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GALAXY FORMATION IN BIASED CDM COSMOGONIES

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ABSTRACT We analize statistical properties of the large scale distribution of galaxies in biased CDM cosmogonies. We explore different schemes for biased galaxy formation with characteristic scale length of $0.5h^{-2}$ Mpc. We consider possible mechanisms for suppresion of galaxy formation in regions of very high mass density and models where galaxy luminosities depend on local density are also analized. For all the models where galaxies are more clustered than mass we find that the angular two point correlation function has not enough power on large angular separations as compared with APM measurements. In antibiased models we find good agreement in the angular correlation function of simulations and observations although the peculiar velocities of the galaxies exceed by a factor $\simeq 1.5$-2 the observed peculiar velocities of galaxies and the velocity dispersions of clusters. The ratio of systematic to rms velocity dispersion of large volumes $\simeq 18h^{-1}$ Mpc is in better agreement with observations than the standard model.

ANALYSIS

We follow the evolution of structure in the universe using $N=10^6$ particles in a 128^3 grid with a particle-mesh code (Hockney and Eastwood 1981). The particles were initially perturbed using the Zel'dovich approximation according to the CDM power spectrum with a random Gaussian density field in a universe with density parameter $\Omega=1$, cosmological constant $\Lambda=0$ and a Hubble's constant $H=100$ h km s^{-1} Mpc^{-1} with $h=0.5$. We adopted in the simulations a box of comoving size 100 h^{-2} Mpc implying a mass per particle $m=2.8\ 10^{11}$ h^{-4} solar masses.

A direct comparison with observations is achieved calculating the two-point angular correlation function $w(\theta)$ corresponding to a projected catalog at Lick depth (equivalent to APM magnitude limit bj=18.4, Maddox *et al.* 1990) using the Limber equation (Peebles 1980).

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We have adopted a luminosity function as in Maddox *et al.* (1990) with no dependence on redshift ($Z(\text{Lick catalog}) \simeq 0.1$):

$$\phi(x) = \phi^{*} x^{\alpha} \exp(-x) \qquad (1)$$

where $x=10^{0.4(M^{*}_{bj}-M)}$, $\phi^{*}= 1.3\ 10^{-2} h^{3}\ \mathrm{Mpc}^{-3}$ $M^{*}bj= -19.8$ and $\alpha=-1$.

Biasing scheme

The scheme adopted assigns a probability $p(\rho)$ to each particle of the simulation to be a galaxy according to the local density of particles ρ in a sphere of radius 0.5 h^{-2} Mpc which is comparable to the grid resolution. This scale is sufficiently small so that the segregation between luminous and dark mass is determined only by local processes. In the positive bias models we consider the probability $p(\rho)$ of a particle to be a galaxy associated to an instantaneous star formation rate (Larson 1977), $\dot\rho$ = Const ρ^{x}_{gas} $1 \leq x \leq 2$. Therefore $p(\rho)$=Const ρ^{x-1} . We have analyzed the angular correlation function scaled to Lick depth (bj=18.4) for the resulting galaxy distribution. We find that the shape of the angular correlation function is not consistent with the observations and we conclude that it is not possible to fit APM measurements on large scales in locally positive biased CDM models. These results are similar than those of White et al for the 'natural' bias CDM model in the sense that more power on large scales is needed in order to be consistent with observations.

Effects of luminosities dependence on environment

We have attempted to analize the effects of possible dependences of the luminosities of galaxies on local density in orden to reproduce in the simulations the angular correlations observed on large scales in APM.

We assigned the luminosities according to (1) and substracted Δm=0.1-0.5 magnitudes to a fraction $\simeq$10-20% of the galaxies in the highest density regions. The angular correlation function is computed through a projected catalog where the luminosities are assigned according to the spatial local density. We find that no model has the correct shape of the correlation function. We conclude that differential effects in the luminosities of galaxies can not account for the departures of CDM positive bias cosmogony from APM large scale angular correlations.

Antibiasing in evolved CDM models

We have explored the possibility that astrophysical mechanisms may have produced a distribution of galaxies less clustered than the mass distribution (antibiased schemes, see for instance Braun et al 1988). The antibiasing scale equals that of the biased models (a sphere of radius 0.5 h^{-2} Mpc). We have evolved CDM models to $\delta\rho/\rho\,|_{8Mpc/h} \simeq 1.2, 1.5$ and 2, implying bias parameters in the range $b \simeq 0.5-0.8$. In these evolved CDM models galaxy formation proceedes well before than it does in positive bias models such as the standard model of White *et al.* A typical redshift for the collapse of galactic halos in a CDM model with present $\delta\rho/\rho\,|_{8Mpc/h} \simeq 1.5$ would be $z \simeq 4$ instead of the more recent epoch $z \simeq 2$ of a standard biased CDM model.

