T., *Numerical Recipes* (Cambridge University Press, Cambridge) 1992.
[12] Ryde F. *et al.*, *A&A*, astro-ph/0411219(2005).
[13] Ryde F., *A&A*, **429** (2005) 869.
[14] SPSS for Windows, Rel. 11.0. 2001. Chicago: SPSS Inc.
[15] http://cossc.gsfc.nasa.gov/compton/data/batse/
[16] http://cossc.gsfc.nasa.gov/batse/batseburst
[17] http://ludens.elte.hu/~boss/grbindex.html