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# SEARCH FOR CORRELATION OF GAMMA RAY BURSTS WITH GRAVITATIONAL WAVE DATA

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**Abstract**

The first extensive search for time correlation between gamma ray bursts (GRB) and the data recorded with resonant gravitational wave (GW) antennas is presented and discussed. The "average" algorithm is applied to the GW data obtained in correspondence of a time window of $\pm$ 20 minutes centered at the GRB trigger time. No significant effect is found at a level of GW bursts with amplitude $h \approx 2 \cdot 10^{-19}$.



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## 1 Introduction

One of the most important astrophysical phenomena still lacking an explanation, although it has been well known to the scientific community for many years, is the occurrence of powerful gamma-ray bursts, lasting several seconds, observed near the Earth with spacecraft [7]. One intriguing fact is that their angular distribution is uniform over the entire sky [14]. This suggests that the sources are located very far from Earth, outside the Galaxy consequently the sources must be extremely powerful, but no convincing model has yet been proposed. The idea that the sources are very far was recently supported by observations with the Beppo SAX satellite [5,6,8]. It observed the X-ray counterparts of some gamma bursts, confirming the importance of carrying on experimental observations with different instrumentation. Other data analysis [4] support, however, the idea that the sources are within our Galaxy. It is plausible that the phenomena responsible for this gamma emission is due to collapsed objects, perhaps the coalescence of compact binary systems. If so, the gamma bursts should be associated with the emission of gravitational waves (GW). Possible scenarios have been conceived [15], most of them suggesting GW fluxes below the sensitivity of the presently operating GW detectors. For example, if the source is assumed to be at a distance of 1 *Gpc*, the GW burst-flux associated with a total conversion into GW of 1 solar mass has amplitude of the order of $h \approx 3 \cdot 10^{-22}$, whilst the present sensitivity of the best GW antennas is $h \approx 6 \cdot 10^{-19}$. However, due the complete novelty of this phenomenon we consider it worthwhile to explore whether a correlation between the gamma bursts and data collected with the GW detectors exists. The search for a possible correlation of the GW data with gamma bursts has been greatly stimulated by the availability of the $GRB_s$ list of gamma events [9]. Here we shall present our initial results obtained from correlating the GRB events with the data of the GW detectors Explorer and Nautilus of the Rome group, using the "average" algorithm described in [11].

## 2 The $GRB_s$ events

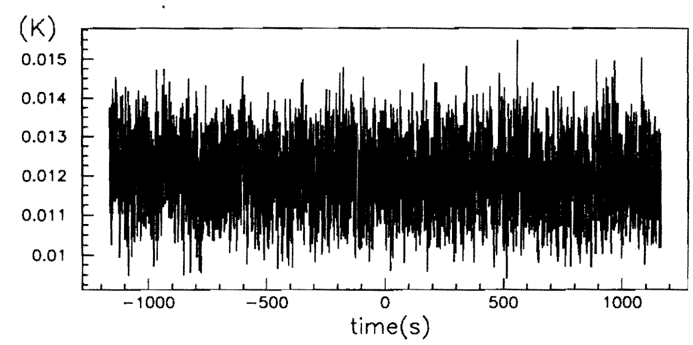
The BATSE database lists nearly 2000 GRB events from April '91 through October '97 [9]. We refer to the Basic list containing the time in decimal seconds of day (UT) of the trigger, and the coordinates of the sources. The burst trigger time could be at the end of three different intervals (64 $ms$, 256 $ms$, 1024 $ms$). The rate of the events is almost daily and they are distributed isotropically over the sky. In this initial analysis we limited ourselves to consider only the time parameter. Future analyses will also consider the burst duration, shape and intensity.

