Observational differences between Swift GRB classes

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Abstract. There are accumulating evidences that GRBs have an intermediate group, beside the short and long classes. Based on the observational data available in the Swift table we compared the observational γ and X ray properties of GRBs making use the discriminant analysis of the multivariate mathematical statistics. The analysis resulted in two canonical discriminating functions giving the maximum separation between the groups. The first discriminating function is dominated by the γ and X-ray fluence while the second one is almost identical with the photon index.

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INTRODUCTION

Detection of observable differences between GRB classes is one of the major tasks of the Swift satellite. The burst alert given by the BAT on board of the satellite is followed by the XRT detection in the X-ray regime, a significant fraction of GRBs is observed in both energy ranges. Since the vast majority of the GRBs are detected by both of the BAT and XRT it is a reasonable question whether there are measurable differences in the gamma and /or X-ray properties between the bursts of different classes observed by the Swift satellite.

The Swift GRB Table at URL location[1] listed 549 GRB detections until writing the poster presented at the conference (Aug. 27, 2010). We excluded those cases where the slewing time of the satellite exceeded 300 sec.

In this work we use the γ and X-ray data measured by BAT and XRT: Fluence, 1-sec Peak Photon Flux, Photon index, Early X-Flux, Initial Temporal Decay Index, Spectral Index and HI Column Density (XNH). Following [1] (see also the poster at this conference) we formed three groups from these cases and compared them making use the discriminant analysis of the multivariate statistical analysis.

MATHEMATICAL SUMMARY

Discriminant analysis aims to make difference between groups in the multivariate parameter space, orders membership probabilities to the cases and one may use this scheme

[1] http://swift.gsfc.nasa.gov./docs/swift/archive/grb_table

for classifying additional ones not having assigned group memberships. We use this technique to look for differences in the distributions of GRBs, classified in the γ hardness duration plane [1] , in the parameter space defined by the BAT and XRT variables mentioned above

Let we have a set of p measured variables on n cases which are assigned to one of the k classes ($k = 3$ in our case). We look for linear combination of the $x_1, x_2, , x_p$ variables which give maximal separation between the groups of the cases. There are altogether $k-1$ discriminant variables. In our case we have three groups so we have two such variables. It means we are looking for the variables

$$y = n_1 x_1 + n_2 x_2 + \ldots + n_p x_p \qquad \textit{where} \qquad \sum_{j=1}^{p} n_j^2 = 1 \tag{1}$$

with a suitable chosen $n_1, n_2, \ldots, n_p$ coefficients ensuring a maximal separation between the two classes. There are several approaches to solve this problem (for more details see [2]). These are usually among the major ingredients of the professional statistical software packages. We used SPSS[2] in our computations.

DESCRIPTIVE STATISTICS OF THE DATA

We excluded those cases from our analysis when the slewing time was greater than 300 sec. With this choice we excluded the GRBs when the normal slewing of the satellite was blocked by some reason. Table 1 summarizes the means and standard deviations of the variables in the analysis.

In the table we listed all cases having measured values in all variables used in the analysis. We marked with bold face where the mean values differ significantly between the groups. We give the results of the test of significance in Table 2.

TEST OF SIGNIFICANCE

In Table 2 we compared the means of the variables in the analysis within the groups. Bold face marks where the differences in the group means are significant. F is the test variable denoting the ratio of the variances between and within the groups.

In our case we have three classes. The analysis calculated two variables (discriminating functions) to discriminate between our classes. The level of significance of this separation is given in Table 3.

CONCLUSIONS

We performed discriminant analysis in order to look for physical differences between GRB classes, detected by the Swift satellite. We used the following variables measured

[2] SPSS is a registered trademark (`http://www.spss.com`)

