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 our universe are isotropic and homogeneous" (P.J.E. Peebles, Principles of Physical Cosmology, Princeton University Press, 1993, page 15). 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 **(Balázs L.G., Mészáros A., Horváth I., Astronomy and Astrophysics, 339, 1, 1998)**. This first discovery was followed by several other ones confirming both the existence of bold anisotropies in the angular distribution of bursts and then the existence of huge Gpc structures in the spatial distribution of the bursts. All this means that these anisotropies must reject the Cosmological Principle, because no large scale averaging can be provided **(Mészáros A. et al., Baltic Astronomy, 18, 293, 2009; Mészáros A. et al., Sixth Huntsville GRB Symposium, AIP Conf. Proc., Vol. 1133, 483, 2009)**. The aim of this contribution is to survey these publications since 1998 till today.

Introduction

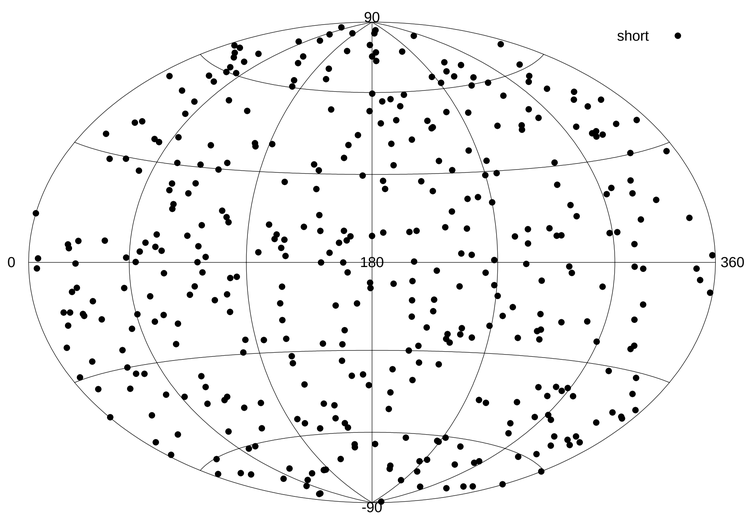
The cosmological principle requires that the Universe be spatially homogeneous and isotropic on scales larger than the size of any structure **(Peebles P.J.E., Principles of Physical Cosmology, Princeton Univ. Press, 1993).** Exactly, it is said on the page 15 of this book that **"...in the large scale average the visible parts of our universe are isotropic and homogeneous".**

Several observations - not based on the gamma-ray burst (GRBs)- show that **there are structures (filaments, voids, superclusters, ...) with sizes around 400 Mpc (Peacock J.A., Cosmological Physics, Cambridge Univ. Press, 2000).** Hence, at redshifts $z < 0.1$ the matter distribution in the Universe is certainly anisotropic and inhomogeneous. There are further observational evidences (cf. **Rudnick L. et al., ApJ, 671, 40, 2007**) that such structures exist also at redshift $z < 1$. If the structures with sizes $\simeq 400$ Mpc are not distributed isotropically at $z < 1$, then some structures should exist even with sizes $\simeq (0.4 - 3.3)$ Gpc. In other words, if this is the case, then **the scale - where the averaging should be done - should be at least of order** $\sim 1\,Gpc$**.** But Gpc scales are already comparable with the size of the observable part of the Universe. Hence, the fulfilement of the cosmological principle is in doubt even from the the observations not using GRBs.

The angular distribution of the gamma-ray bursts (GRBs) allows to test this principle too, because - if this principle holds - GRBs should be distributed isotropically on the sky, if they are dominantly at $z > 0.1$. For this test it is convenient that GRBs should well be seen in the gamma-band also in the Galactic plane, too. Indeed, in 1996 it was declared that the cosmological origin with the isotropic angular distribution of BATSE's bursts held (**Tegmark M. et al., The Astrophysical Journal, 468, 214 (1996)**).

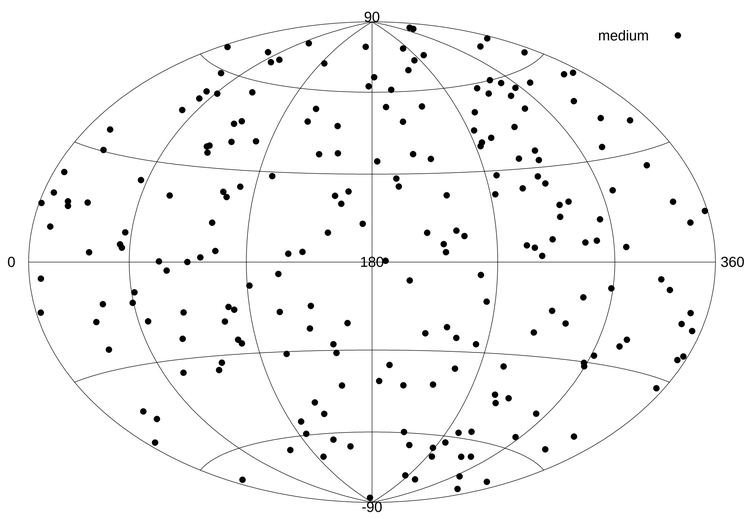
The first detection of the anisotropy in sky distribution of GRBs: short BATSE's bursts

