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On the origin of the dark gamma-ray bursts(*)

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Summary. — The origin of dark bursts—*i.e.* that have no observed afterglows in X-ray, optical/NIR and radio ranges—is unclear yet. Different possibilities—instrumental biases, very high redshifts, extinction in the host galaxies—are discussed and shown to be important. On the other hand, the dark bursts should not form a new subgroup of long gamma-ray bursts themselves.

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1. – Introduction

In Jochen Greiner's list [1], up to June 30, 2004, there were collected 222 gamma-ray bursts (GRBs). Only 71 objects (*i.e.* roughly the one-third fraction) have observed afterglows (AGs) at lower energies. In the following, the remaining two-thirds are defined as the fraction of the dark bursts. (Note that there is no unambigous definition of the dark burst itself, and usually only that GRBs are dark, which have no optical AGs [2]. For our purpose the best definition is to take a GRB dark when there is no observed AG (regardless in which band) and also no redshift is measured.)

In accordance with [3] there can exist four possible explanations for this phenomenon:

I. the observational biases play a role;

II. a large fraction of bursts is at high redshifts;

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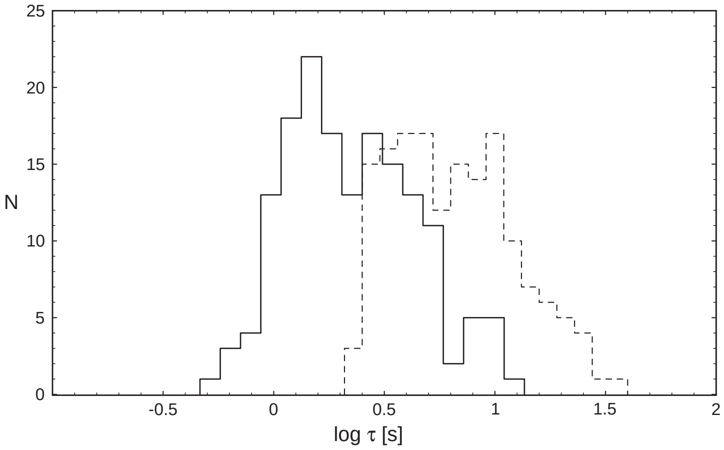

Fig. 1. – Distribution of the autocorrelation function widths τ (for more details see [7]) for 160 GRBs. The redshifts were based on [8]. The logarithmic histograms of the widths are corrected (solid line) or not corrected (dashed line) for the cosmological time dilation. In both cases the distributions seem to be unimodal, in contradiction with [7].

III. a large fraction of bursts is obscured by the interstellar matter in host galaxies;

IV. the darkness is intrinsic and some bursts really have no AGs.

Obviously, if only the first three possibilities were occurring, then any GRB would still have AG; *i.e.* for any GRB the AG would exist, but simply would not be detected. On the other hand, if the fourth possibility is also occurring, then there would be a special subclass of long GRBs having no AG. The study of GRB 000330 [3] has shown that all four eventualities were possible. References [4] and [5] give maximally a $\simeq$ (10–30) fraction for the fourth explanation.

Our aim in this article is to search for more concrete conclusions concerning these four possibilities.

It is well-known that there are short and long bursts; probably also intermediate ones (see [6] and the references therein). Here we discuss only long GRBs, because all GRBs in Greiner's list should belong to this subclass. This also means that—if possibility IV were occurring—then the long subclass would be separated and there would be—in total—4 subclasses of GRBs. The most recent support for this separation of the long subgroup itself comes from [7]. Nevertheless, repeating the same procedure with the gamma photometric redshifts of [8], we obtain no evident separation (fig. 1). In this article we will give further arguments against the subclass separation of long GRBs.

2. – The method

We will discuss the possibilities I-III. Let us assume that all long GRBs have AGs, and the fourth possibility is incorrect. If this is the case, then biases, GRBs at high redshifts, and absorption at the hosts must be, together, so effective that the two-third fraction of GRBs must remain unseen due to these effects. We will show by statistical arguments that really such great amount of AGs may remain unseen by these effects. Then, simply, the fourth possibility is not needed.

TABLE I. – *The redshifts (z) and peak-fluxes (P_{256}) of GRBs that have both BATSE triggers and measured spectroscopic redshifts. The values are compiled after* [7] *using the Current BATSE Catalog* [10].

