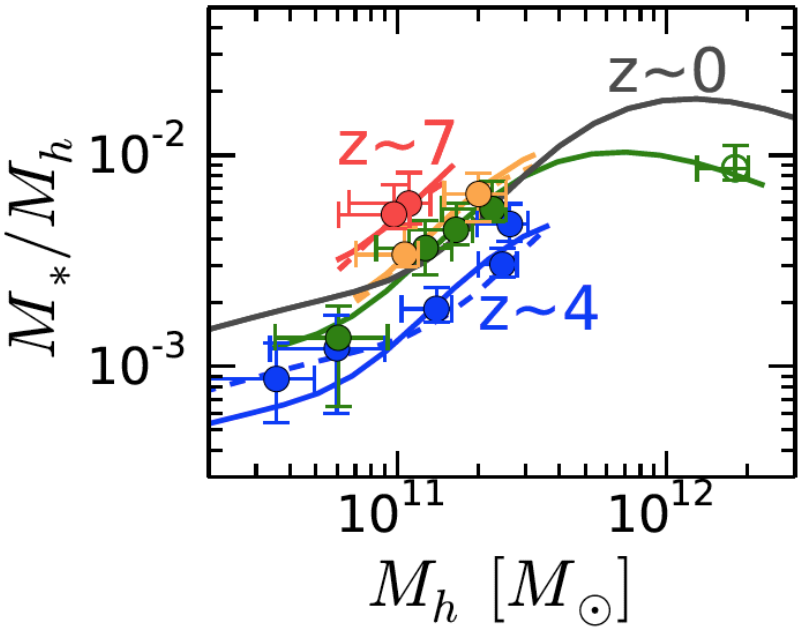
Evolution of Stellar-to-Halo Mass Ratio at z=0-7 from Hubble Imaging & Early Subaru/HSC Data

(Harikane+16, ApJ 821, 123, HSC project 87)



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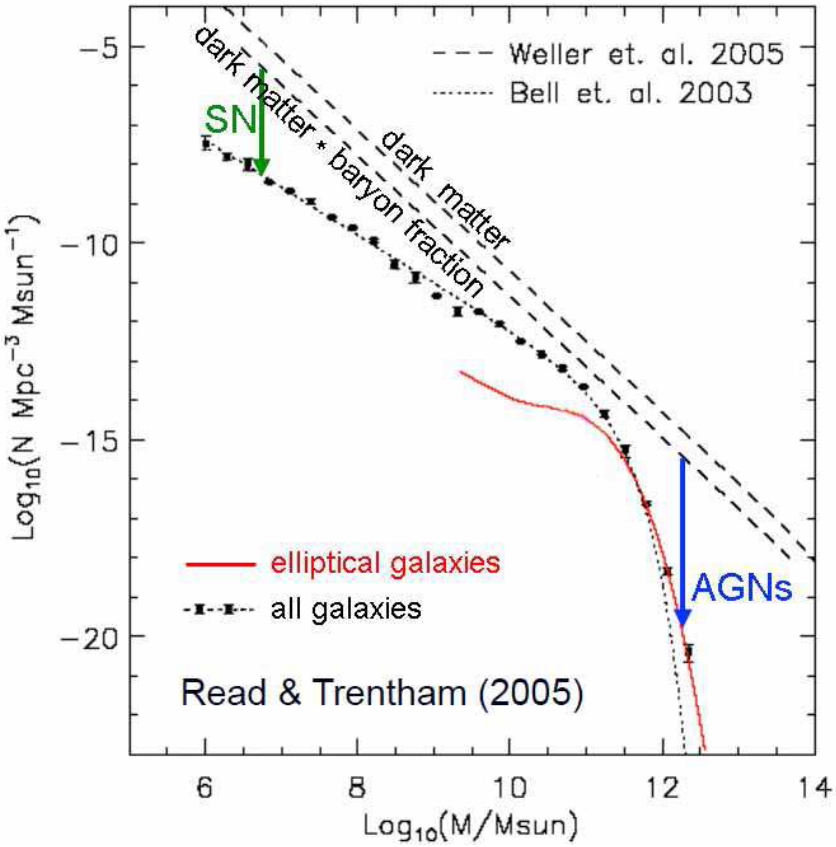
Outline

- Stellar-to-halo mass ratio (SHMR)
- HSC & Hubble Data and LBG Sample
- Clustering Analysis
- Results and Discussion