The first discovery of the anisotropy in the angular distribution of GRBs was done in year 1998. The article **Balázs L.G., Mészáros A., Horváth I., Astronomy and Astrophysics, 339, 1 (1998)** claims that **the sky distribution of short BATSE's GRBs is not isotropic**. This proclaim was then confirmed by several other articles of the author and his collaborators: **Balázs L.G. et al., Astronomy and Astrophysics Supplement, 138, 417 (1999), Mészáros A. et al, Astronomy and Astrophysics, 354, 1 (2000), Vavrek R. et al. Monthly Notices of the Royal Astronomical Society, 391, 1741 (2008)**. The anisotropic sky distribution of the short BATSE's GRBs in equatorial coordinates is shown on the following figure:



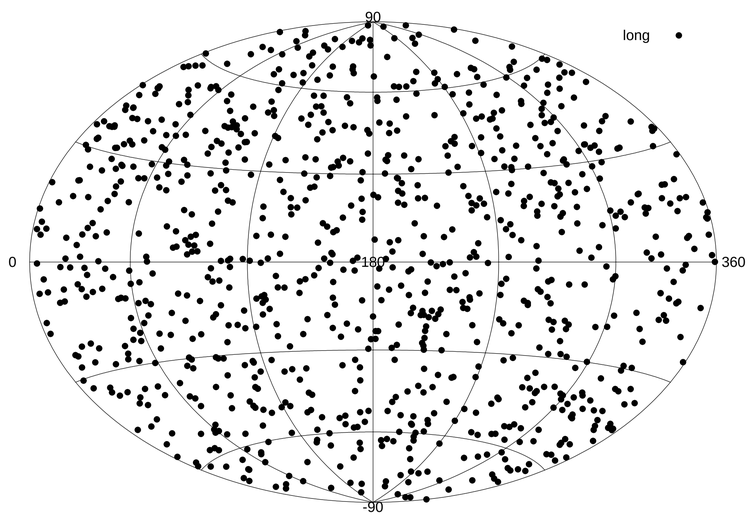
A further anisotropy in sky distribution of GRBs: intermediate BATSE's bursts

In year 1998 two simultaneous publications remarked that - beyond the standard short/hard and long/soft GRBs - also a third intermediate subclass of GRBs can exist (**Mukherjee S. et al., The Astrophysical Journal, 508, 314 (1998); Horváth I., The Astrophysical Journal, 508, 757 (1998)**). In year 2000 the author - with his collaborators - have shown that they also were distributed anisotropically on the sky (**Mészáros A., The Astrophysical Journal, 539, 98 (2000)**). The anisotropic sky distribution of these intermediate BATSE's GRBs in equatorial coordinates is shown on the following figure:



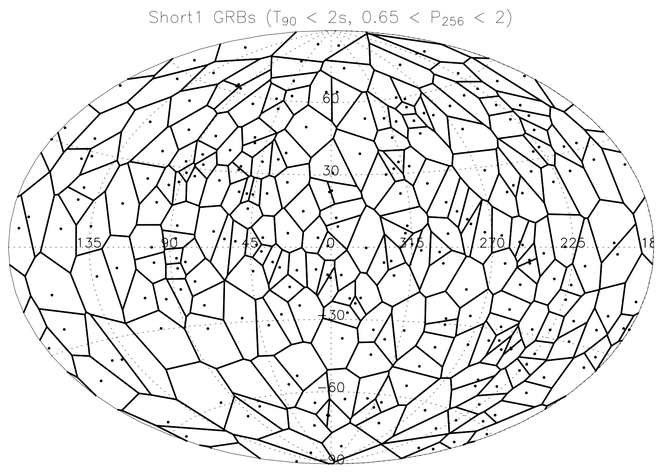
A further anisotropy in sky distribution of GRBs: long BATSE's bursts

In year 2003 the author, with his collaborator, has shown that also the long BATSE's GRBs were distributed anisotropically on the sky (**Mészáros A., Štoček J., Astronomy and Astrophysics, 403, 443 (2003)**). The anisotropic sky distribution of these long BATSE's GRBs in equatorial coordinates is shown on the following figure:



Impact of the anisotropies in sky distribution of BATSE's GRBs on the cosmological principle

A detailed study of the BATSE's GRBs (**Vavrek R. et al. Monthly Notices of the Royal Astronomical Society, 391, 1741 (2008)**) confirmed again on high significances the anisotropies both for the short and for the intermediate subclasses, respectively, in the BATSE database. For the long GRBs it was obtained that they are not distributed as the short ones. Intense numerical studies - based on Voronoi tessalation - were provided. This study is illustrated on the following figure, where the short BATSE's GRBs are in Galactic coordinates:



After that paper it was declared the breakdown of the cosmological principle: Mészáros A. et al., Baltic Astronomy, 18, 293, 2009; Mészáros A. et al., Sixth Huntsville GRB Symposium, AIP Conf. Proc., Vol. 1133, 483, 2009.

Newest studies

At the last years the author's colleagues provided several other tests probing the intrinsic isotropy in the angular sky-distribution of GRBs collected in other samples (**Balázs L.G. et al., MNRAS, 452, 2236 (2015); Horváth I. et al., Astronomy and Astrophysics, 584, A48, (2015)**). These studies also found bold anisotropies and hence structures on the Gpc scale.