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The Evolution of Galaxies on Cosmological Timescales
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Evolution of Clustering and Bias in a ΛCDM Universe

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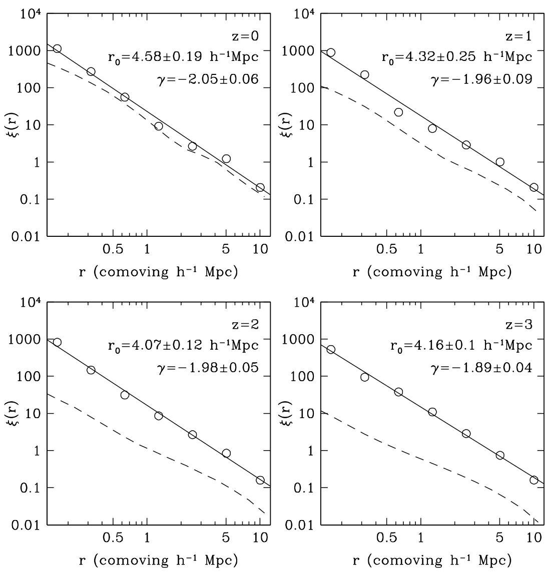
Abstract. We determine the evolution from $z = 3 \rightarrow 0$ of the galaxy and mass correlation functions and bias factor in a $50h^{-1}$Mpc ΛCDM hydrodynamic simulation with $10h^{-1}$kpc resolution. The mass correlation function grows with time, but the galaxy correlation function shows little evolution and is well described by a power law. At early times, galaxies are biased traces of mass, with bias being higher on smaller scales. By $z = 0$, galaxies trace the mass, and the bias shows little scale dependence.

The correlation function of galaxies, ξ_g, is a standard observational measure of structure in the Universe. Understanding the relationship between this observable and the correlation of the underlying mass distribution, ξ_m, is crucial for relating observations of galaxy clustering to predictions of cosmological models. The relationship between ξ_g and ξ_m is usually characterized through the bias parameter $b \equiv \sigma_g/\sigma_m$, where σ is the rms fluctuation on some specified scale. Here we investigate the evolution of ξ_g, ξ_m and b in a ΛCDM simulation.

We simulate a random $50h^{-1}$Mpc cube in a ΛCDM universe, with $\Omega_m = 0.4$, $\Omega_\Lambda = 0.6$, $H_0 = 65$, $n = 0.95$, and $\Omega_b = 0.02h^{-2}$. We use Parallel TreeSPH to advance 144^3 gas and 144^3 dark matter particles from $z = 49$ to $z = 0$. Our spatial resolution is $10h^{-1}$ kpc, and our mass resolution per particle is $m_{SPH} = 8.5 \times 10^8 M_\odot$ and $m_{dark} = 6.3 \times 10^9 M_\odot$. Using a 60-particle criterion for our simulated galaxy completeness limit [1] implies that we are resolving most galaxies with $M_{baryonic} \gtrsim 5 \times 10^{10} M_\odot$. We include star formation and thermal feedback. Galaxies are identified using Spline Kernel Interpolative DENMAX. At $z = 3, 2, 1$, and 0, we identify 929, 1781, 4138, and 5264 galaxies, respectively. Note that the majority of galaxies form between $z = 2$ and $z = 1$ in this model.

We consider the 500 most massive galaxies at each redshift, representing a constant comoving galaxy density of $n = 0.004h^3$Mpc^{-3}, comparable to that of Lyman break galaxies and present-day L_* galaxies. The galaxy correlation function ξ_g at each redshift is shown as open circles in Figure 1. A power-law fit to these points is shown as the solid line, and the best-fit values for the correlation length r_0 and slope γ are indicated in the upper right. The mass correlation function ξ_m is shown as the dashed line.



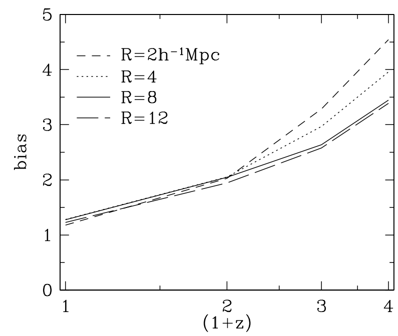


Figure 1 (left 4 panels): Correlation function of galaxies and mass at various redshifts.

Figure 2 (right panel): Galaxy bias on various scales as a function of redshift.

ξ_g evolves little from $z = 3$ to $z = 0$, in agreement with previous studies[2]. r_0 is roughly constant, with a slight increase to lower redshifts. γ also evolves only slightly, with ξ_g becoming steeper at low redshift. Conversely, ξ_m increases substantially with time. The $z = 0$ correlation function of this model is in good agreement with observations.

The difference in evolution of ξ_g and ξ_m is reflected in the evolution of $b(R)$. We consider 4 scales, $R = 2, 4, 8$ and $12h^{-1}$Mpc. The evolution of the bias parameter on these scales is shown in Figure 2. At early times, galaxies are highly biased tracers of the underlying mass distribution, in agreement with previous studies(see e.g. [3]). This implies that Lyman break galaxies do not trace the underlying mass distribution at high z. For $R \lesssim 8h^{-1}$Mpc, b increases to smaller scales at high z. The bias factor declines with time on all scales, and shows little scale dependence for $z \lesssim 1$. By $z = 0$, $b \approx 1.2$ on all scales from $R = 2 \rightarrow 12h^{-1}$Mpc, reflecting $\sigma_8 = 0.8$ chosen for our simulation.

References

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[3] Katz, N., Hernquist, L., Weinberg, D. H. 1999, ApJ, 523, 463