The diversity of GRBs statistically (is there a third group? physical meaning? relation to XRFs?)

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Abstract The separation of gamma-ray bursts (GRBs) into short/hard and long/soft subclasses, respectively, is today well supported. Since 1998 there are several statistical tests suggesting the existence of more than two subgroups. The author with other collaborators provided several statistical studies in this topic. The references concerning this GRB diversity are briefly surveyed in this contribution.

Keywords: Gamma-Ray Burst, Statistics

1. Separation into two subgroups

After the discovery of gamma-ray bursts (GRBs) (Klebesadel et al. 1973) Mazets et al. (1981) have shown that there are two types of GRBs. This separation of GRBs into short/hard and long/soft subgroups was then confirmed by several other studies (for a survey see, e.g., Mészáros (2006)). The limiting duration is around ≃2 sec.

2. The third subgroup?

In 1998 two articles declared simultaneously the existence of a third subgroup (Mukherjee et al. 1998, Horváth 1998). This claim came from the statistical studies of the dataset of BATSE instrument being on the Compton Gamma Ray Burst Observatory[f]. Since that time several other papers confirmed the same result for the BATSE dataset (Horváth 2002, Hakkila et al. 2003, Hakkila et al. 2004, Horváth et al. 2006). This third subgroup should have an intermediate duration (between ≃2 and 10 seconds). This means that in essence the earlier long subgroup should further be separated.

The subgroup was found also in the Swift dataset[g] (Veres et al. 2010). For the RHESSI[h] satellite the existence of the third subgroup was also found (Řípa et al. 2012). On the other hand, no intermediate subgroup was found in the Fermi's[i] observations (Tarnopolski 2015).

[f] https://heasarc.gsfc.nasa.gov/docs/cgro/index.html

[g] https://swift.gsfc.nasa.gov

[h] https://hesperia.gsfc.nasa.gov/rhessi3

[i] https://fermi.gsfc.nasa.gov

Similarly, no third subgroup is declared to exist in the Konus/WIND[j] catalog (Tsvetkova et al. 2017).

It must be added that even in the case, when the three subgroups are found by statistical tests, it is not sure that there are really three astrophysically different phenomena, because different biases, selection effects, etc. can play a role (Hakkila et al. 2003, Tarnopolski 2016). For example, in the Swift database the third group is found by tests, but a more detailed study shows that the third group is given by the so-called X-Ray Flashes (XRFs) - which are in essence long GRBs (Veres et al. 2010). But, on the other hand, in some cases it is claimed that the third subgroup cannot entirely be given by the long GRBs. For example, for the BATSE and mainly for the RHESSI database, the identification of the intermediate GRBs with XRFs cannot be done (Řípa & Mészáros 2016).

3. Further subgroups?

There are studies claiming the existence of other subgroups - being not identical - to the intermediate one.

In the BATSE database there were hints for the separation of the long GRBs themselves into the harder and softer parts (Pendleton et al. 1997).

The longest GRBs can also form an extra - ultra-long - subgroup (Tikhomirova & Stern 2005, Virgili et al. 2013, Levan et al. 2014). Because there are only few GRBs in this ultra-long subgroup, from the statistical point of view this subgroup hardly can be declared as an astrophysically different phenomenon - for example, they can simply be outliers.

Recently, in the Fermi database five subgroups were found (Acuner & Ryde 2018). Theoretically, it is meant that even seven different subgroups should exist (Ruffini et al. 2018). This paper means that the long subgroup should further be separated.

It is already possible to study the diversity of GRBs also from other intrinsic quantities for the limited sample, when the redshifts are known. This follows from the fact that the intrinsic luminosity (L_{iso}) and the intrinsic total emitted energy (E_{iso}) can be calculated for a given GRB, if its redshift is known. Such a probe is provided by (Levan et al. 2014) on the duration vs. L_{iso} (E_{iso}, respectively) plane. In Fig.2 of Levan et al. (2014) such effort is done. Several possible subgroups are seen beyond the long and short GRBs (soft gamma repeaters, low luminosity long GRBs, ultra-long GRBs, tidal disruption events, etc.). On the other hand, there is no intermediate subgroup.

4. Conclusion

There are known several statistical tests, theories, ideas, modeling, etc... about the further subgroups beyond the well confirmed short/hard and long/soft subclasses. A brief - never complete - survey was provided here. Summing these works it can be said that mainly the long/soft subgroup does not seem to be a unique one single subclass. But, on the other hand, any astrophysically different phenomenon - beyond the two (short/hard and long/soft) types - is further in doubt, because both the intermediate subgroup and the possible subgroup of the low-luminosity long GRBs are not proven yet unambiguously. In addition, any eventual further subgroups are also in doubt, because they are low populated.

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[j] http://www.ioffe.ru/LEA/kw/

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