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LIMITS TO THE BURSTER REPETITION RATE AS DEDUCED FROM THE 2ND CATALOG OF THE INTERPLANETARY NETWORK

J.-L. Atteia, C. Barat, K. Hurley, M. Niel, G. Vedrenne
C.E.S.R., B.P. 4346, 31029 Toulouse Cedex, France

W.D. Evans, E.E. Fenimore, R.W. Klebesadel, J.G. Laros
Los Alamos National Laboratory, Los Alamos, NM

T. Cline, U. Desai, B. Teegarden
Goddard Space Flight Center, Greenbelt, MD

I. Estulin*, V. Zenchenko, A. Kuznetsov, and V. Kurt
Institute for Space Research, Moscow, U.S.S.R.

*Deceased

ABSTRACT

The burster repetition rate is an important parameter in many gamma ray burst models. The localizations of the interplanetary network, which have a relatively small combined surface area, may be used to estimate the average repetition rate. The method consists of 1) estimating the number of random overlaps between error boxes expected in the catalog and comparing this number to that actually observed, 2) modeling the response of the detectors in the network, so that the probability of detecting a burst can be estimated, and 3) simulating the arrival of bursts at the network assuming that burster repetition is governed by a Poisson process. The application of this method for many different burster luminosity functions shows that 1) the lower limit to the burster repetition rate depends strongly upon the assumed luminosity function, 2) the best lower limit to the repetition period obtainable from the data of the network is about 100 months, and 3) that a luminosity function for all bursters similar to that of the 1979 Mar 5 burster is inconsistent with the data.

1. Introduction. The time between successive gamma ray bursts from a single source is a parameter which can in principle be used to distinguish between theoretical models of bursters. To date, only two cases of repeating bursts have been found: 3 soft gamma ray bursts were observed from one source (Mazets, et al., 1979) and a total of 16 bursts have been observed from the 1979 Mar 5 source (Golenetskii et al., 1984). None of the events from the former, nor any of the repeating events from the latter, was found in the data used to compile the 2nd catalog of the interplanetary network (Atteia et al., 1985). The soft spectra of these repeating bursts, and the exceptional features of the 1979 Mar 5 burster suggest that these recurrences may be unrelated to the question of hard gamma ray burst repetition in general. Hence an effort has been made to examine the data of the 2nd interplanetary network catalog for evidence of burster repetition.

As might be expected considering the sizes and shapes of the localizations in the 2nd catalog, a number of overlapping error regions were found: 2 error box/error box overlaps, 27 annulus/error box overlaps, 2 annulus/annulus/error box overlaps, and 8 annulus/annulus/annulus overlaps. However, a rough calculation indicates that the number of overlapping regions is very close to that which would be expected from a random distribution. We adopt the hypothesis that no repeaters were detected in these data, and proceed to estimate the lower limits which can be placed on the recurrence time scale. It is of course possible that several cases of burster recurrence are present in these data, and that we have incorrectly identified them as "random" overlaps. However, as long as there are no more than 2 or 3 such cases, this will not change the upper limits substantially.

2. A Modeling Procedure The 9 experiments used for this study (Prognoz 7, Venera 11 and 12 including both the SIGNE and KONUS detectors, Pioneer Venus Orbiter, Helios 2, International Sun-Earth Explorer 3, and Vela) had a wide range of geometries, sensitivities, and operating timetables, which must be taken into account in any model. Here, we have assumed a) isotropic response for the network as a whole, b) a step function probability for burst detection as a function of

fluence, with different threshold fluences (between 3×10^{-7} and 3×10^{-6} erg/cm^2) for each instrument, and c) a time averaged detection probability which is different for each instrument, and taken to be constant. All of these assumptions are simplifications, but the parameters used to model the detector responses are found by a semi-empirical procedure which results in a good agreement between the model and the data; more details may be found in Atteia et al. (1985).

A Monte-Carlo program was used to simulate the arrival of bursts at the instruments and their subsequent detection or non-detection. The following assumptions were made.

1) Bursts from a single source are produced randomly in time, with a mean number of events r per unit time, so that the probability of a time interval in the range t to t+dt for 2 bursts from the same source is $dP_t = r\ \exp(-rt)\ dt$. All bursters are considered to be described by the same parameter r.

2) Following Jennings (1982), the integral luminosity function for bursts from a single source follows a power law; i.e., the number of bursts with luminosities $\geq$L is proportional to L^{α}. All bursters are described by the same parameter α in this model.

3) The fluences of repeating bursts from a single source extend over a dynamic range ξ (=lowest fluence/highest fluence). The highest fluence has generally been taken to be 2×10^{-4} erg/cm^2. The lowest fluence may extend below the threshold sensitivity of the instruments, resulting in undetectable bursts.

