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SN/GRB connection: A statistical approach with BATSE and Asiago Catalogues(*)

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Summary. — Recent observations suggest that some types of GRB are physically connected with SNe of type Ib/c. However, it has been pointed out by several authors that some GRBs could be associated also with other types of core-collapse SNe (type IIdw/IIn). On the basis of a comphrensive statistical study, which has made use of the BATSE and Asiago catalogues, we have found that: *i)* the temporal and spacial distribution of SNe-Ib/c is marginally correlated with that of the BATSE GRBs; ii) we do not confirm the existence of an association between GRBs and SNe-IIdw/IIn.

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1. – Introduction:

The association between Supernovae of type Ib/c (SNe-Ib/c) and long duration GRBs has been firmly established only in a few cases (see [2] for a review). However, there have been claims, based on spatial and temporal SN-GRB coincidencies, that also some other types of core-collapse SNe, the so called SNe-IIdw (see [6] for a review) might be associated with GRBs [5, 9, 8]. To test this idea we have correlated the GRBs from BATSE catalogue (2702 GRBs from April 1991 to May 2000) with SNe of the Asiago catalogue detected in the same period of BATSE (736 SNe).

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TABLE I. – a*: The number and the frequency for each type of SN, by correlating Asiago and BATSE catalogues (see text) In the sample of SNe we ignored the association (SN1998bw-GRB980425);* b*: The number and frequency for each type of SN included in the Asiago catalogue in the temporal window of BATSE (1991-2000).*

SNe	Ia	II	IIb	IIn	Ibc	Tot.
N(a)	15	12	0	3	6	36
%	41.7	33.3	0	8.3	16.6	100

SNe	Ia	II	IIb	IIn	Ibc	Tot.
N(b)	448	202	4	38	44	736
%	60.9	27.4	0.5	5.2	6.0	100

2. – Correlation between Asiago SNe and BATSE GRBs catalogues.

We selected all pairs GRB-SN from the BATSE and Asiago catalogues that match the following spatial and temporal requirements:

– all SNe falling within one sigma error radii of BATSE error-boxes increased with the sistematic error of the BATSE instrument of 1.85 degrees [1]. This choice is motivated by the fact that the typical size of the error box associated with GRBs, varies from 0.5 to several degrees, which is much larger than the 'average' error box ($\sim$ a few arcsec) associated with SNe of the Asiago archive.

– we assumed, on the basis of the SN/GRB associations so far discovered, that SNe and GRBs go off simultaneously. Thus the temporal window is set by the lenght of the rising time of the SN from the epoch of the explosion to maximum light. This parameter is not well known, however we can assume, on the basis of SN 1998bw, $T_{rise} \sim 15$ days. Given the uncertainty affecting the epoch of the SN maximum light, we assume $T_{rise} \pm 11$ days.

3. – Preliminary analysis

In table Ia, we report, for each SN type, the number (N(a)) and the fraction (%) of GRB-SN pairs, obtained by searching for each GRB error-box, the SNe possibly exploded in that error-box, with maximum light at $15^d \pm 11^d$ afther GRB occurence.

These figures have to be compared with the analogous entries in table Ib, where we report, for each type of SN, the number (N(b)) and the fraction (%) of SNe included in the Asiago catalogue. If SNe and GRBs are not physically connected, the temporal constraints will not introduce any bias in forming SN/GRB pairs. In other words, one should expect to find similar or lower frequencies of SNe in table Ia and in table Ib. This is certainly the case for type Ia, normal II, IIb, IIn, whereas for type Ib/c the pairs frequency is about three times as much as expected, after assuming the pair frequency due to random coincidences. Simple applications of Poissonian statistic in regime of small numbers ([4]) suggest a significance of the order of $\sim 93\%$. Note that we did not include in our analysis SN 1998bw.

Afterwards we have repeated the cross-correlation by varying the time windows (*i.e.* $T_{rise} \pm \Delta T/2$; with $\Delta T = 22, 30 \ldots$ days) and computed the statistical significance, of

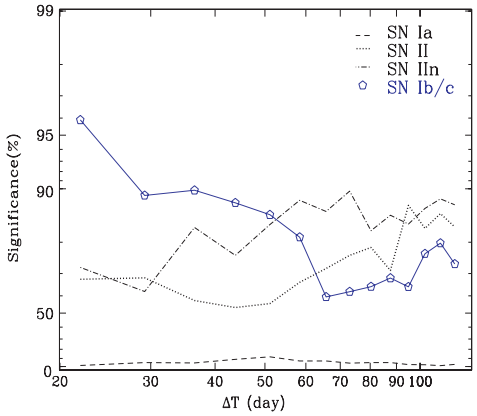

Fig. 1. – Statistical significance of the frequencies of occurence of the pairs SN/GRB, for different classes of SNe, as a function of the Temporal Window ($= T_{rise} \pm \Delta T/2$).

the number of pairs obtained after each run, with a Montecarlo simulation. For the result of this simulation, see the Discussion.

4. – The Monte Carlo simulations

We built up 1000 Simulated Samples of SNe (SS) by keeping the SN positions in the sky (according to the SN catalogue) and changing randomly the SN types. We have repeated this procedure for 14 temporal windows and we have computed the probability to obtain, by chance, the distributions of the SN-GRB pairs actually observed. The results are shown in fig. 1.

5. – Discussion

We can summarize our results as follows:

1) None of the trends shown in fig. 1 is statistically significant with the possible exception of SNe-Ib/c for which, in correspondence of a temporal window 26–4 days before maximum ($\Delta T = 22$, the first point of the figure), the frequency of Ib/c obtained with the Asiago and BATSE archive is significant at the level of 96%, consistently with our preliminary analysis (see sect. 3). Our findings confirm the results of [10] and

TABLE II. – *The 6 pairs SN-GRB, with the SN Ib-c, selected with the described method.*

SN	Type SN	Epoch SN	redshift SN	GRB	Epoch GRB	ErrorBox GRB	Type GRB
1993R	Ic	1993.41	0.0055	930524	17h44m52s	18.0	short
1996bx	Ic	1996.88	0.062	961029	06h34m37s	3.3	long
1997B	Ic	1997.03	0.01	961218	19h35m31s	12.7	long
1997dq	Hyp	1997.83	0.0032	971013	08h43m23s	8.8	long
1999dn	Ib-c	1999.62	0.0094	990810	07h24m53s	4.4	short
1999ex	Ib-c	1999.85	0.0114	991021	01h58m41s	12.3	unknown

disagree with the conclusions of [7] (both works have used smaller samples of GRBs and SNe).

2) The other types of SNe do not show any physical connection with GRBs. In particular we do not find any evidence for the existence of a physical association between GRBs and SN-IIdw as proposed on the basis of spatial and temporal coincidencies for GRB 970514/SN 1997cy ([5, 9]) and GRB 980910/SN 1999E ([8]). Our results suggest that SNe-IIdw are not the major class of progenitors for GRBs, although one can not exclude that sporadically SNII-dw are able to produce GRBs (see for example [3]).

3) Since most SNe listed in the Asiago catalogue have been discovered within $z < 0.1$ our results apply only to SN/GRB associations which occur in the "local" universe.

4) A remarkable result of this statistical approach is to obtain a restricted sample of SN/GRB associations (see table II) worth being further investigated.

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