Burst	BATSE trigger	z	P_{256} ph/(cm^{2}s)	Remark
970508	6225	0.835	1.17	
970828	6350	0.9587	–	no P_{256} value
971214	6533	3.4127	2.32	
980329	6665	3.97	13.28	z upper limit only
980425	6707	0.0085	1.08	SN1998bw
980703	6891	0.966	2.59	
990123	7343	1.60	16.63	
990506	7549	1.3066	22.16	
990510	7560	1.619	10.20	
991216	7906	1.020	15.17	
000131	7975	4.5	–	no P_{256} value

The observed dark–non-dark separation is in the ratio $\sim 2:1$ at most. It is practically sure that some GRBs will have AGs, but these AGs remain unseen. As is shown by [9], there is a selection effect leading to the result that bright GRBs have more effectively observed AGs. This observational bias can be called a "brightness bias". Hence, there can be, in principle, three types of long GRBs: GRBs having observed AGs (non-dark GRBs) & GRBs having AGs, but they remain unseen due to this bias ("observationally dark" GRBs) & GRBs having no AGs ("intrinsically dark" GRBs).

What is the ratio of the second type GRBs to the first type? It is sure that this ratio is non-zero, because both non-dark GRBs and observationally dark GRBs exist [9]. To answer this question consider the GRBs—observed by BATSE [10]—which have measured redshifts (either concrete redshifts or at least upper limits) from the AG observations. In table I these GRBs are listed using [7]. It is immediately remarkable that the P_{256}'s are unusually high. For example, 5 GRBs have $P_{256} > 10\,\mathrm{ph/(cm^2s)}$ among the 9 P_{256} values. On the other hand, in the BATSE Catalog for $T_{90} > 10\,\mathrm{s}$ only 9% of GRBs fulfil the condition $P_{256} > 10\,\mathrm{ph/(cm^2s)}$. In [9] it is shown that this is *not* chance: the brighter GRBs in gamma-ray range can be observed more easily at lower energies.

In the BATSE Catalog 9% of long GRBs are brighter than $10\,\mathrm{ph/(cm^2s)}$ in the P_{256} peak-flux. Hence, if there were no observational biases, and if all GRBs were followed by AGs, one would detect roughly 10 times more AGs for GRBs with peak-flux below $10\,\mathrm{ph/(cm^2s)}$ than above this level. Because we observe 5 AGs above the peak-flux level, we should see a further ~ 50 AGs below this $P_{256} = 10\,\mathrm{ph/(cm^2s)}$ limit. Instead of 50 GRBs, 4 ones have been detected. Instead of the 9 GRBs collected in table I we should have $\simeq 55$ GRBs in the same table. Because the brightness bias exists, $[(55-9)/55] \times 100 = 84\%$ of GRBs should have unseen AGs. Hence, the brightness bias alone is able to explain even a ratio $55:9 \simeq 6:1$ for the observationally dark–non-dark population. This is much bigger than the observed $\simeq 2:1$ ratio.

Of course, there is a great uncertainty concerning the obtained $\simeq 6:1$ ratio, because of the extrapolation of a property, obtained from a sample containing 9 objects to a sample for 211 objects. Also the cut at $P_{256} = 10\,\mathrm{ph/(cm^2s)}$ is *ad hoc*. In addition, the newer instruments (BeppoSAX, HETE2, INTEGRAL) have different thresholds in the gamma-ray band than that of BATSE. Nevertheless, keeping all this in mind, we stress that the brightness bias is so strong that even alone it is able to explain the fact that the two-third fraction of long GRBs have existing but unseen AGs.

3. – GRBs at very high redshifts and the extinction

Several papers ([8], [11]– [16]) estimate that a few tens of % of GRBs are at $5 < z < 20$, where z is the redshift. In [17] it is claimed that even the majority of GRBs are at $z > 10$. It is already an observational evidence (see [18] for more details and references therein) that some dark GRBs are dark due to the extinction at the hosts. Trivially, the existing population of GRBs at very high redshifts together with the confirmed extinction strengthen the fraction of the observationally dark GRBs.

4. – Conclusion

The three effects I-III together may well cause that GRBs, detected only in gamma-ray band but having existing unseen AGs, may have a six or more times bigger population than that of GRBs with seen AGs. Hence, dark GRBs in Greiner's list may well be explained by these three instrumental effects alone, and there is no need to introduce any intrinsically dark subgroup of long GRBs without AGs.

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