## 3 The GW data

The antenna Explorer started to operate in 1991, but it was off the air for long periods of time because of maintenance and upgrades in the experimental apparatus to improve its sensitivity. Nautilus started operation in 1995, also with long periods of interruption. We essentially have data for Explorer and Nautilus in some periods during the years 1995, '96, '97 and during six months for the Explorer in 1991. The GW raw data obtained with the antennas Explorer and Nautilus of the Rome group have been filtered with a Wiener-Kolmogoroff algorithm [3] to obtain the best signal to noise ratio (SNR) for delta-like signals. At the output of the filter we have a sequence of filtered samples, at about 3.4 $Hz$, which we simply refer to as "samples", expressed in Kelvin units . The frequency bandwidth of both Explorer and Nautilus in 1997 is of the order of 1 $Hz$, which means that the correlation time of the filtered data is of the order of one second. It can be shown [12] that the probability for a sample to have energy equal or greater than E - in presence of well behaved noise originated from Brownian and electronic noises both of gaussian nature - has exponential distribution. The average value of the noise is indicated with $T_{eff}$.

## 4 The analysis procedure and the sensitivity

To study the problem of a possible correlation between the gamma bursts and the GW data we consider, in a predetermined period of time, the gamma bursts whose trigger time we indicate with $t_i$ $(i = 1, 2, \ldots, N)$. Searching through the files of the GW filtered data, we extract N sequences of data, each sequence lasting almost forty minutes centered at each $t_i$ ($\pm$ about nineteen minutes). More precisely, each sequence will include 8001 samples, with $\Delta t = 0.2908$ being the sampling time, corresponding to a total time of $8001 \cdot \Delta t = 38.78$ minutes. We assign to each of these samples a time t relative to that of the corresponding gamma-ray-bursts trigger, $t = UT$ of the sample - $t_i$. The algorithm we used is the combination of the N sequences by summing up the data occurring in each sequence at the same relative time $t$, for all the values of $t$. The sum has a $\chi^2$ distribution and is divided by N to get the average value ("average" algorithm). During the periods of data taking the performances of the two GW detectors were not stationary: sometimes they operated with good low noise, sometimes the noise was larger. Therefore, for this first analysis we decided to select periods when the noise was reasonably small. The noise, $T_{eff}$, was determined over each 40 minute period and the data were accepted only if $T_{eff}$ was smaller or equal to 20 $mK$, which corresponds to a burst sensitivity of $h \approx 1 \cdot 10^{-18}$. Another data selection was operated by choosing only those sequences when no sample with energy E greater than 10 $T_{eff}$ (200 $mK$) existed. The motivation was that in such cases a



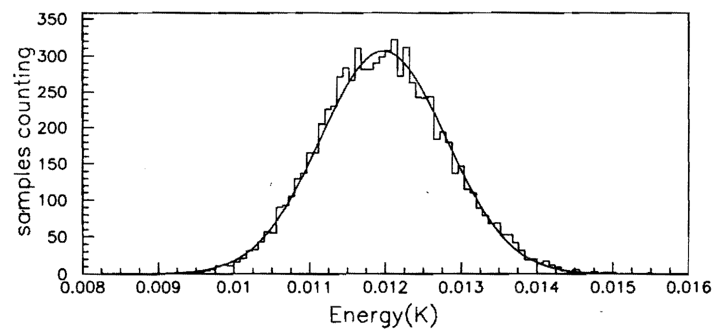



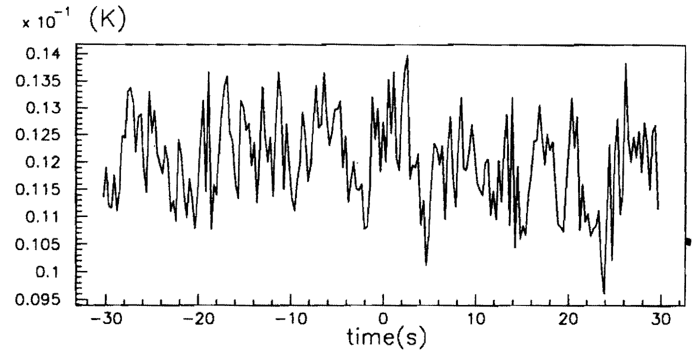

Figure 1: Average energy versus time, referred to the gamma-burst trigger time.

