Spectral Classification of Fermi GRBs

Racz I. I.[1], Balázs L. G.[1,2], Bagoly Z.[1], Horváth I.[3], Tóth L. V.[1,2]
[1]Eötvös University, [2]Konkoly Observatory, [3]National University of Public Service

Abstract

The recently published catalog of Gamma-ray bursts (GRBs) detected by GBM contains 1823 bursts. There are four types of spectra fitted to all of the recorded bursts: Band, Comptonian, power law and smoothly broken power law. The catalog also contains the best fitted spectra to all of the GRBs in it. Making use of the linear discriminant analysis (LDA) of the multivariate statistical analysis we studied the differences between the measured physical properties of the GRBs (Duration, Peak flux, Fluence). The LDA resulted in three canonical discriminant functions, two of them appeared to be statistically significant. There are statistically significant differences between the four spectral classes. The results are briefly discussed.

Mathematical summary

Linear discriminant analysis (LDA) finds axes (k − 1 canonical coordinates, k being the number of classes) that best separate the categories. These linear functions are uncorrelated and define, in effect, an optimal k − 1 space through the n-dimensional cloud of data that best separates (the projections in that space of) the k groups. We used the Linear Discriminant Analysis with Jackknifed Prediction from *'MASS'* package in R.

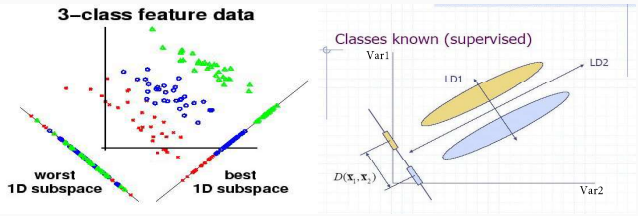

Fig. 1: It is the typically linear discriminate problem with more discriminators.

We calculated the significance with the Wilks's lambda parameters:

$$\chi^2 = -(n - \frac{p+g}{2} - 1) \cdot log(\prod_{j=1}^{m} \frac{1}{1+\lambda_j}) \quad (1)$$

,where n/p/g are the number of GRBs/variables/groups, and λ is the eigenvalue.

Results 1 – Discriminant functions

There are 4 spectral classes so it means 3 discriminant functions ('LD1', 'LD2', 'LD3'). The first linear discriminant explains the 96.56% of the between-group variance (the second is 2.46%, and the third is only 0.98%.)

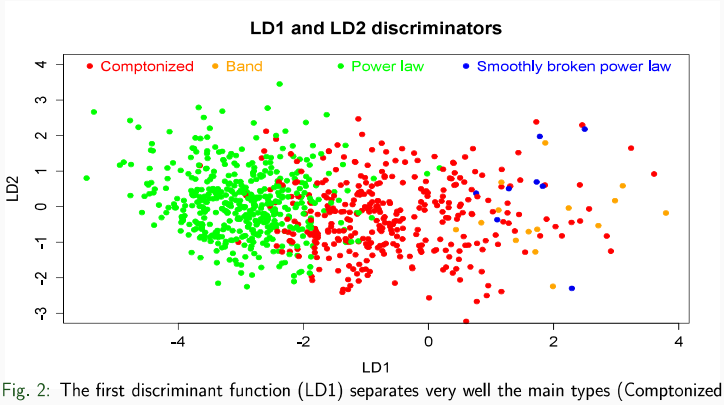

Fig. 2: The first discriminant function (LD1) separates very well the main types (Comptonized (red) and Power law (green) types). The second function discriminates much less than the LD1. Unfortunately these discriminators don't have effect on the other two spectral type sources so further studies are needed (with other parameters).

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Contact

Istvan I. Racz from Eötvös University, racz@complex.elte.hu

GRB data

The Fermi Gamma-ray Space Telescope (FGST) is a space observatory being used to perform gamma-ray astronomy observations from low Earth orbit since 2008. There are two instruments, the Large Area Telescope (LAT), and the Gamma-ray Burst Monitor (GBM). The GBM is being used to study gamma-ray bursts.
There is a big database from the Fermi GBM detectors which is called the FERMIGBRST catalog. In the database there are more than 1800 GRBs with lots of parameter, as position, ID, visual and spectral properties. These parameters were calculated from the light curves and spectral fitting.

Spectral classification

The spectra parameters were calculated by two timescales (from fluence and peak flux). We used the peak flux category. The GRBs were fitted with 4 types models and the "goodness-of-fit" values (reduced χ^2) were calculated.

- ⋆Power law ('plaw')
- ⋆Comptonized (exponentially attenuated power law; 'comp')
- ⋆Band ('band')
- ⋆Smoothly broken power law ('sbpl')

The reduced chi-squared statistic for the model was calculated on every GRBs fitting, which indicates the goodness of the fit. We used only 826 GRBs for the high confidence, where this number was smaller than the median of values.

Results 2 – Significance

The first function correlates the 1024ms flux (cor=0.992) and fluence (cor=0.72) but the LD2 is more complex where the strongest correlation is only -0.52 (low anti-correlate with the fluence).

Table 1: The structure matrix show the discriminator correlation with the variable.

Variable	LD1	LD2	LD3
T50	0.075	-0.428	**-0.323**
T90	0.128	-0.394	**-0.292**
fluence	0.721	**-0.515**	-0.256
fluence(like Batse)	0.705	**-0.518**	-0.233
flux(256 ms)	**0.917**	0.187	-0.113
flux(1024 ms like Batse)	**0.992**	-0.136	0.205

We have calculated the Wilks lambda parameter from which we have said the significance. The first function is very significant (maybe also the LD2) based on the Wilks lambda parameter, p-value:

- ⋆LD1: practically zero, so very significant
- ⋆LD2: 0.06, not too high significance

Conclusions

GRBs from the Fermi GBM database were classified in the 4 types. We examined the groups with Linear Discriminant Analysis.

- ▶ There are differences in some physical parameters of GRBs between the different spectral types
- ▶ We calculated the 3 discriminant function based on GRBs spectral types from the Fermi GBM database
- ▶ The first discriminant function is explained by mostly the flux
- ▶ Only the first and second functions are significant

References

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