X-RAY OF GAMMA-RAY BURSTS OBSERVABLE BY HEAO-B

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Abstract. On grounds of Mazets et al. (1980a) conclusion that all gamma-ray bursts recorded were emitted at the distance \( < 1 \) kpc from the Sun it is shown that bursts from the Galaxy and from another galaxies may be observable by Einstein Observatory (HEAO-B). The HEAO-B observing programs are considered and the numbers of possibly recorded events are estimated. It is concluded that the important information about sources of gamma-bursts may be obtained in this way.

Cosmic gamma-ray bursts had been discovered by Klebesadel et al. (1973). Until KONUS experiment on Venera 11 and Venera 12 space probes has been started (see, e.g., Mazets and Golenetskii, 1979), only the most intensive events were recorded (about 10 per year). The large increase of KONUS sensitivity leads to essential increase of the number of detected events. Thus, during 385 days of observations about 150 bursts have been recorded. Increased statistics together with new data obtained about the spectral and temporal characteristics of gamma-ray bursts, permit to consider the astronomical properties and the physical nature of the bursting sources at the new higher level.

From the dependence of the bursts' intensity on the duration \( t_{br} \) it follows that the mean power varies for different events much smaller than the mean intensity (Mazets et al., 1980a). The difference of the power is assumed to result mainly from the different distances from the sources, the power \( P_0 \gtrsim 10^{-5} \) erg cm\(^{-2}\) s\(^{-1}\) corresponding to the nearest ones. Hence, the distance from the nearest sources may be estimated as \( d_0 \approx 0.3 L_{38}^{1/2} \) kpc (where \( L_{38} \) is the mean luminosity of the bursting source in units of \( 10^{38} \) erg s\(^{-1}\)). With the decreasing power the total number of events \( N(P) \) with power \( > P \) increases as \( P^{-3/2} \) till \( P \approx P_1 \sim 10^{-5} \) erg cm\(^{-2}\) s\(^{-1}\). This dependence corresponds to isotropic and homogeneous distribution of the sources. Indeed, the localizations of the most intensive events show the isotropic distribution (Mazets et al., 1980a). The slowing of the growth of \( N(P) \) for \( P < P_1 \) seems to result from the limitation of the sources distribution along one direction. The distance to the boundary may be estimated as \( d_0 \). The calculated limit of KONUS sensitivity corresponds to \( P_0 \approx 5 \times 10^{-7} \) erg cm\(^{-2}\) s\(^{-1}\), the real one being even lower. This means, that practically all bursts generated nearer than \( d_0(P_0/P_\ast)^{1/2} \approx 1.3 L_{38}^{1/2} \) kpc should be recorded. Their number is about 100 units per year.

Following Mazets et al. (1980a) let us assume that the source of gamma-ray bursts belong to our Galaxy and lie in the vicinity of the Sun. The converse possibility that the isotropic distribution in the sky results from very large distances to the nearest sources (\( \gtrsim 30 \) kpc) seems rather improbable. Then, for the typical luminosity \( L_{38} = 0.1-1 \) the

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distance to the nearest sources is $d_0 = (0.1-0.3)$ kpc. The mean distance of the sources from the Galactic plane is $z \leq d_0$, and the distance limited by sensitivity is $d_* \simeq (0.4-1.3)$ kpc. On the ground of these estimations it is shown below that a large number of gamma-ray bursts have possibly been recorded by the Einstein Observatory (HEAO-B).

The first question to be considered if the typical X-ray luminosity of the bursting source of gamma-ray in the energy range of Einstein Observatory (0.2-4) keV. In the energy range of KONUS experiment (30-2000) keV the bursts have the typical spectrum $dN(E)/dE \sim E^{-\alpha} \exp(-E/E_0)$, where $dN(E)$ is a number of counts per second per energy interval $(E, E + dE)$, and parameter $E_0$ varies from 100 keV to 1 MeV and has typical value about 300 keV (Mazets et al., 1980b). Extrapolation of this spectrum to the lower energies gives $\alpha = L_x(\leq 4 \text{ keV})/L(30 \text{ keV}-2 \text{ MeV}) \simeq 0.01$. Gamma-ray burst (5 April 1972) had been recorded at Apollo 16 in soft and hard energy ranges (Metzger et al., 1974). Corresponding value of $\alpha \simeq 2 \times 10^{-2}$ confirms the estimation above. Lastly, assuming that gamma-ray bursts are generated near the surface of neutron stars we may conclude that a large fraction of the outburst energy should be re-radiated as X-rays by the heated surface of the star. In this case $\alpha$ may be as large as 1. Below the estimation $0.01 < \alpha < 1$ is accepted.

To estimate the total number of gamma-ray burst sources one may suppose, as the first step, that the density of this sources is proportional to the density of the stars $\rho$ in our Galaxy and in others. In the vicinity of the Sun $\rho_0 \simeq 0.13 M_\odot \text{ pc}^{-3}$, and it varies throughout in Galaxy in accordance with the known law (e.g., Allen, 1973).

If in the volume of safe registration $W_* = \pi d_*^2 z$ around the Sun $n \simeq 100$ bursts per year occur, then in this region spatial density of bursts per year is $n_0 = n/W_* \simeq 63 L_{38}^{-3/2} \text{ kpc}^{-3} \text{ yr}^{-1}$. Corresponding number of burst per year per $1 M_\odot$ of stars is $n_0 = n_0/\rho_0 \simeq 4.8 \times 10^{-7} L_{38}^{-3/2} M_\odot^{-1} \text{ yr}^{-1}$. The mean rate of gamma-ray bursts in the Galaxy is $\sim 6.7 \times 10^4 L_{38}^{3/2}(M_{\text{Gal}}/1.4 \times 10^{11} M_\odot) \text{ yr}^{-1}$ or $\sim 2.2 \times 10^{-3} L_{38}^{3/2}(M_{\text{Gal}}/1.4 \times 10^{11} M_\odot) \text{ s}^{-1}$. Their input to the total luminosity of the Galaxy is $\sim 2.4 \times 10^{36} L_{38}^{1/2}(t_r/10 \text{ s}) (M_{\text{Gal}}/1.4 \times 10^{11} M_\odot) \text{ erg s}^{-1}$. The total number of the outbursts depends on the mean time of their recurrence $t_r$. One may estimate this number as $\geq 10^6 L_{38}^{3/2}(t_r/10 \text{ yr}) (M_{\text{Gal}}/1.4 \times 10^{11} M_\odot)$ because during $\sim 10 \text{ yr}$ of observations the recurrence of gamma-ray bursts from one source had not been observed (with two exceptions; see Golenetskii et al., 1979; or Mazets et al., 1979b). Therefore these sources seem to represent the most numerous class of the objects associated with neutron stars. These sources are likely to be identical with close binaries of low mass, consisting of a red dwarf and neutron star (see, e.g., Kumkova and Mitrofanov, 1980).

To verify the suggestion that the sources of gamma-ray bursts may be recorded and possibly have been recorded by the Einstein Observatory, the specific scientific programs (see Giacconi et al., 1978, 1979, 1980) should be considered.

Columbia Astrophysical Laboratory (CAL) carries out the observations of the Center of Galaxy using the Imaging Proportional Counter (IPC), which has field of view about 1 × 1°. The solid angle 1 × 1° at this direction contains about $2.5 \times 10^9 M_\odot$.