THE STATISTICAL PROPERTIES OF COSMIC GAMMA-RAY BURSTS

A. S. POZANENKO and I. G. MITROFANOV

Institute for Space Research, Academy of Sciences of the USSR, Moscow, U.S.S.R.

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Abstract. Recent localizations of cosmic gamma-ray bursts (GRBs) are studied taking into account the estimations of their intensities. The increase of the average intensity of GRBs along galactic longitudes $l = 220-260^\circ$ and $l = 40-80^\circ$ is found. It may be associated with the Orion spiral arm and the central region of the Galaxy. Corresponding enhancement of the number of intense GRBs for directions along the Orion arm is also found. Astrophysical conclusions from this possible galaxy-scale distribution of GRBs are discussed.

Up to now there is still no understanding of the origin of cosmic gamma-ray bursts despite large experimental efforts in the past 20 yr: several hundreds of GRBs were recorded with rough estimations of total intensity $S$ and maximal power $F$ and about one hundred events were localized on the sky (Klebesadel et al., 1982; Mazets et al., 1981; Atteia et al., 1987). The joint statistical analysis of cumulative distributions $\log N / \log S$ or $\log N / \log F$ (the dependence of the total number of events $N$ with intensity $> S$, or maximal flux $> F$) together with the sky distribution does not lead to the commonly accepted model of spatial distribution of the sources. Now the isotropic distribution on the sky is in conflict with slopes of the $\log N / \log S$ as well as $\log N / \log F$ curves. The observable slopes are more gentle than theoretical law $d(\log N) / d(\log S) = -3$, which one would expect for homogeneous, isotropic 3-dimensional distribution in space (Mazets et al., 1978; Higdon and Lingenfelter, 1986; Barat et al., 1982). The more direct approach to the statistical analysis of cumulative distribution using maximal counting rate $P$ instead of $F$ appears to be less biased by selection effects (Belli, 1984; Mazets, 1985; Jennings, 1985). But the distribution $\log N / \log P$ still remains in conflict with sky isotropy (Jennings, 1988).

It was proposed to explain this disagreement by selection effects connected with missing of weak events (see, e.g., Klebesadel et al., 1982; Mazets et al., 1987; Barat et al., 1982; Higdon and Lingenfelter, 1986, and references therein). In this case the galactic disk model of GRB sources could be accepted with the mean distance to the nearest sources about $< 100$ pc. Meanwhile, as it was shown in balloon experiments that determine the slope of $\log N / \log S$ or $\log N / \log F$ curves at low fluence (see, e.g., Fishman et al., 1978), observed curves hardly could differ from the theoretical law $-3/2$ corresponding to homogeneous spatial distribution due to selection effects only. Therefore, for GRB sources the alternative model of corona-like distribution was proposed, the distances to the nearest sources being assumed as large as several kpc (cf. Jennings, 1984; or Shklovsky and Mitrofanov, 1985).
Without the astronomical model for the spatial distribution of GRB sources it is impossible to evaluate the mean energy radiated in an outburst. The possibility that sources are distributed on a galaxy-distance scale is checked below by the statistical analysis of known characteristics of GRBs.

For this analysis the data for 74 events were used including both sky coordinates and estimations of intensities. The sky coordinates were taken from the Atteia et al. (1987a) catalogue (totally 63 events excluding GB 790305A, GB 790929A, GB 791018, and GB 800103 due to the absence of intensity estimations), which covered period from September 1978 to February 1980. Additional information for GRBs localizations from the end of 1981 till March 1983 (11 GRBs) was used from Atteia (1987). GB 790107 begins a series of bursts from SGR 1806–20 repeater (cf. Laros et al., 1986; Atteia et al., 1987b). It has been excluded from the data set. Taking into account exceptional properties of GB 790305B and the appearance in the error box SN remnant N49 in the LMC, it has been also excluded from the analysis.

In this catalogue coordinates of GRBs were obtained by time-of-arrival technique with two, three or more spacecrafts, which allows to determine the position of GRBs in a ring on the sky, intersection of two rings (two error boxes) or a single error box. For the present analysis only two latter types of localization (point-like localization) were used. For 14 events with two alternative error boxes both were used with statistical weight of 0.5.

The existence of the galaxy-scale structure was checked for the total amount of localized 74 GRBs. They are isotropically distributed on the sky. There is not any evident concentration of sources to the galactic plane: the number of sources (33) inside the belt with latitudes \(-30^\circ < b < 30^\circ\) is comparable with the sum of sources (41) in the both polar regions \(|b| > 30^\circ\). It means that either the scale of distance to detected events should be much smaller than the disk thickness, or disk model should be rejected in favour of the extended halo model. But for extended halo one might expect to find the concentration of GRB sources around directions to the center of galaxy. No significant longitudinal dependence of this type has been found for known events (Figure 1).

For further analysis we use the intensity of localized GRBs just like stars brightness is used by studying the spatial structure of different populations in the Galaxy (see, e.g., Schmidt-Kaler, 1975). The arms of spiral galaxies are known to be well-pronounced in visible light due to relatively large number of young bright stars within them. The number density distribution of all stars does not manifest the spiral structure so evidently. Similarly, one might try to find the galaxy-scale structure of GRB sources using their intensity distribution.

The intensity of cosmic gamma-ray bursts is not measured accurately enough. To evaluate intensity, spectra of gamma-photons \(f(E)\) are needed, while for each burst the measured value is the counting rate in given spectral channels. The uncertainty of intensity arises mainly from two reasons. First, statistical fluctuations in counts lead to errors of intensity, which have never been presented for known events. Secondly, to transform measured counting rate spectra into photons spectra a special procedure of