Figure 2: Distribution of the data of fig. 1.

disturbance was probably present (this last requirement should be reconsidered in a new analysis). In the data archives of the two antennas it was possible to select 226 sets of 8001 samplings satisfying both requirements, corresponding to the GRB events having average noise temperature $< T_{eff} >= 12\,mK$. We recall that, with a GW burst of 1 $ms$ duration, for both Explorer [1] and Nautilus [2], the amplitude sensitivity is given by [12]:

$$h \simeq 2.5 \cdot 10^{-19} \sqrt{T_{eff}(mK)} \tag{1}$$

The application of the average algorithm allows to improve the sensitivity. The noise of the average among N sequences, each one having the same $T_{eff}$, is in fact smaller by $\sqrt{N}$. In our case with $N = 226\ GRB_s$ we have a final average noise of the combined data of $\frac{12}{\sqrt{N}}\,mK = 0.8\,mK$, corresponding to an amplitude sensitivity of $h \approx 2 \cdot 10^{-19}$. However, in terms of signal to noise ratio, this result is valid only if we assume that a signal appears in all sequences and always at the same time.



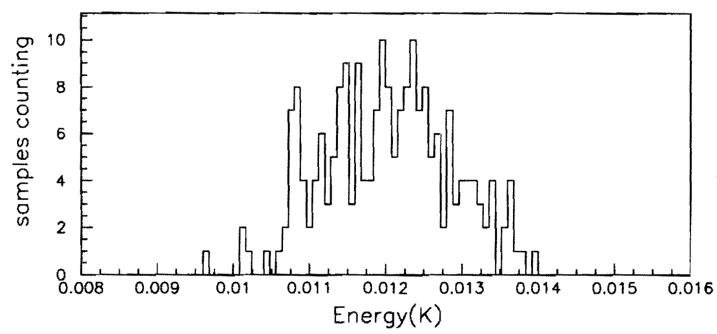




Figure 3: The same data of fig. 1 limited to one minute around the GRB trigger time.

Figure 4: Distribution of the data of fig. 3.

## 5 The results

In fig. 1 we show the time distribution of the 8001 averaged samples of 226 sequences selected in the GW antennas data. The horizontal axis represents the time relative to the GRB trigger time. The relative energy distribution, in fig. 2, shows a good fit with normal distribution. This indicates that no clear GW signal is present at the same time for all gamma-bursts, and the background is determined. In absence of a clear indication by the theory, we can try to see if a statistically significant fluctuation occurs in the vicinity of the gamma burst trigger times. So, in fig. 3 we show a zoom around the zero time of the previous figure. They are about 200 samplings that describe the behavior during one minute. Their energy distribution is given in fig. 4. To see if statistically significant fluctuations occur we compare this distribution with the background shape determined in fig. 2. The Kolmogoroff test gives a probability of almost 80 % that the distribution agrees with the noise. This confirms the impression received by inspection of the time behavior in the fig. 3 where we do not note any significant signal.

## 6 Comments and conclusions

This analysis is an initial experimental search for correlation between two phenomena which, according to theoretical predictions [10,13], are connected at cosmological distance. The result is null, under the hypothesis that GW bursts should occur always and each time with the same time delay with respect to the gamma trigger time. On the other hand, at present, the reachable sensitivity is worse than theoretically necessary by at least two orders of magnitude. A basic problem is that we need very similar and stationary GW data sequences in order to avoid heavy "a priori" data selection of the GW data. For a more complete analysis other physical parameters of the $GRB_s$, as intensity, time duration, etc., or other procedures have to be taken into account. It is also important to develop algorithms which include the possibility that, if any GW emission occurs, this happens at times, relative to the gamma trigger time, different for each gamma. Useful comments came from the audience at this Conference. Summarizing, at present, with the amplitude sensitivity $h = 2 \cdot 10^{-19}$ for a $1\ ms$ GW burst, no time signature has been seen in a window of $60\ s$ around the $GRB_s$ trigger time in the GW data background, with a c.l. of $80\ \%$. We wish to remark the importance to make use, in spite of a still low sensitivity, of the data collected with the GW antennas, that can be regarded as active observatories with a steadily improving sensitivity.

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