Galaxy Formation is Inefficient

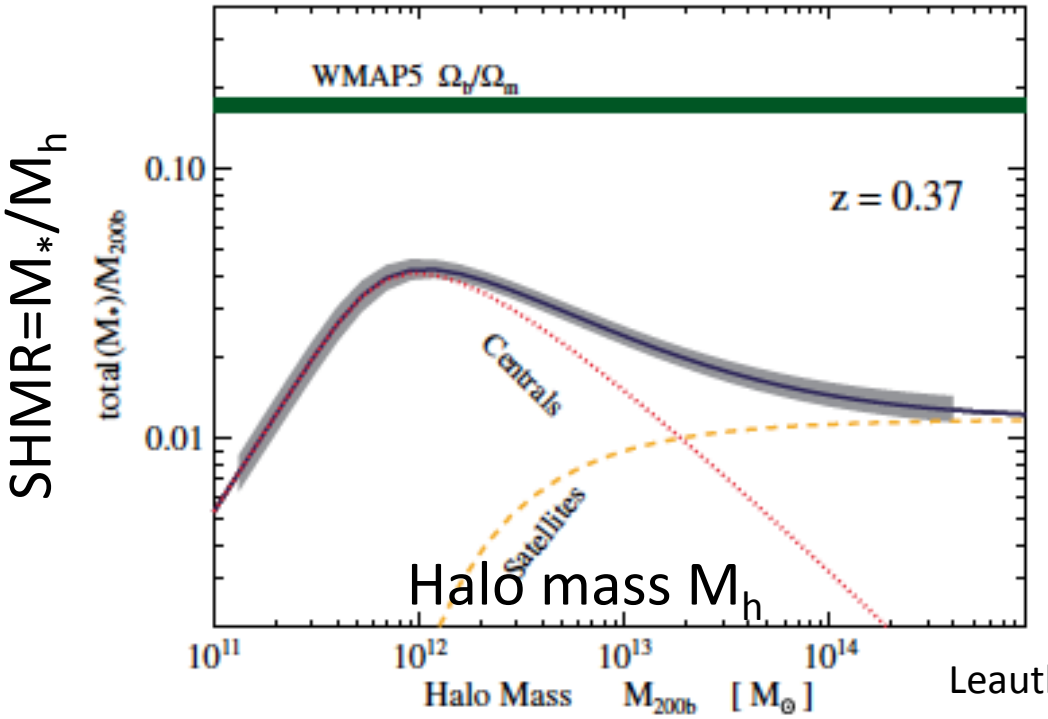
- All of baryons are not converted to stars.
  - SN or AGN feedbacks? Inefficient gas cooling?
  - How do we understand this?



Kormendy+13

Galaxy-Dark Matter Halo Connection

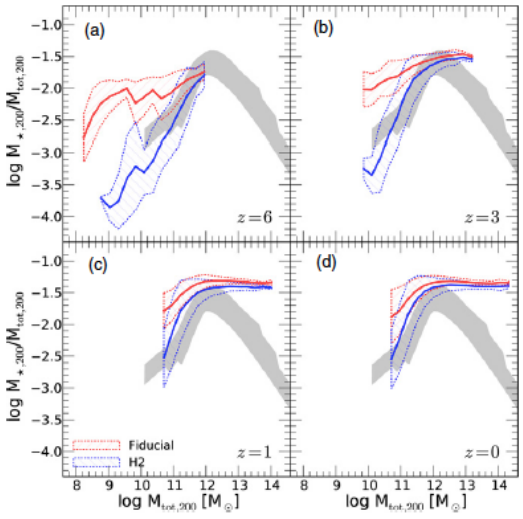
- Galaxy formation processes are closely related to dark matter halo mass (M_h).
- Stellar-to-halo mass ratio (SHMR=M_*/M_h)
  - Fraction of mass converted to stars (M_h=~M_{total})