3. Results From the above description, it is easy to see that the lower limit to the recurrence time deduced from the data may depend strongly upon the luminosity function chosen: a function which places many of the repeating bursts below the instrumental threshold will obviously result in the detection of few bursts from any given source, and the lower limit estimated for the recurrence time will be small. This is seen in Figure 1, which displays the 3σ lower limit to the recurrence time as a function of the power law index α and the dynamic range ξ. Arbitrarily small values of the recurrence time may be obtained by assuming small values of ξ and/or α. However, a maximum of about 100 mo. is obtained by assuming values of α and ξ such that all bursts from all sources are above the instrumental threshold.

A special case is worth mentioning. The data on the 16 bursts from the 1979 Mar 5 source (Golenetskii et al., 1984) give a luminosity function with $\alpha=-0.5$, dynamic range $\xi=0.00033$, and a recurrence time of 1.4 mos. after correcting for the observation and data recovery periods. If all bursters were described by this luminosity function, and again had a maximum fluence of 2×10^{-4} erg/cm^2, the Monte-Carlo procedure predicts that about 18 recurrences should have been detected in the data base of the 2nd catalog; the probability of detecting no recurrence is about 10^{-8}, and we conclude that Mar 5-type recurrence does not describe the bursters observed here.

Schaefer and Cline (1985) have also studied the burster repetition question, using a similar approach to the one outlined here, but a different data base. Generally speaking, their conclusions are in agreement with ours. Two exceptions should be noted, however. They find that a 10 year recurrence time is consistent with their data for monoluminosity bursts. Here, we have shown that even luminosity functions with a wide dynamic range are consistent with about the same recurrence time. Second, a Mar 5-type luminosity function would be consistent with the data of Schaefer and Cline, but is quite inconsistent with ours. The essential difference in the two data sets appears to be in the probability of detection and localization of bursts: Schaefer and Cline have used much of the older data, from periods when the number and sensitivities of the instruments were smaller than those of the 2nd catalog. Thus the data used in the present study provide slightly stronger constraints on burster repetition.

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5. References

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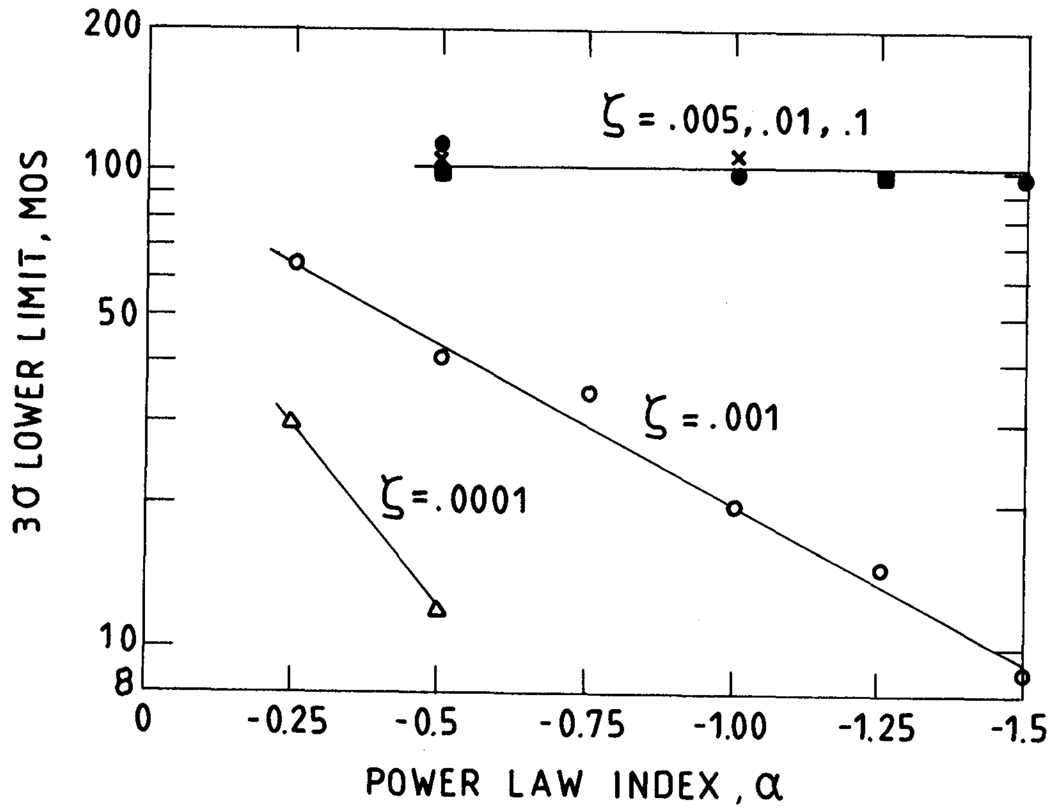

Fig. 1. Lower limit to burster recurrence period as a function of luminosity law index. Dynamic ranges of 0.0001 to 0.1 have been assumed, with a maximum burst fluence of 2×10^{-4}.