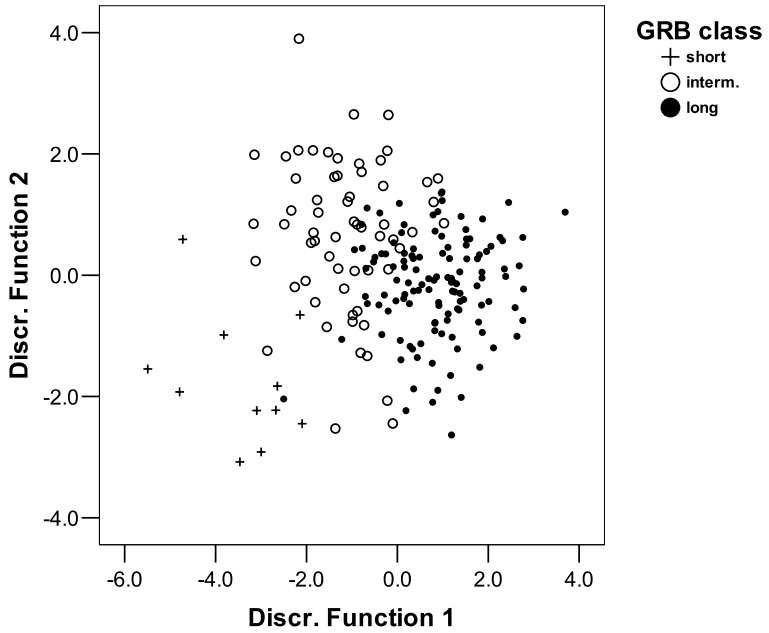

FIGURE 1. Scatter plot between the discriminant functions. Different symbols marks different classes. The $Function\,1$ is dominated by the γ and early $X-ray$ fluences while $Function\,2$ is almost identical with the γ photon index.

by BAT and XRT: Fluence, 1-sec Peak Photon Flux, Photon indes, Early X-Flux, Initial Temporal Decay Index, Spectral Index and Hydrogen Column Density (XNH).

The analysis demonstrated significant differences between the groups defined. The difference is significant at a high level. The difference is driven by two discriminant functions obtained in the analysis: Function 1 is dominated by the γ and $X-ray$ fluences and Function 2 is almost identical with the Photon index.

Our result indicates that the classification of GRBs in the hardness-duration plane has also a significant impact in other observed γ and $X-ray$ properties of these events.

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REFERENCES

1. Horváth, I, et al., 2010, *ApJ*, 713, 552
2. M.G. Kendall & A. Stuart, *The Advanced Theory of Statistics*, Charles Griffin & Co. Ltd., London & High Wycombe, 1973

TABLE 1. Means and standard deviations of the variables in the analysis (we marked with bold face where the mean values differ significantly between the groups).

class	Variable	Mean	Standard dev.	No of cas.
short	**Pind**	**1.02**	**.41**	**11**
	Xdec	1.79	1.82	11
	Xsp	2.24	2.61	11
	logFlu	**.07**	**.53**	**11**
	logP	.23	.48	11
	logXflu	**.29**	**1.47**	**11**
	logXNH	**-.05**	**.57**	**11**
Int.	**Pind**	**1.86**	**.49**	**61**
	Xdec	2.07	1.68	61
	Xsp	2.23	.75	61
	logFlu	**.62**	**.42**	**61**
	logP	.09	.40	61
	logXflu	**.59**	**1.01**	**61**
	logXNH	**.13**	**.55**	**61**
long	**Pind**	**1.50**	**.33**	**123**
	Xdec	2.24	1.53	123
	Xsp	1.95	.44	123
	logFlu	**1.36**	**.48**	**123**
	logP	.22	.49	123
	logXflu	**1.56**	**1.01**	**123**
	logXNH	**.35**	**.49**	**123**

TABLE 2. Test of significance of the differences in the mean values between the groups.

Variable	Wilks' λ	F value	df1	df2	Significance
Pind	**.765**	**29.420**	**2**	**192**	**.000**
Xdec	.994	.561	2	192	.571
Xsp	.970	2.957	2	192	.054
logFlu	**.554**	**77.440**	**2**	**192**	**.000**
logP	.983	1.691	2	192	.187
logXflu	**.817**	**21.495**	**2**	**192**	**.000**
logXNH	**.941**	**6.072**	**2**	**192**	**.003**

TABLE 3. Significance of the differences measured by the discriminant functions.

Test of Function	Wilks' λ	Chi-square	degree of freedom	Significance
1 through 2	.289	234.926	14	.000
2	.745	55.530	6	.000