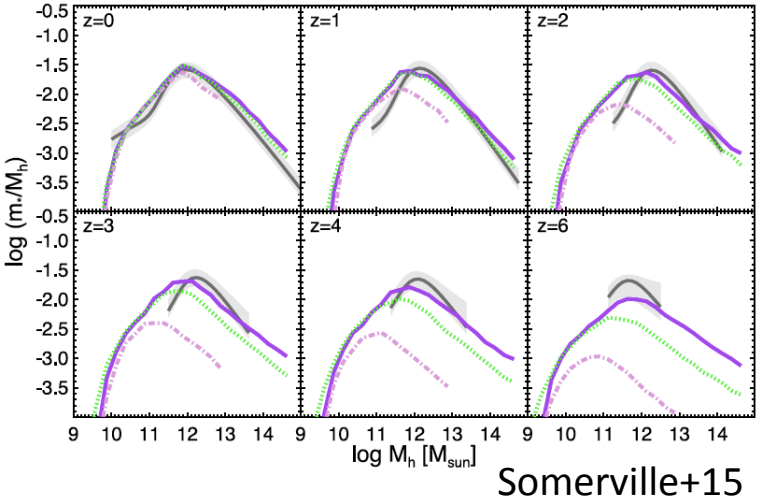
Leauthaud+12

SHMR=M_*/M_h at High Redshift

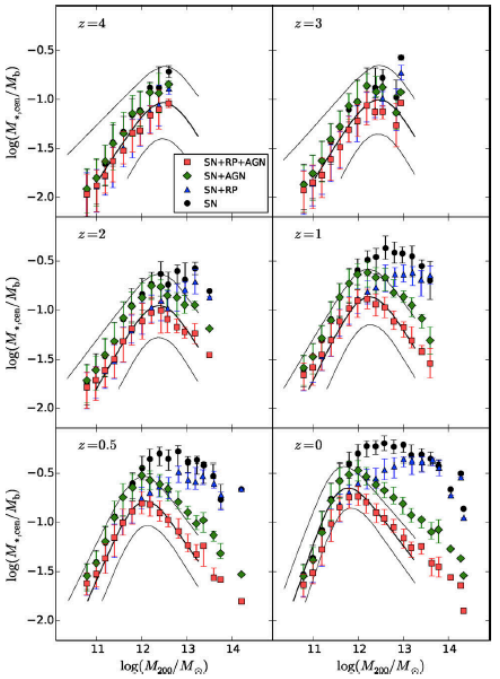
- Related to evolution of cooling, feedback, merger…
- Theoretical predictions at high redshift
  - Monotonic increase from high-z to low-z at fixed M_h
- Observation: poor due to limited data (Foucaud+10)
  (c.f., abundance matching)



Thompson+14



Somerville+15



Okamoto+15

This Study

Data:

- Hubble comprehensive archival data (10 fields)
- Subaru Hyper-Suprime Cam (HSC) early data

