STUDY OF THE LARGE-SCALE DISTRIBUTION OF GAMMA-RAY BURST SOURCES BY THE METHOD OF PAIRWISE DISTANCES

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The method of pairwise distances developed earlier by the authors is used to study the spatial distribution of 352 sources of gamma-ray bursts with measured redshifts. Three cosmological models are considered: a model with a Euclidean metric, the “tired light” model, and the standard ΛCDM model. It is found that this set has fractal features and may be multifractal. The fractal dimensionalities are estimated.

Keywords: gamma-ray bursts: large-scale structure: method

1. Introduction

Gamma-ray bursts are among the most powerful sources of radiant energy. It turns out that these objects are of extragalactic origin and can be used as “markers” for the large-scale distribution of matter on scales of $z \sim 1$.

The spatial distribution of 201 long gamma-ray sources (times $T_{90} > 2^3$) with measured redshifts has been studied [1] using data from the then-current version (December 10, 2009) of the Gamma-ray Burst Online Index catalog [2]. It was shown that the distribution is fractal: the fractal dimensionality takes values $D = 2.2 + 2.5$, depending on the cosmological model that is used and is essentially independent of limitations on the red shift $z$.

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Over the last five years the sample of gamma-ray burst sources has increased considerably. Thus, the version of the gamma-ray burst online catalog that we use here (September 2014) [3] contains 352 objects with measured red shifts.

2. The sample

The positions of the 352 gamma-ray burst sources with measured red shifts were plotted on the celestial sphere (Fig. 1). That figure shows that the distribution on the celestial sphere is roughly uniformly random, except for some regions near the galactic equator where there is a deficit of sources. Our special studies showed that this large-scale inhomogeneity, as well as the exclusion or inclusion of sources of short (times $T_{90} < 2^4$) gamma-ray bursts, has little effect on the results. Thus, we consider the entire available sample.

Figure 2a shows the differential and integral distributions of the gamma-ray burst sources with respect to $z$. The differential distribution has a single global maximum and a number of local peaks that are not significant and are probably caused by statistical fluctuations. A power law approximation to the integral distribution for $z < 1.5$ was obtained with an exponent of 1.404±0.013.

Figure 2b shows the distribution of the gamma-ray burst sources with respect to the difference $t$ (billions of years) between the age of the universe in the current epoch and the time a photon was emitted (the look-back time) in the ΛCDM model [4] for $H_0 = 70$ km/s/Mpc. The distribution has a maximum at $t = 10$ billion years. Note that the gamma-ray bursts with the maximal known $z$ were emitted roughly a billion years after the onset of cosmological expansion.

![Fig. 1. The distribution of the gamma-ray burst sources with measured red shifts on the celestial sphere in equatorial coordinates.](image-url)