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Gamma-ray bursts in the early Universe

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Abstract. The long gamma-ray bursts are at high redshifts, and they trace the star-formation rate. Hence, they may well serve as milestones in the early Universe.

Keywords. gamma rays: bursts, stars: Wolf-Rayet, supernovae: general, cosmology: early universe

1. Introduction

There are three subgroups of the gamma-ray bursts (GRBs) separable with respect to the duration and hardness (analogy of the color in the gamma band). The three subgroups of GRBs (see Figure 1) were confirmed in the databases of different satellites: Compton (BATSE) – Horváth (1998), Horváth (2002), Horváth *et al.* (2006); Swift – Horváth *et al.* (2008), Huja *et al.* (2009); RHESSI – Řípa *et al.* (2009); BeppoSAX – Horváth (2009); for more aspects about the subgroups of GRBs see also Gehrels *et al.* (2006).

2. Overview

Short GRBs give the fraction of $\sim (10-20)\%$ of the detected GRBs, and on the sky they are distributed anisotropically (Vavrek *et al.* 2008). Intermediate GRBs form

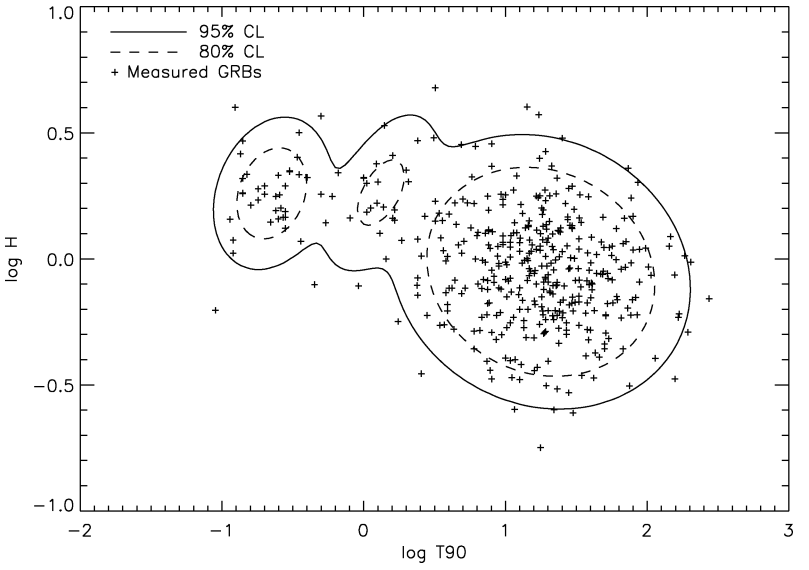

Figure 1. On the figure the RHESSI's GRBs are separated into three subgroups with respect to the duration T90 and hardness H (T90 is in seconds, CL means confidence level, H is dimensionless).

a fraction of $\sim 10\%$ of the detected GRBs. On the sky they are also distributed anisotropically (Mészáros A. *et al.* 2000). The redshifts are not clarified yet for the intermediate subgroup. The short GRBs should be till redshift ~ 1 challenging the cosmological principle due to their anisotropic distribution (Mészáros A. *et al.* 2009).

The long GRBs give the majority ($\sim (60 - 80)\%$) of the observed GRBs. Contrary to the remaining two subgroups, they seem to be distributed isotropically on the sky (Vavrek *et al.* 2008). They are strongly related to Type Ic supernovae and to the Wolf-Rayet stars (Mészáros P. 2006). They can be at very high redshifts (up to redshift 8.2) (Bagoly *et al.* 2006, Krimm *et al.* 2009).

3. Long GRBs, star-formation rate and the impact on the first stars

The redshift distribution of the long GRBs follows the star-formation rate (Mészáros A. *et al.* 2006, Le & Dermer 2007). This result has an interesting impact on the cosmology: Because the long bursts are coupled to supernovae (hence, to massive stars), and the long bursts are at very high redshifts, the long GRBs support observationally the existence of the stars at very high redshifts (up to ~ 8). Hence, they may well serve as milestones in the early Universe.

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