+

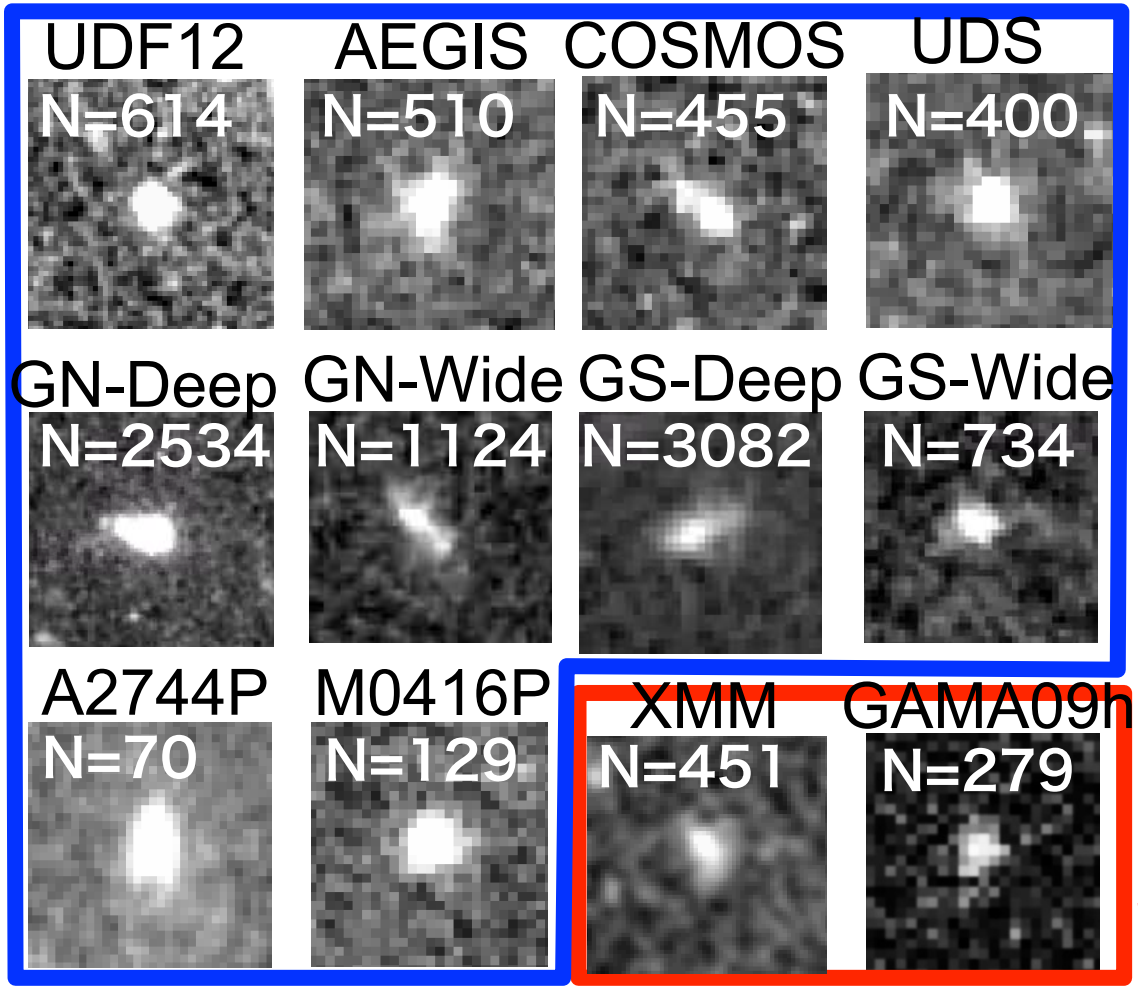
Method: Clustering Analysis

↓

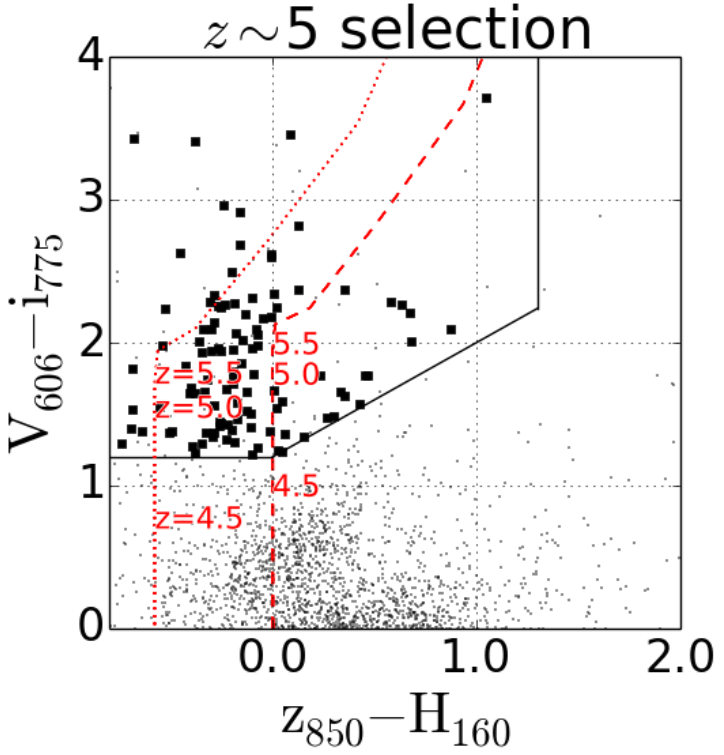
SHMR at high redshift

Data & Sample Selection

Lyman break galaxy (LBG) selection @z~4, 5, 6, 7



Hubble (~600arcmin^2)



Subaru/HSC (~15deg^2)

Total of 10,381 LBGs at z=4-7

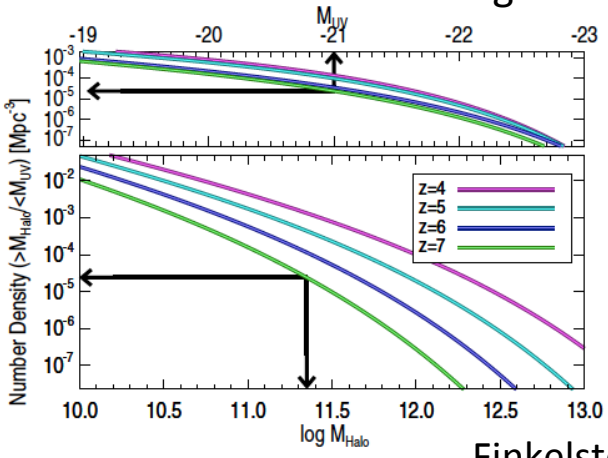
How to Measure Galaxy's Halo Mass

	Num. of Galaxies	Redshift	Assumptions
Weak Lensing	>~10000	0<z<2	-
Clustering	>~1000	0<z<7	Structure formation, HOD (later)
Abundance Matching (AM)	>~100	0<z<8	+ Duty cycle, Satellite galaxy (subhalo)

