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Spatial Distribution of the Gamma-ray Bursts and the Cosmological Principle

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Abstract. The Cosmological Principle claims that in the large scale average the visible parts of the universe are isotropic and homogeneous. In year 1998 the author, together with his two colleagues, discovered that the BATSE's short gamma-ray bursts are not distributed isotropically on the sky. This first discovery was followed by other ones confirming both the existence of anisotropies in the angular distribution of bursts and the existence of huge Gpc structures in the spatial distribution. All this means that these anisotropies should reject the Cosmological Principle, because the large scale averaging hardly can be provided. This was claimed in year 2009. The aim of this contribution is to survey these publications since 1998 till today.

Keywords. Cosmology: large-scale structure of Universe, observations, theory, miscellaneous

1. Cosmological Principle and the Large Scale Averaging

The Cosmological Principle requires that the Universe be spatially homogeneous and isotropic on scales larger than the size of any structure (Peebles 1993). Exactly, it is said on the page 15 of this book that "...in the large scale average the visible parts of our universe are isotropic and homogeneous". The observable part of the Universe has the size of $\sim (10-20)$ Gpc, if one uses the so called "proper-motion distance" (for the relevant formulas see, e.g., Weinberg (1972) and Carroll *et al.* (1992)), and thus the averaging should happen far below these scales. In other words, there should exist a transition scale not larger than, say, ~ 1 Gpc, and above this one no structures should exist. Yadav *et al.* (2010) means that this transition scale is $\simeq 260h^{-1}$ Mpc, where h is the Hubble-constant in unit 100 km/(sMpc), and the Cosmological Principle holds.

But, rarely, there are publications claiming supports for the structures with $\sim$ Gpc sizes. For example, Collins & Hawking (1973) and Birch (1982) speak about a possible global rotation in the observable part of the Universe. Other observations (Rudnick *et al.* 2007) claim the existence of structure with size ~ 140 Mpc, but at redshift around 1. A recent publication about the spatial distribution of quasars (Clowes *et al.* 2013) claims the existence of a structure with a scale > 1 Gpc.

The angular distribution of the gamma-ray bursts (GRBs) allows to test this Principle too, because GRBs should be distributed isotropically on the sky. For this test GRBs are especially useful, because they are seen in the gamma-band also in the Galactic plane, too. In year 1996 it was declared that the isotropic angular distribution of BATSE's bursts was fulfilled (see Tegmark *et al.* (1996) and the references therein).

2. Anisotropies in the sky distribution of the gamma-ray bursts

The article Balázs *et al.* (1998) claimed first that the sky distribution of short BATSE's GRBs was not isotropic. This proclaim was then confirmed by several other articles of the author and his collaborators (see Balázs *et al.* (1999), Mészáros *et al.* (2000a), Vavrek

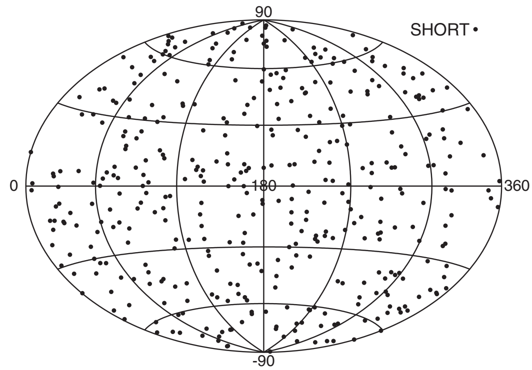

Figure 1. Sky distribution of BATSE's short GRBs in equatorial coordinates.

et al. (2008)). The anisotropic sky distribution of the short BATSE's GRBs is shown on the Figure 1. In addition, both the BATSE's intermediate and long subclasses were found to be distributed also anisotropically (see Mészáros *et al.* (2000b), Mészáros & Štoček (2003)) and Vavrek *et al.* (2008) for more details). After Vavrek *et al.* (2008) the existence of the Gpc structures and thus the problems of the Cosmological Principle were declared by Mészáros *et al.* (2009a) and Mészáros *et al.* (2009b).

Recently, the coauthors of the author, having large enough sample of measured redshifts and with which the study of 3D structures became possible, also found structures on the Gpc scales (Horváth *et al.* 2014, Horváth *et al.* 2015, Balázs *et al.* 2015). Also other authors found similar remarkable results (Sokolov *et al.* 2015, Verkhodanov *et al.* 2015, Ukwatta & Woźniak 2016).

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