ANALYSIS OF GAMMA-BURST SPACE DISTRIBUTION

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Abstract. The distribution of BATSE-events over the sky is studied by the method based on the probability theory. The short presentation of the method is given. The results might indicate the presence of some anomaly in a broad region around the Andromeda nebula.

The origin of gamma-ray bursts (GRBs) is one of the unsolved problems of modern astrophysics. Several hundred GRB-sources have been registered so far. The origin and distance of these sources to the Earth remain unknown. There are various models to explain the observed distribution, but none of them has been confirmed decisively. In these circumstances a detailed analysis of the observed GRB distribution may provide an important argument to support one or other theoretical scheme.

The usual methods of analysis average the quantities of interest over all points of the ensemble, so they can show the presence of deviations (from the mean values) only on the average; they are insensitive to the presence of a single fluctuation (even a large one). Simultaneously, in the process of averaging the information about the exact location of a particular fluctuation is lost. We are trying to develop [1] another approach to this problem, based on the probability theory [2], using which it might be possible to reveal the local anomalies in GRB distribution, when usual methods are ineffective. The main ideas of the method are presented below in the simplest example, when only the density distribution of events is of interest.

Let $M$ be the total number of points positioned on a surface of a sphere of unit radius. Every point of the ensemble may be observed from the centre of the sphere within a cone of arbitrary angle $\theta_w$, which cuts on the surface of the sphere the circle of radius $r_w = \theta_w$. We shall call such a circle area a ‘window’. The window’s area will be denoted as $S_w$ and the area outside the window as $S_{out} = S_0 - S_w$, $S_0 = 4\pi$.

If $M$ particles (or points) are randomly thrown one by one on the sphere (implying equal access to every part of its surface) the probability of one particle falling inside the window is $p_{in} = S_w / S_0$, and the probability of it falling outside the window is $p_{out} = S_{out} / S_0 = 1 - p_{in}$. The expected number of particles in the window (after throwing $M$ particles) is $m_* = M p_{in}$.

Let the window’s centre coincide with some point $j$ of our ensemble and let the number of neighbors at the chosen point be $n$ (the total number of particles inside the window is $m = n + 1$). The difference between the observed value $n$ and expected $n_*$ indicates the presence of density fluctuation in the window, located at the position $j$. Below we shall estimate the significance of this fluctuation.

When $M$ particles are randomly scattered over the sphere, different configurations $G(m)$ arise, with $m$ particles occupying the window and the rest $M - m$ particles falling outside. According to the probability theory [2], when $M$ indistinguishable particles are scattered into 2 distinguishable cells, the probability of observing the configuration $G(m)$ is given by the formula

$$P(m) = \frac{M!}{m!(M - m)!} p_{in}^m p_{out}^{M-m}.$$  \hspace{1cm} (1)

The configuration probability $P(m)$ depends on the window’s radius $r_w$. Making the window’s centre coincide consequently with all points of the ensemble and calculating $P(m)$ one can find the configuration which has the smallest value $P(m)$. Simultaneously, the exact location of this configuration will be known, because every configuration belongs to the specific point $j$ with known coordinates. Thus one finds the window of maximal anomaly.

The probability $P(m)$ is convenient to find the location of anomaly, but is insufficient to judge its significance. To estimate the significance of a particular anomaly $A_0$ (observed in some window $r_w$ on the BATSE-map) the following computer simulated procedure was used. We scatter $M$ points randomly over the sphere and register how frequently the $A_0$-type configurations appear in random ensembles. Let $N_r$ random distributions be generated and $f_r$ is the number of times when $A_0$-type configuration emerges anywhere in the sky. The chance of finding the $A_0$-type anomaly in a single distribution would be $w_r = f_r/N_r$ ($N_r \gg 1$). One may judge the anomaly’s significance by the magnitude of $w_r$. If $w_r$ is too small, the presence of such a rare configuration on the BATSE-map might mean the violation of the random distribution law, or the existence of some local cause. We elucidate this general approach below.

Evidently, the results of the analysis depend on the window’s radius $r_w$. It is convenient to introduce a dimensionless radius $\varepsilon = r_w/L$, where $L$ is the mean angular distance between points. The results will be presented below as a function of the dimensionless parameter $\varepsilon$.

In BATSE-1 catalog $M = 260$ GRB locations are recorded [2]. The mean interparticle distance for this ensemble is $L = 14.2^\circ$ (the exact value is of no importance). The following procedure was used. We specified the window’s radius $r_w = \varepsilon L$ ($0.1 \leq \varepsilon \leq 4$, step $d\varepsilon = 0.1$), and found the number of neighbors inside a window $r_w$, opened around each of $M$ points. The probability $P(n)$ to observe $n$ neighbors in case of random distribution was calculated according to Equation (1) (with $m = n + 1$).

The windows with maximal population were of special interest. In Fig. 1a the probabilities $P(n)$ for windows with maximal population are plotted as a function of the window’s radius $\varepsilon$. For instance, the windows of radius $\varepsilon = 0.7$ ($r_w = 10^\circ$), opened around every point, show the maximal population in the window located at the point having the Galactic coordinates $l = \ldots$