Weak Lensing

NASA/STScI

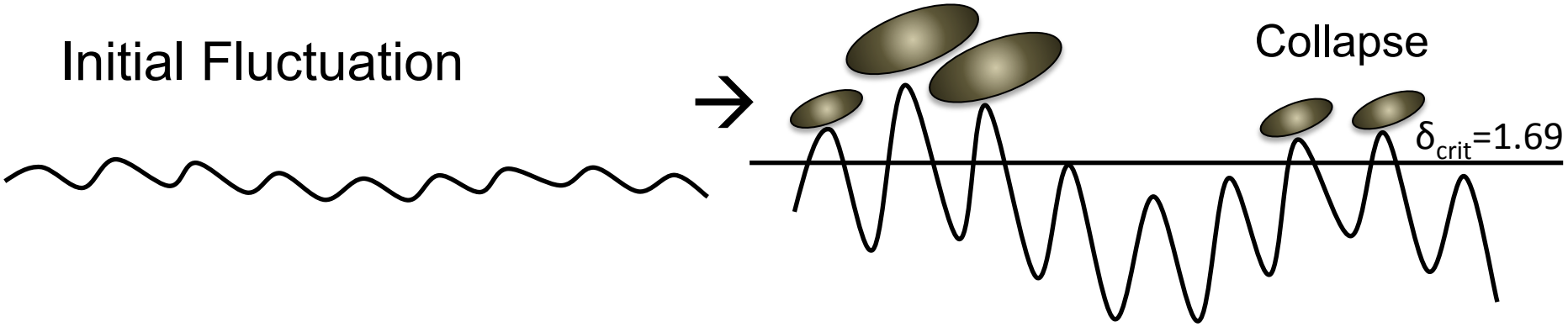
Abundance Matching



Finkelstein+15

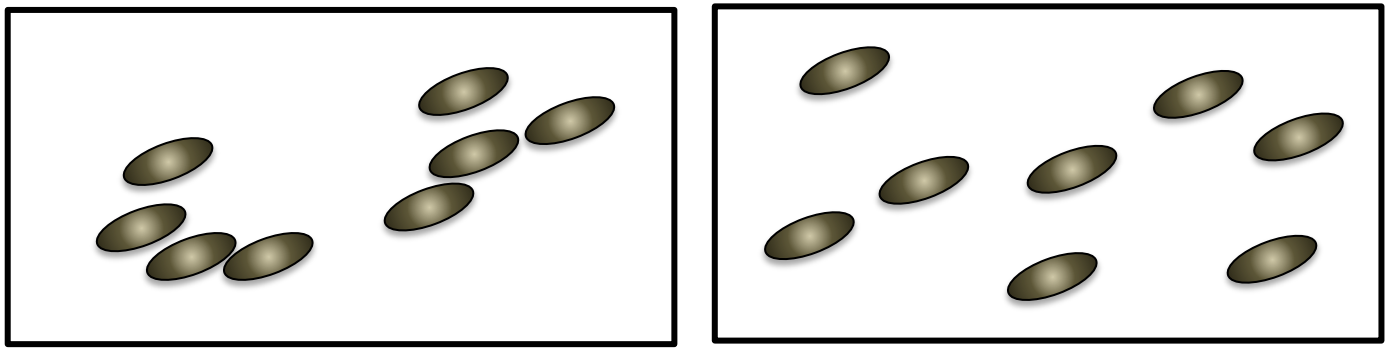
Galaxy Clustering

- Structure formation in Lambda CDM universe
  - High mass halos are strongly clustered



(Extreme examples)

Galaxies in high mass halos In low mass halos



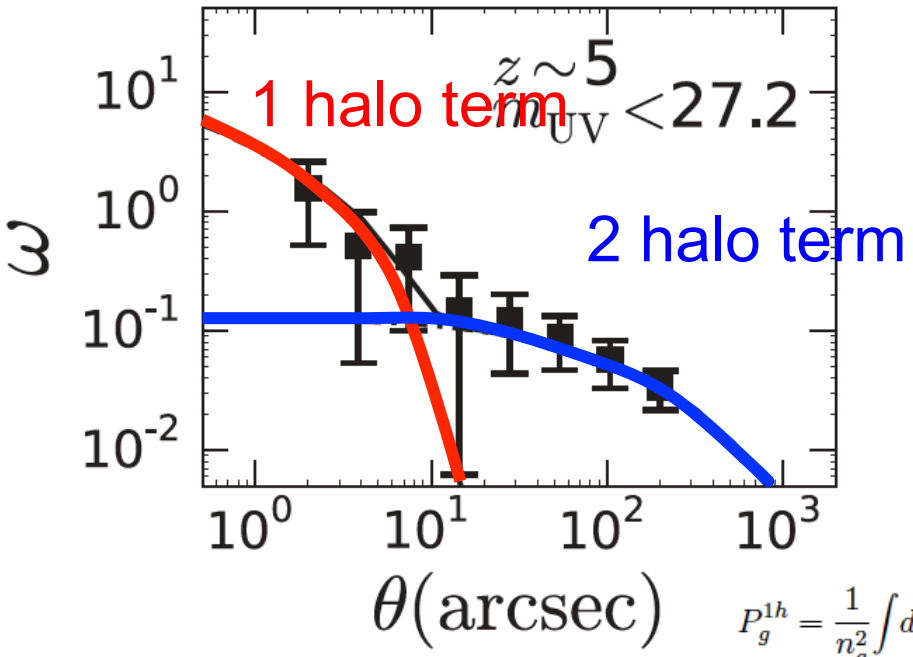
Clustering Analysis w/ HOD Model

$$\omega(\theta) = \int dz N^2(z) \left(\frac{dr}{dz}\right)^{-1} \int dk \frac{k}{2\pi} P_g(k, z) J_0[r(z)\theta k].$$

