NOTE ON A SUPER-HORIZON-SCALE INHOMOGENEOUS COSMOLOGICAL MODEL

K. TOMITA
Yukawa Institute for Theoretical Physics,
Kyoto University, Kyoto 606-01, Japan

1. Introduction

Many observations of large-scale and cosmological structures in the universe have been collected, but so far there is no consistent theoretical explanation. In the region within 100 Mpc from us, the observed two-point correlations of galaxies and clusters of galaxies can be described well by low-density homogeneous cosmological models (Bahcall & Cen 1993; Suto 1993). On the other hand, the observed anisotropies of the cosmic microwave background radiation have been explained well by comparatively high-density cosmological models such as the Einstein-de Sitter model (Bunn & Sugiyama 1994). In the intermediate scale, the angular sizes of the cores of quasars have been measured and their redshift dependence has been shown to be more consistent with the Einstein-de Sitter model than with the low-density models (Kellermann 1993). The number count-magnitude relation for remote galaxies supports low-density models with a nonzero cosmological constant (for example, Fukugita et al. 1990), but these models may be inconsistent with the observed distribution of Lyα clouds (Fukugita & Lahav 1991).

To avoid this contradictory situation it may be useful to drop homogeneous models and examine the observational consequences of an inhomogeneous cosmological model that consists of a local, low-density, negative curvature region, an inhomogeneous region, and a nearly flat, homogeneous region. This model is analogous to the void models, which have been studied by many people, and it is well-known that there is a narrow region with comparatively high density in these models. In view of the large-scale structure of the universe, we shall be confronted with severe observational contradictions if the high density shell lies at redshifts $z < 1.5$. However, it may be possible to have the shell between the redshifts of $z_1 = 1.5$-2.0 and

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$z_2 \sim 5$, which corresponds to the epoch when the number of quasars and Lyα clouds changed dramatically (Hartwick & Schade 1990; Bechtold 1994). In a recent paper (Tomita 1995a) I derived such a spherically-symmetric inhomogeneous cosmological model and some of its observational properties.

2. An Inhomogeneous Cosmological Model

The Universe is assumed to consist of three regions: an inner low-density homogeneous region (a), a self-similar region (b), an outer, nearly-flat, homogeneous region (c). Its evolution is described in terms of the Tolman-Bondi solution without a cosmological constant. The present densities of the regions are $\Omega_0(a) = 0.1\text{-}0.2$, $\Omega_0(c) \simeq 1.0$, and the shell region has $\Omega_0(b) > \Omega_0(c)$. The observer must be near the origin of the inner region, to be consistent with the small dipole-anisotropy of CMB (Tomita 1995b).

In this model we derived the redshift dependence of angular, d_A, and luminosity distances, d_L, the number density N_u of Lyα clouds per unit redshift, and the number counts $N(m)$ of faint galaxies. The angular diameter of quasar cores is proportional to $1/d_A$, and we found that it can reproduce the observed behavior (Kellermann 1993), because it is approximately the Einstein-de Sitter model for $z > z_1$. The number density N_u can reproduce the observed rapid changes in the numbers of quasars and Lyα clouds. Moreover, number counts in the present model can produce the observed excess over the counts in homogeneous models with $\Lambda = 0$, because of the larger number density of galaxies. Thus, this inhomogeneous model may play an important role in observational cosmology.

References

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