Halo Occupation Distribution of Massive Galaxies since z=1

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We present a clustering analysis of ~60 000 massive (stellar mass $M_{star} > 10^{11}$ M_{sun}) galaxies at z < 1, drawn from 55.2 deg^2 of the UKIDSS and SDSS-II Supernova Survey. Through a halo occupation distribution (HOD) modeling, the measured angular correlation functions (ACFs) of the galaxies provide the valuable pieces of evidence about the massive dark-matter halos hosting massive stellar systems.

For further details see Matsuoka, S.M., Sugiyama & Kawara (2010), MNRAS, in press, arXiv: 1008.0516

1. Galaxy Sample (Matsuoka & Kawara 2010)

- K-band selected (K < 17.9 mag)
  SDSS-II Supernova Survey (*ugriz*) and UKIDSS Large Area Survey (*YJHK*)
- photo-z accuracy $\sigma_{z/(1+z)} \sim 0.04$
- stellar-mass accuracy $\sigma_{\log M_{star}} \sim 0.2$
- The present sample is nearly complete to z = 1.

Classification (symbols in Figs. 1, 3, 4)

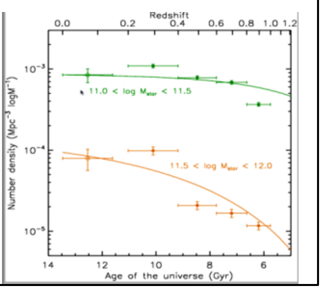
(1) "massive" (green diamonds) : $M_{star} = 10^{11.0\text{-}11.5}$ M_{sun}

(2) "very massive" (orange diamonds) : $M_{star} = 10^{11.5\text{-}12.0}$ M_{sun}

(3) "blue" (blue diamonds) :
$M_{star} = 10^{11.0\text{-}12.0}$ M_{sun} , rest-frame U-V < 1

(4) "red" (red diamonds) :
$M_{star} = 10^{11.0\text{-}12.0}$ M_{sun} , rest-frame U-V > 1

[Fig. 1] Observed number density evolution of the galaxies with the different stellar masses. The solid lines represent the predictions of a semi-analytic (SA) model (De Lucia et al. 2007).



2. Halo Occupation Distribution Models

Number of galaxies (under consideration) hosted by a halo with a mass *M* (Zheng et al.2005)

- central galaxies
$$N_{\rm cen}(M) = 0.5\left[1 + {\rm erf}\left(\frac{\log(M/M_{\rm cut})}{\sigma_{\rm cut}}\right)\right]$$
- satellite galaxie
$$N_{\rm sat}(M) = \left(\frac{M}{M_0}\right)^{\beta}$$

where M_{cut}, σ_{cut}, M_0, and β are free parameters. These values are adjusted in such a way that the HOD models reproduce the observed number densities (n_{gal}) and the clusterings of galaxies.

Spatial clustering of galaxies (e.g., Cooray & Sheth 2002, Tinker et al. 2005, Blake et al. 2008)

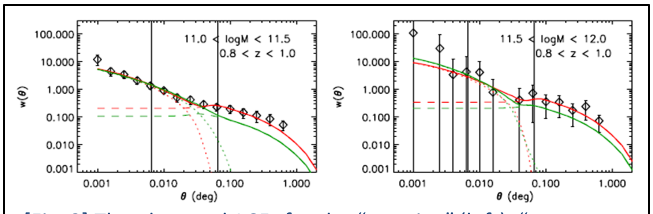
- one-halo term:
  *central-sattelite
$$1 + \xi_{1,c-s}(r) = \int_{M_{\rm vir}(r)}^{\infty} dM\, n(M) \frac{N_c(M)N_s(M)}{n_g^2/2}\frac{\rho(r|M)}{M}$$
  *sattelite-sattelite
$$P_{1,s-s}(k) = \int_0^{\infty} dM\, n(M)\frac{N_c(M)N_s^2(M)}{n_g^2}|u(k|M)|^2$$
- two-halo term:
$$P_2(k,r) = P_m(k)\times \left[\int_0^{M_{\rm lim}(r)} dM\, n(M)\, b(M,r)\frac{N(M)}{n_g'(r)}u(k|M)\right]^2$$

where *n(M)* is the halo mass function, ρ is the halo density profile, *u(k|M)* is the normalized Fourie transformed profile, *b(M,r)* is the scale dependent halo bias, *N(M)* is equal to $N_{cen}(M)+N_{sat}(M)$, and $P_m(k)$ is the non-linear matter power spectrum.

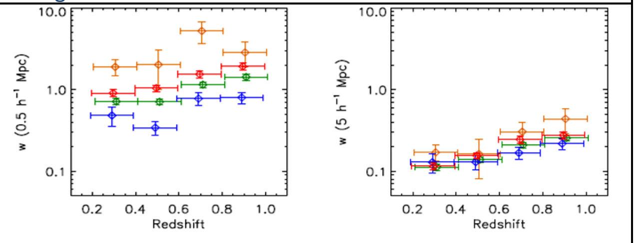
We include the triaxial halo exclusion effect approximately in calculating the two-halo term using *'n'_g-matched'* method described by Tinker et al.(2005).

3. Angular Correlation Function

The ACFs of the observed galaxies are quantified with the Landy & Szalay (1993) estimator.



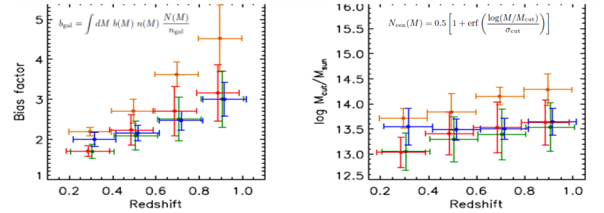
[Fig. 2] The observed ACFs for the "massive" (left), "very massive" (right), galaxies at 0.8 < z < 1.0 for example. The red and green lines represent the HOD models which reproduce the observed ACFs with the different constraints in the model fittings.



[Fig. 3] The measured ACF amplitudes at 0.5 and 5 h^{-1} Mpc.

Fig.3 shows that more mature (more massive or redder) galaxies are more clustered. It implies that more mature galaxies have started stellar-mass assembly earlier within the highly-biased region where the structure formation has also started earlier.

4. Main Results from the Clustering Analysis



[Fig. 4] The example results from HOD modeling. The derived galaxy bias factors (left panel) and halo mass estimates M_{cut} (a threshold mass for hosting a central galaxy; right panel).

Through the HOD modeling of the observed ACFs, we find that:

(1) The evolution of galaxy bias factors indicates rapid evolution of dark-matter spatial distributions relative to those traced by the massive galaxies, while the transition of host halo masses might imply that the fractional mass growth rate of halos is less than those of stellar systems.

(2) The threshold halo masses M_{cut} become lower at lower-z for all populations. It means that the lower mass halo can host the massive galaxies at low-z.

(3) The inferred effective halo masses (~10^{14} M_{sun}) and high fractions of central galaxies (> ~90%) indicate that the massive galaxies in the current sample are possibly equivalent to central galaxies of galaxy clusters.

(4) The current HOD models may have some difficulties in reproducing the clustering and number density of massive galaxies, maybe due to its too simple treatment of HOD.