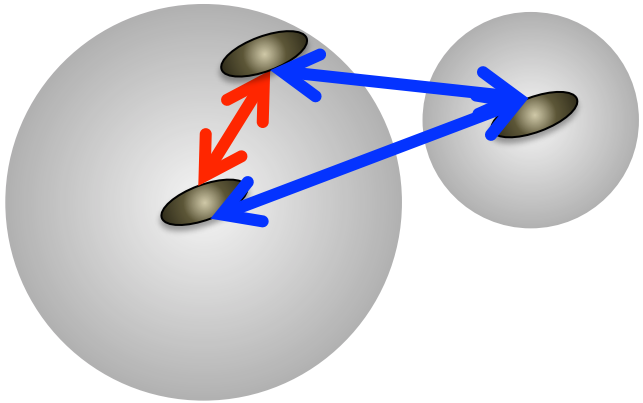
Angular correlation function (observed clustering strength)

$$dP = n^2[1 + \omega(\theta)]d\Omega_1 d\Omega_2$$

Galaxy power spectrum from halo occupation distribution (HOD) model (function of M_h)

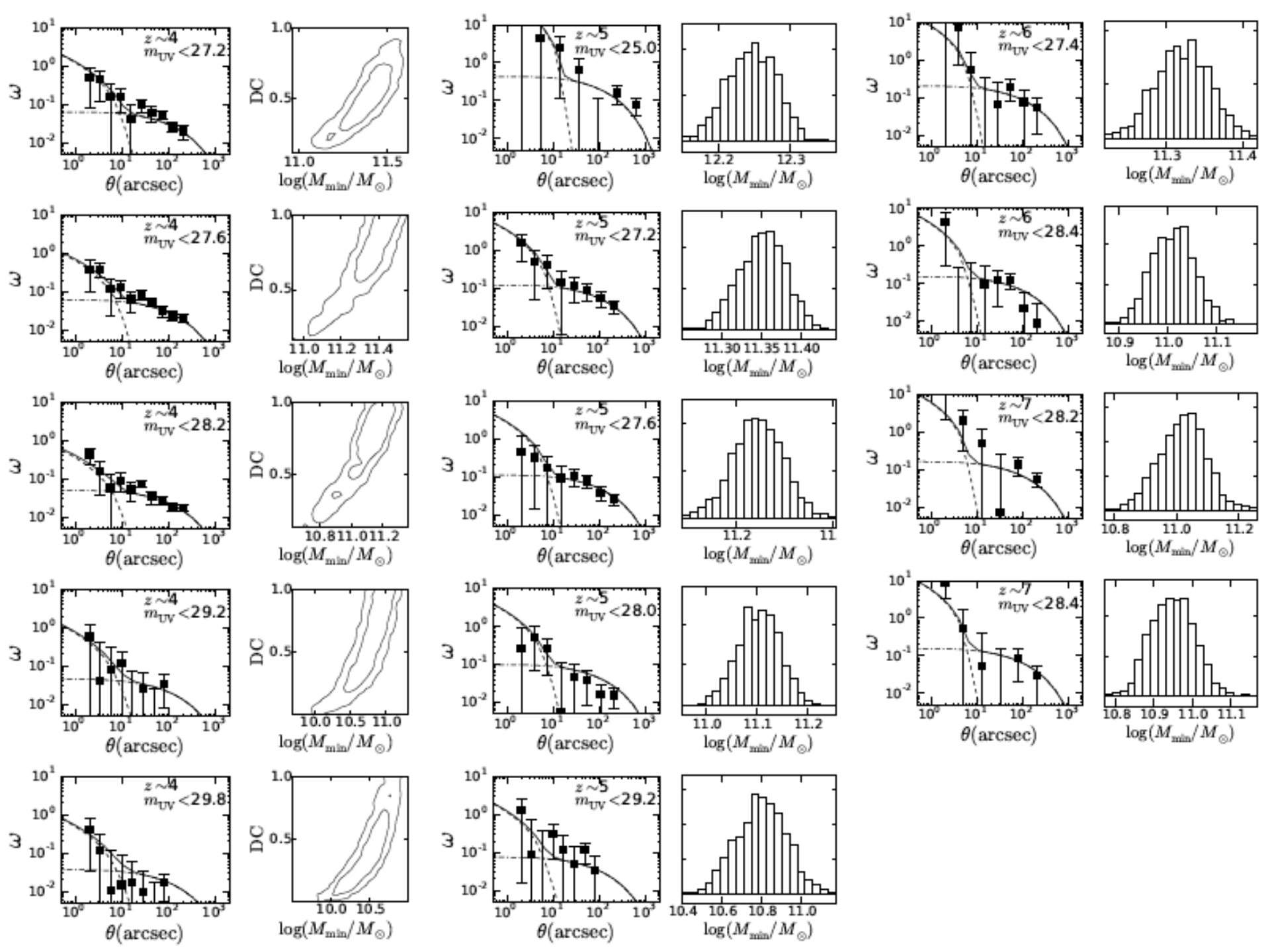


