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# Many time scales in a single GRB (*)(**)

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**Summary.** — In some Gamma-Ray Bursts (GRBs) it has been possible to identify different time scales of variability. Certainly such a behaviour can easily be revealed in strong events, but it might represent a general behaviour of the GRBs. In this paper we report results of temporal variability for 5 events, 2 recorded by the previous experiments SIGNE and KONUS and 3 by the experiment BATSE on board the CGRO satellite. This kind of analysis up to date can give new information to understand the origin of GRBs and the relative scenario of the burst energy emission.

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## 1. – Introduction

In a previous paper [1] we studied the light curves of 40 GRBs recorded by the French-Soviet space experiment SIGNE [2] and we observed two different principally recurring temporal behaviours: the first one, more frequent, presenting a random time distribution of the pulses performing the burst; the second one, rarer, having a quasi-periodic subpulses distribution. The count rate statistics of the events were not sufficient to provide us with more information. It is up to now unknown whether these two different behaviours characterize the event, each excluding the other, or they may be simultaneously present instead, with different time scales, in the same event. In this work we try to investigate this point, analysing the temporal behaviours of two peculiar events recorded some years ago, respectively, by the space experiments KONUS [3] and SIGNE [2] on board the soviet VENERA probes, and three events selected among the events reported in the catalogue [4] of the Burst and Transient Source Experiment (BATSE) on board the CGRO (Compton Gamma-Ray Observatory) satellite. This last experiment is more sensitive by a few orders of magnitude than the previous ones.

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(**) The author of this paper has agreed to not receive the proofs for correction.

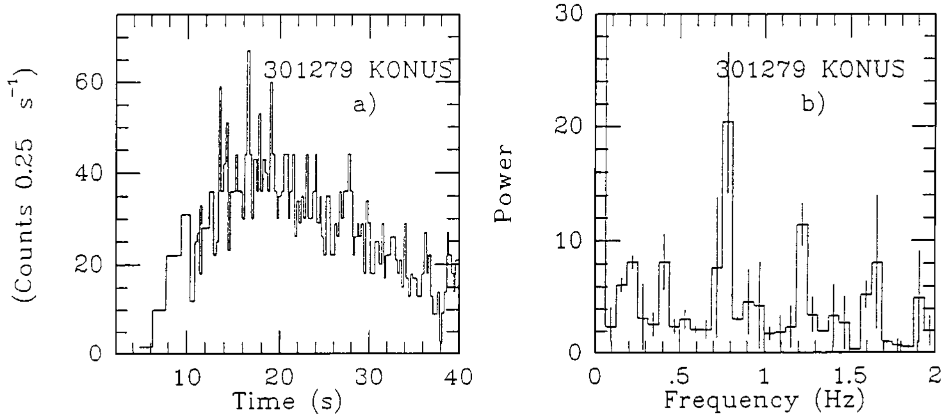


Fig. 1. – a) Temporal history of the GRB791230. b) Power Spectrum Density.

## 2. – Data analysis

To study the temporal behaviour of the selected events we used the Fast Fourier Transform (FFT) of the temporal series shown in the figures [5]. The resulting PSDs (power spectral density) were normalized, following the suggestion of Leahy *et al.* [6], by dividing each PSD point by half the total number of photons in the process (half the total expected variance). Thus, the expected level of the Poissonian noise is 2. We did not use any window function because it was not required by the shape of the GRBs light curves, which present appreciable rise and decay times. We plotted the PSDs obtained with this analysis using different representations in the different cases, in order to obtain the best evidence of the possible temporal structures. We used the linear-logarithmic scale in fig. 1b) and fig. 3b), the log-log scale with equal logarithmic intervals in fig. 2b) and log-log with equal intervals in fig. 4b) and fig. 5b). In fig. 4b) the first two PSD estimates have not been binned. We recall that the light curves of the selected events have different duration and number of temporal bins with different size. This circumstance is due to the relative time

