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Even for the observed luminosity distance $D_L(z)$ which suggests the existence of the dark energy, we show that the inhomogeneous dust universe solution without the dark energy is possible in general. Future observation of $D_L(z)$ for $1 \lesssim z < 1.7$ may confirm or refute this possibility.

I. INTRODUCTION

Recent measurements of the luminosity distance $D_L(z)$ using Type Ia supernovae [1–3] suggest that accurate $D_L(z)$ may be obtained in near future. Especially SNAP [4] will give us the luminosity distance of ~2000 Type Ia supernovae with an accuracy of a few % up to $z \sim 1.7$ every year. On the other hand from the observation of the first Doppler peak of the anisotropy of CMB, it is now suggested that the universe is flat [5,6], which may be proved in future by MAP and Planck. Under the assumption of the homogeneity and the isotropy of our universe, these observations suggest that the dark energy is dominant at present. However at present we do not have a firm and reliable theoretical basis to discuss such a small amount of energy scale compared with the Planck one. Recently we have considered to construct a possible inhomogeneous dust universe derived from the observed $D_L(z)$ without any dark energy [7].

II. RESULTS AND CONCLUSION

The main question of [7] is whether or not the dark energy is the only solution to the apparent acceleration of the universe. Our answer for this question is "no dark energy". To derive this conclusion we have performed the "reconstruction" of the universe from the $D_L(z)$ which is considered to be plausible from the SNIa observations. The assumptions in this analysis are that the $D_L(z)$ is correct for all z and that the dark energy does not exist. The result is that we can reconstruct the universe up to $z \sim 1$ without difficulty and the crucial difference appears at $1 < z < 1.6$. Therefore we conclude that if there is not dark energy, $D_L(z)$ should be different from Eq. (1) in [7] and these differences would be observed by future or ongoing projects.

Recently, the SNIa at the redshift of ~ 1.7 was found [8,9] with rather large error bars. However only a single SNIa at the redshift of ~ 1.7 is not enough to construct the accurate $D_L(z)$. The first Doppler peak as well as the higher ones will give us another constraints to the inhomogeneous universe models. One may suspect that the existing observations in $0 < z < 1$ such as : (i) evolution of cluster abundance, (ii) lensing rate, (iii) ages of stellar populations already rule out the inhomogeneous models. The model dependence including various undetermined parameters and the observational uncertainty are much larger than the dependence on the cosmological parameters. Therefore we think that these observations can not easily rule out the inhomogeneous model.

In conclusion, the dark energy is not the only solution to the apparent acceleration of the present universe but inhomogeneous dust models can also explain the observations.

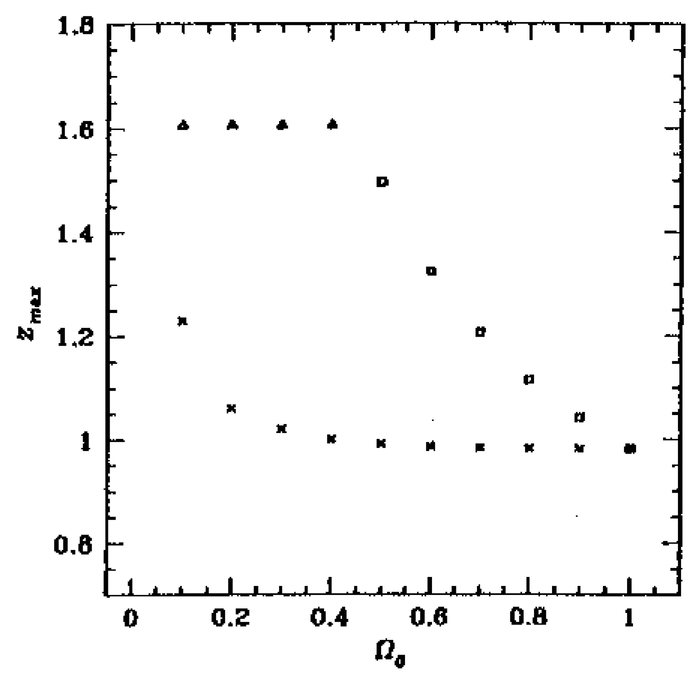

FIG. 1. Plots of maximum redshifts when either of inequalities in Eq. (16) in [7] is violated as a function of the present density parameter. The open triangles and the open squares are the ones for the Big-Bang time inhomogeneity. The cross marks are the ones for the curvature inhomogeneity case.

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