HOD model



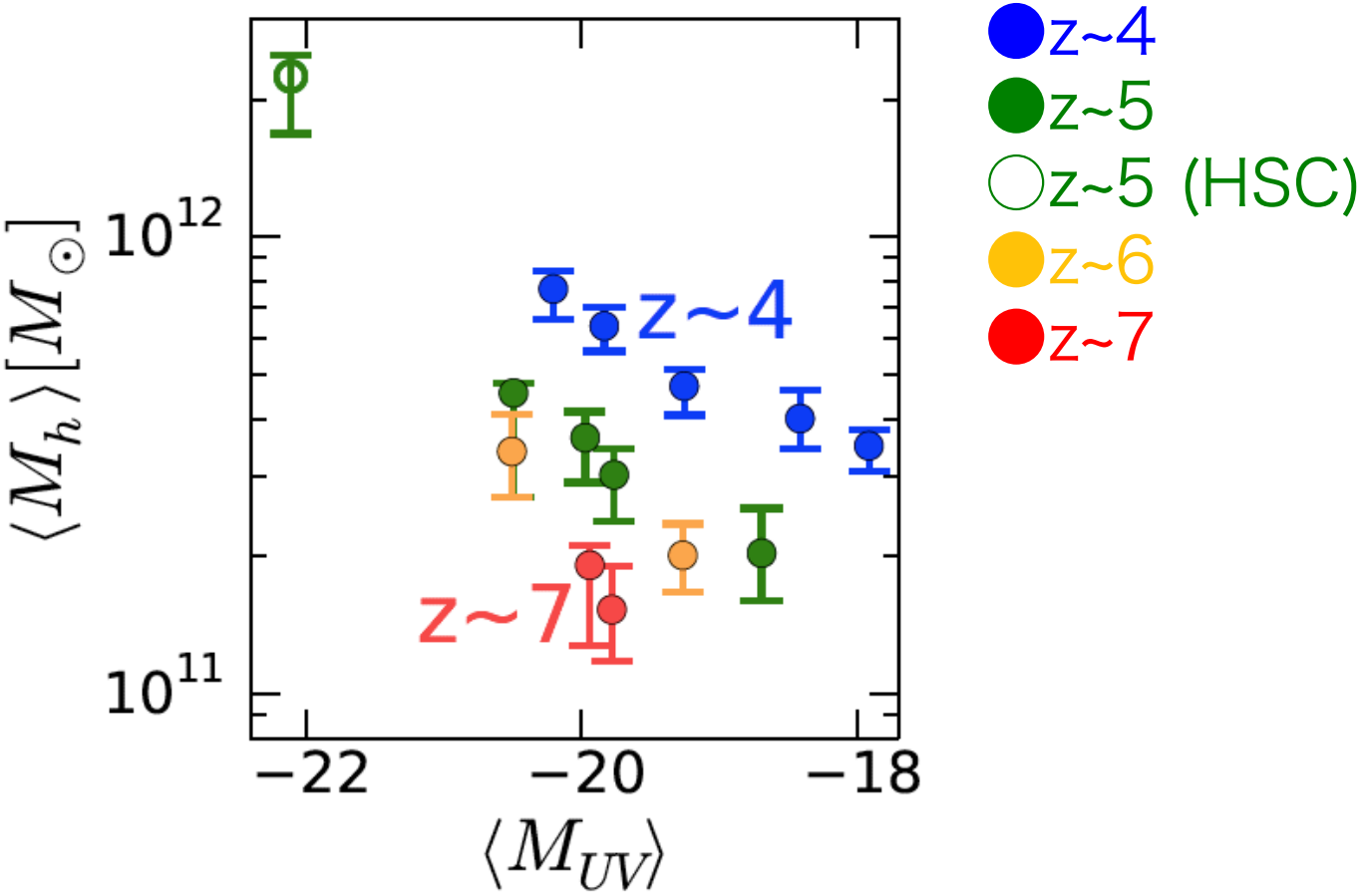
$$P_g^{2h} = P_m(k,z)\left[\frac{1}{n_g}\int dM N(M)\frac{dn}{dM}(M,z)b_h(M,z)u(k,M)\right]^2$$

$$P_g^{1h} = \frac{1}{n_g^2}\int dM\left[N_s(M)N_s(M)u^2(k,M) + 2N_s(M)N_c(M)u(k,M)\right]\frac{dn}{dM}(M,z)$$


