DISTURBANCE OF THE CBR BY ISOTHERMAL PERTURBATIONS

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Following the standard scenario of galaxy formation, density fluctuations with amplitude $\delta \sim 10^{-3}$ should have been present at the recombination time t_R in order that galaxies and clusters of galaxies can be formed. Recent observations of the anisotropy of the cosmic background radiation(CBR), however, indicate that δ is less than 10^{-4} at t_R for adiabatic perturbations in the baryon-dominated universe.

It is widely believed that this difficulty can be avoided if the initial density fluctuations are isothermal type. Here we show that this conventional prejudice is not correct. We only consider the pre-recombination stage in the baryon-dominated universe.

First we explain the essential feature of evolution of isothermal perturbations. In the linear perturbation theory baryon and radiation density contrasts, $\delta_b=\delta\rho_b/\rho_b$ and $\delta_r=\delta\rho_r/\rho_r$, are expressed in terms of $\delta=\delta\rho/\rho(\rho=\rho_b+\rho_r)$ and the perturbation to entropy, $S\equiv 3\delta_r/4-\delta_b$ as

$$\delta_b = \frac{\rho}{h}\delta - \frac{4\rho_r}{3h}S, \qquad \delta_r = \frac{4\rho}{3h}\delta + \frac{4\rho_b}{3h}S, \qquad (1)$$

where $h=\rho_b + 4\rho_r/3$. Due to the strong coupling between photons and baryons S stays constant. On the other hand δ can be shown to remain much smaller than S on superhorizon scales. Hence δ_r/δ_b increases with ρ_b/ρ_r and eventually it may become greater than unity in the baryon-dominated stage. Thus on these scales the isotropy of the CBR constrains δ_b more strongly for isothermal perturbations than for adiabatic ones.

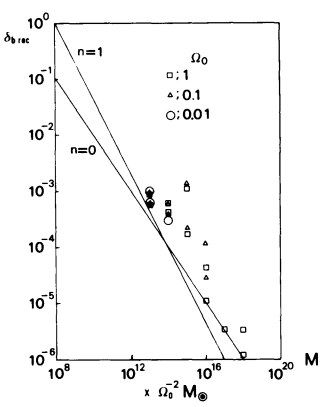

Fig.1

In order to obtain a precise constraint, we have numerically calculated the values of δ_r and δ_b at t_R and compared them with the observation of the CBR. In Fig.1 the resultant upper limits on δ_b at t_R are shown. From this figure we can conclude that it is difficult for the structures on scales, at least, larger than clusters of galaxies to form. This result holds even in a dark matter dominated case on supercluster scales. Further this figure indicates that even the formation of galaxies is difficult if δ_b on mass scale M at t_R obeys the power law $M^{-(n+3)/6}$ with $n \leq 1$.

References

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