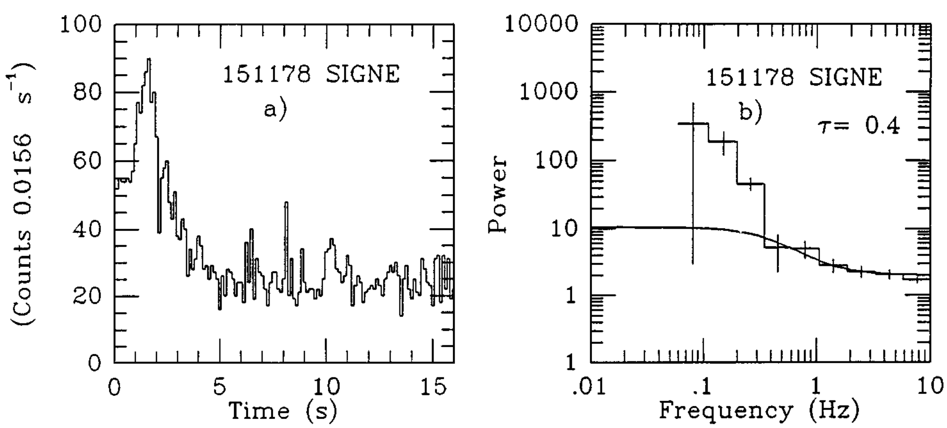


Fig. 2. – a) Temporal history of the GRB781115. b) Power Spectrum Density.

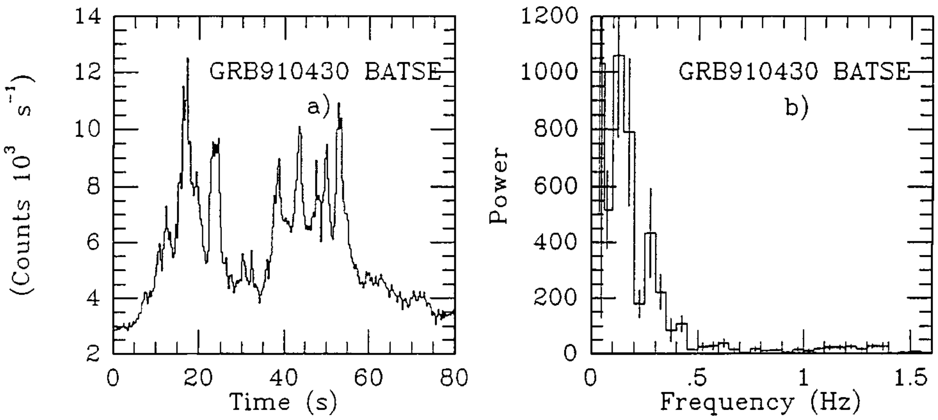


Fig. 3. – a) Temporal history of the GRB910430. b) Power Spectrum Density.

resolution of the KONUS, SIGNE and BATSE experiments. For the BATSE experiment it is also due to the representation of the events provided by the catalog. The first studied event GRB791230, recorded by the KONUS experiment, presents in the light curve a single peak with superimposed quasi-periodic oscillations of period $\sim$ 1 second. Figure 1 shows, from left to right, the light curve and the relative PSD of the event. In the PSD it is possible to see a 5 $\sigma$ peak at 0.8 Hz with some other possible harmonics, which is the frequency of the oscillations suggested by the light curve.

The light curve of the second event GRB781115 in fig. 2a) has been observed by the French-Soviet SIGNE experiment. Figure 2b) shows that it is possible to fit the high-frequency bins of the PSD with a Lorentzian law. The power at the low frequencies is due to the exponential peak, over which the shorter peaks are superimposed [5].

The three selected events GRB910430, GRB910501 and GRB910722, recorded by the BATSE experiment, as we already said, have counting rates at least one hundred times higher than the preceding ones. For this reason we might expect clearer results. The

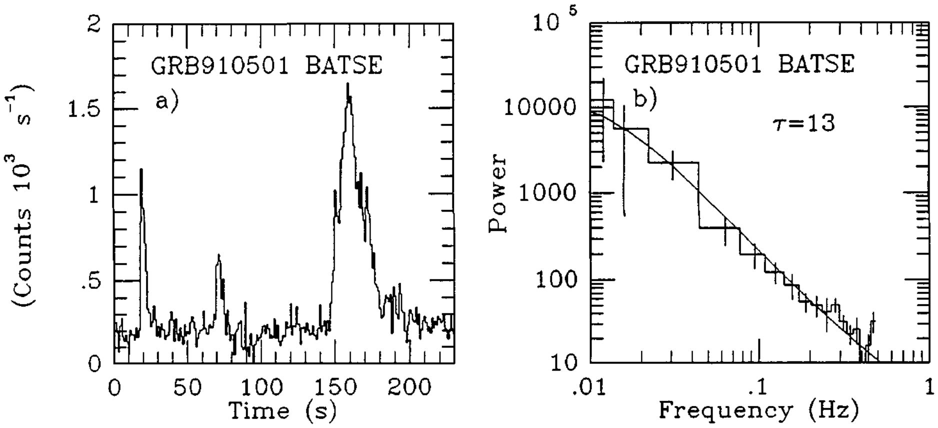


Fig. 4. – a) Temporal history of the GRB910501. b) Power Spectrum Density.