We show in figure 1 the distribution of particles in the xy plane (15% of the particles are plotted) for an antibiased CDM model with $\delta\rho/\rho\,|_{8Mpc/h} \simeq 1.5$.

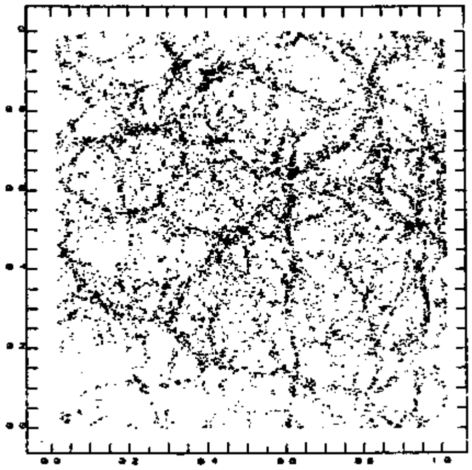

Fig. 1. Projected distribution of 'galaxies' in the xy plane in the antibiased model. Only 15% of 'galaxies' are plotted.

Figure 2a shows the angular correlation function of the mass and the galaxies for this model scaled to Lick depth. In the figure, Lick and APM results are also shown for comparison. We see that this model succesfully reproduce APM two-point angular correlation function. In this particular case roughly half of the particles were identified as galaxies with a probability $p(\rho)$=const.ρ^{-1}.

The suppression of galaxy formation in regions of high mass density would be related with galaxy merging processes, star winds and gas heating in regions of local high mass densities.

In the bias CDM model with $\delta\rho/\rho\,|_{8Mpc/h} = 0.6$, the most massive clump of the simulation has $\sigma \simeq 1200$ km/s, similarly in a CDM $\delta\rho/\rho\,|_{8Mpc/h} \simeq 1.5$-model, $\sigma \simeq 3000$ km/s. The antibiased model implies very deep potential wells and an increasing mass to luminosity ratio with local density. Hydrodynamical effects could mitigate this problem smoothing the velocity field in regions of high densities. Peculiar velocities $\leq$ velocity of our galaxy with respect to the microwave background ($\simeq$600 km/s) have a probability of only $\simeq$8% indicating an excess as compared with the observations (see figure 2b).

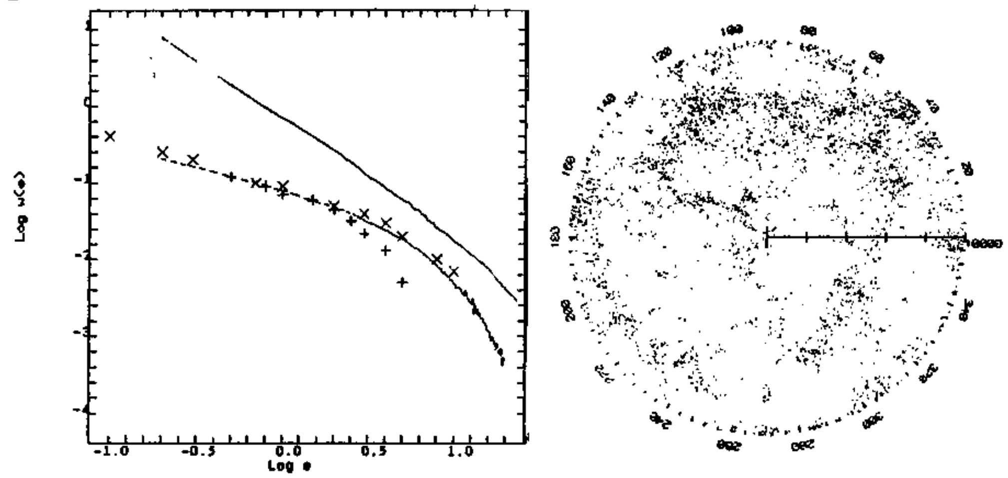

Fig 2. a) Angular correlation functions: (x) APM catalog, (+) Lick catalog, *solid line* total mass, *dashed line* 'galaxies' in the antibiased model. b) Distribution of radial velocities of 'galaxies' in the antibiased model in a slice vr$\leq$10000 km/s, $35^{\circ} \leq \delta \leq 55^{\circ}$.

We follow Parks' (1990) calculations of Mach's cosmic number (Ostriker and Suto 1990) in the simulations. We obtain a probability P=0.07 of occurrence of the observed $v/\sigma|_{r=18\ Mp/c/h} \simeq 1.3\pm0.4$ within 1σ in the biased model. In the antibiased model we find P=0.4. Thus, systematic to random motions are larger in the antibiased model and are in better agreement with observations.

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