IMPACT ON COSMOLOGY OF THE CELESTIAL ANISOTROPY
OF THE SHORT GAMMA-RAY BURSTS

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Abstract. Recently the anisotropy of the short gamma-ray bursts detected by BATSE was announced (Vavrek et al. 2008). The impact of this discovery on cosmology is discussed. It is shown that the anisotropy found may cause the breakdown of the cosmological principle.

Key words: cosmology gamma-rays: bursts

1. INTRODUCTION

Several statistical studies show that there are short, intermediate and long gamma-ray bursts (GRBs) (Horváth 1998, 2002, 2009; Mukherjee et al. 1998; Hakkila et al. 2000, 2004; Horváth et al. 2002, 2004, 2008; Balázs et al. 2004; Gehrels et al. 2006; Rípa et al. 2009; Huja et al. 2009). The names of groups follow from the facts that they can be separated mainly with respect to their durations. The short and long GRBs are associated with different objects (Balázs et al. 2003; Nakar 2007) but the interpretation of the intermediate GRBs is still unknown (Horváth et al. 2008).

The sky distributions of GRBs of different durations are shown in Figure 1. The short GRBs, collected in the BATSE catalog (Mallozzi et al. 2001), are distributed anisotropically. The sky distribution of the intermediate GRBs is also anisotropic. No obvious anisotropy was found for the long bursts - hence they can be distributed isotropically (Vavrek et al. 2008).

In this paper we discuss cosmological consequences of anisotropic distributions. Obviously, once the cosmological principle is fulfilled, i.e., the mass distribution in the Universe is homogeneous and isotropic on a large scale (Peebles 1993), then isotropical distribution of GRBs is expected. This seems to be valid for the long GRBs, but not for the remaining two types. This may mean that in the range of redshifts, where these two types of GRBs happen, the cosmological principle is not valid. In this paper we try to verify this possibility by estimating redshifts of the short GRBs from the BATSE catalog. The redshifts of the intermediate bursts
2. REDSHIFTS OF THE SWIFT SHORT BURSTS

No directly measured redshifts are known for the BATSE short bursts. Therefore we will try to estimate the range of their redshifts indirectly, comparing them with known redshifts of short bursts from the Swift database. Short GRBs from BATSE will be discussed in the next section.

In the Swift database till 2009 February 28 there were 133 GRBs with known redshifts (Gehrels et al. 2009). Among them we find only nine (Table 1) which are considered as short by Zhang et al. (2009) and for which the measured $T_{90}$ values (in seconds) are not higher than $2(1 + z)$ ($z$ is the redshift).

Note that there is a controversy concerning GRB080913 with $z = 6.7$. It has $T_{90} = 8$ s, and thus it can still be a short burst, because its intrinsic duration is smaller than 2 s. According to Zhang et al. (2009) this GRB probably is not a short burst, although such a possibility is not excluded. We decided not to include GRB 080913 in the list of short GRBs.

The mean of the redshifts of GRBs from Table 1 is $\mu_z = 0.62$, the dispersion is $\sigma_z = 0.49$, and the median is $z = 0.46$. The redshifts cover the interval between 0.11 and 1.8.

3. THE REDSHIFTS OF BATSE’S SHORT BURSTS

The short GRBs with known redshifts detected by Swift and the short GRBs
Table 1: Short GRBs from Swift with known redshifts.

| GRB name | Redshift | $T_{90}$ | Fluence | Peak-flux |
|----------|----------|----------|---------|-----------|
| 050509B  | 0.22     | 0.073    | 0.09    | 0.28      |
| 050813   | 1.80     | 0.44     | 0.44    | 0.94      |
| 051221A  | 0.55     | 1.4      | 11.5    | 12.0      |
| 060502B  | 0.29     | 0.13     | 0.4     | 0.62      |
| 061201   | 0.11     | 0.76     | 3.34    | 3.86      |
| 061217   | 0.87     | 0.212    | 0.42    | 1.49      |
| 070429B  | 0.90     | 0.47     | 0.63    | 1.76      |
| 070724A  | 0.46     | 0.4      | 0.3     | 1.0       |
| 071227   | 0.38     | 1.8      | 2.2     | 1.6       |

from the BATSE catalog (Mallozzi et al. 2001) are not necessary located in the same redshift range. For example, due to some selection effects (the Swift data and the BATSE data were obtained by different instruments), we cannot exclude the possibility that the short GRBs in the BATSE sample are predominantly at $z < 0.1$. If this were the case, then their anisotropy would be expected, because in the Universe bold inhomogeneities are observed up to $z = 0.1$ (Peebles 1993).

A comparison of the GRBs from Table 1, and the 406 short GRBs from the BATSE catalog shows that this is not the case. Balázs et al. (2003) have shown that the mean fluence of the BATSE sample is $5 \times 10^{-7}$ erg/cm$^2$ with a dispersion as large as $\sim 50\%$. Table 1 shows that the mean fluence of the Swift sample is $2.1 \times 10^{-7}$ erg/cm$^2$, again with a large $\sim 100\%$ dispersion. The two fluences are in a good agreement. The mean peak-flux for the BATSE sample is 3 photons/(cm$^2$s) (Balázs et al. 2003) and for the Swift sample from Table 1 it is 2.4 photons/(cm$^2$s). Bearing in mind that in both cases the dispersions are large ($\sim (50 - 100\%)$, the peak fluxes are also in good agreement. All this suggests that the redshifts of short GRBs collected both from the BATSE and Swift catalogs are mostly between 0.1 and 0.9.

Two notes are essential here. First, Nakar (2007) considers that the short/hard GRBs should be formed in the mentioned redshift range. Second, we cannot exclude that among the short GRBs even higher redshifts ($z > 1$) can be present, if GRB080913 belongs to the short GRBs (Zhang et al. 2009). Even GRB090423 with the highest known redshift ($z = 8.2$) can happen to belong to this type (Krimm et al. 2009).

4. CONCLUSION

The cosmological principle requires that the Universe must be spatially homogeneous and isotropic on the scales larger than the size of any structure (void, filament, supercluster, etc.). In other words, the scale of averaging must be higher than the size of any structure. But, at the same time, the averaging scale must be smaller than the Hubble radius (Peebles 1993). Most of the short GRBs which are distributed anisotropically are at redshifts up to 0.9. The proper-motion distance (Weinberg 1972) corresponding to $z = 0.9$ is 3 Gpc for the Hubble radius 14
Gpc. The proper motion distance \( d_{PM} \) is defined as
\[
d_{PM} = d_{LM} / (1 + z),
\]
where \( d_{LM} \) is the luminosity distance (Weinberg 1972). All distances here are taken as proper-motion distances for the most probable cosmological parameters
\[
H_o = 71 \text{ km/(s} \times \text{Mpc) ,}\quad \Omega_M = 0.27 \quad \Omega_\Lambda = \lambda c^2 / (3H_o^2) = 0.73; \quad H_o \text{ is the Hubble-constant,}
\]
\( \lambda \) is the cosmological constant, \( c \) is the velocity of light in vacuum, and \( \Omega_M \) is the ratio of density of the Universe to the critical density (Wright 2009).

Thus, the short GRBs suggest the presence of structures of the Gpc scales. This is a great challenge to cosmology, because a scale of averaging between 3 and 14 Gpc should be present; in principle, this is still possible, but obviously complicated enough. If there are short GRBs also at \( z > 0.9 \), then any averaging is already impossible, because the corresponding proper-motion distance for \( z = 8.2 \) is 9.2 Gpc; i.e. \( \simeq 66\% \) of the Hubble radius.

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