TABLE I. – *Bursts temporal parameters.*

| Event | Frequency (Hz) | $\tau$ (s) | $\Delta t$ (s) | $L$ (s) |
|---|---|---|---|---|
| GRB 301279 KONUS | 0.8 | – | 0.25 | 32 |
| GRB 151178 SIGNE | – | 0.3 | 0.0156 | 16 |
| GRB 910430 BATSE | 0.13 | – | 0.31 | 80 |
| GRB 910501 BATSE | 0.2 | 13 | 1.0 | 230 |
| GRB 910722 BATSE | – | – | 0.004 | 0.4 |

GRB910430 in fig. 3a) presents two principal peaks with many peaks superimposed with a quasi-periodic behaviour. The PSD in fig. 3b) shows a frequency peak at 0.125 Hz and two others at frequencies multiple and submultiple of the first one, which is that of the pulse period in the light curve. The second BATSE event GRB910501 in fig. 4 presents three peaks not equidistant in time and not equally high in counting rate. The best fit of the PSD with a Lorentzian law, in fig. 4b), provides us with the mean value of the characteristic Lorentzian time $\tau$ [5]. Finally the third examined event of the CGRO Satellite, GRB910722, in fig. 5a), has a high counting rate, and presents a single substructured peak, but the relative PSD, fig. 5b), does not show the presence of different statistically significant features.

Table I summarizes for each event the values of frequency peaks of quasi-periodicities, if present, the characteristic Lorentzian time constant $\tau$, if evaluated, the temporal bin size and the total time interval of data series.

## 3. – Conclusions

We present preliminary results of a temporal analysis of 5 gamma-ray bursts from three different space experiments. The obtained results do not disagree with the idea that a high similarity of temporal behaviours is present in the events at different time scales. Generally the single event is characterized either by a random or by a quasi-periodic behaviour. In only one burst, GRB910501, we found indication of simultaneous

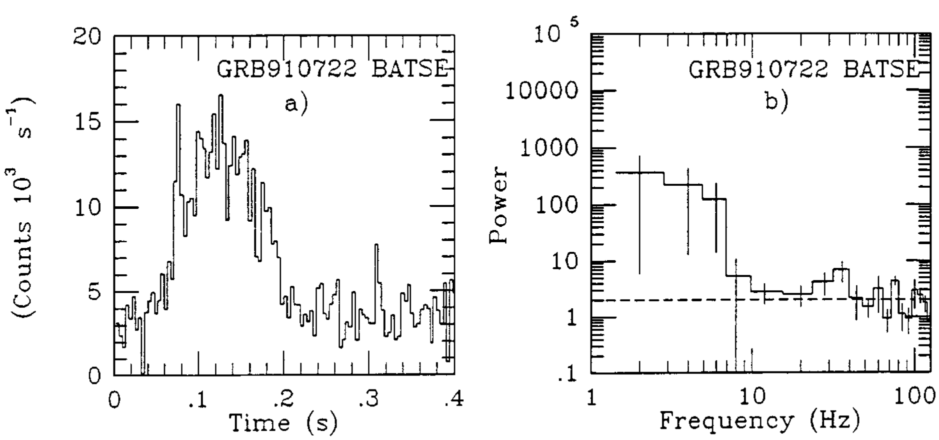


Fig. 5. – a) Temporal history of the GRB910722. b) Power Spectrum Density.

periodic and random distribution of pulses, but the significance of the periodicity is very poor. It is not possible, at this moment, to establish whether the random distribution of pulses constituting the burst and the quasi-periodic one can be present in the same event.

The identification of different time scales in a single gamma-ray burst has been up to now only episodic with partial results. We suggest to extend this kind of analysis to a wider sample of events to study the distributions of the different time scales and the possible correlations between them. The results of this analysis might provide new information to understand the mechanisms producing these strong emissions of energetic photons.

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