$z\sim4$ $m_{\rm UV}<27.2$
$z\sim4$ $m_{\rm UV}<27.6$
$z\sim4$ $m_{\rm UV}<28.2$
$z\sim4$ $m_{\rm UV}<29.2$
$z\sim4$ $m_{\rm UV}<29.8$
$z\sim5$ $m_{\rm UV}<25.0$
$z\sim5$ $m_{\rm UV}<27.2$
$z\sim5$ $m_{\rm UV}<27.6$
$z\sim5$ $m_{\rm UV}<28.0$
$z\sim5$ $m_{\rm UV}<29.2$
$z\sim6$ $m_{\rm UV}<27.4$
$z\sim6$ $m_{\rm UV}<28.4$
$z\sim7$ $m_{\rm UV}<28.2$
$z\sim7$ $m_{\rm UV}<28.4$
ω
θ(arcsec)
DC
$\log(M_{\rm min}/M_\odot)$

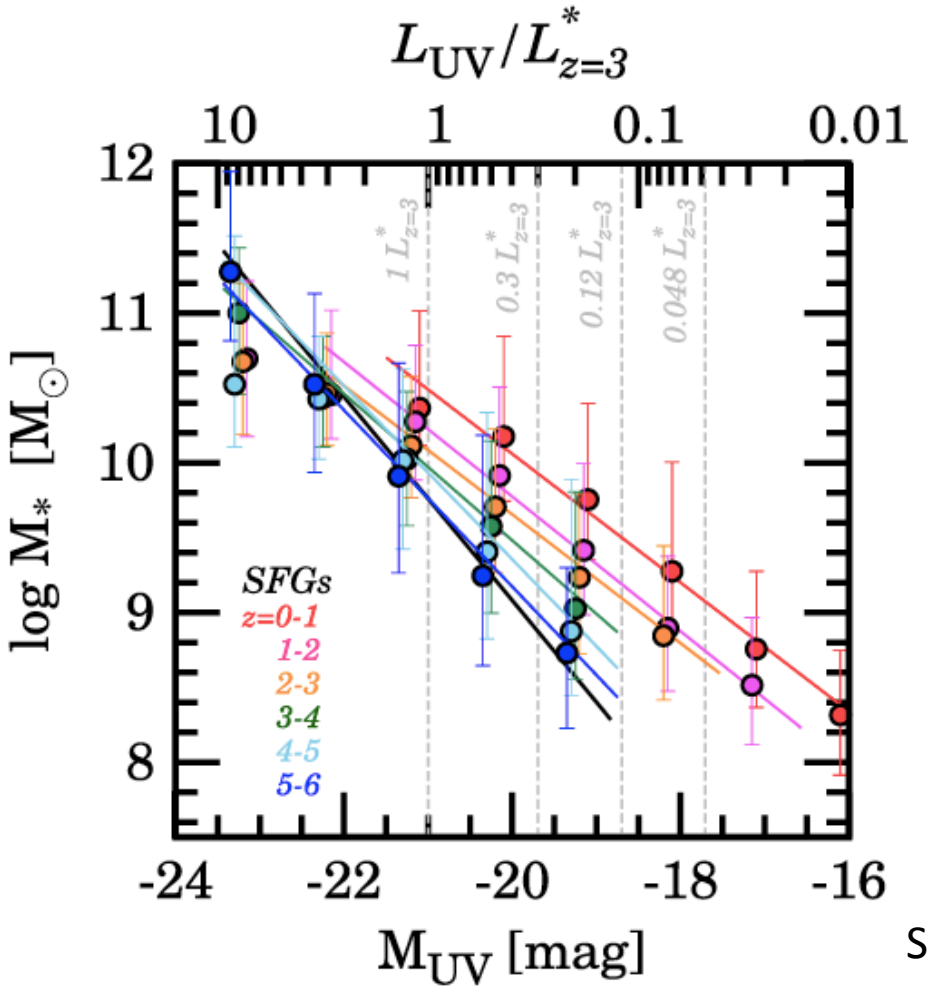
Dark Matter Halo Mass

- Hubble: M_h~10^{11}-10^{12} M_{sun}.
- Subaru/HSC: M_h>10^{12} M_{sun}.



Stellar Mass Estimate

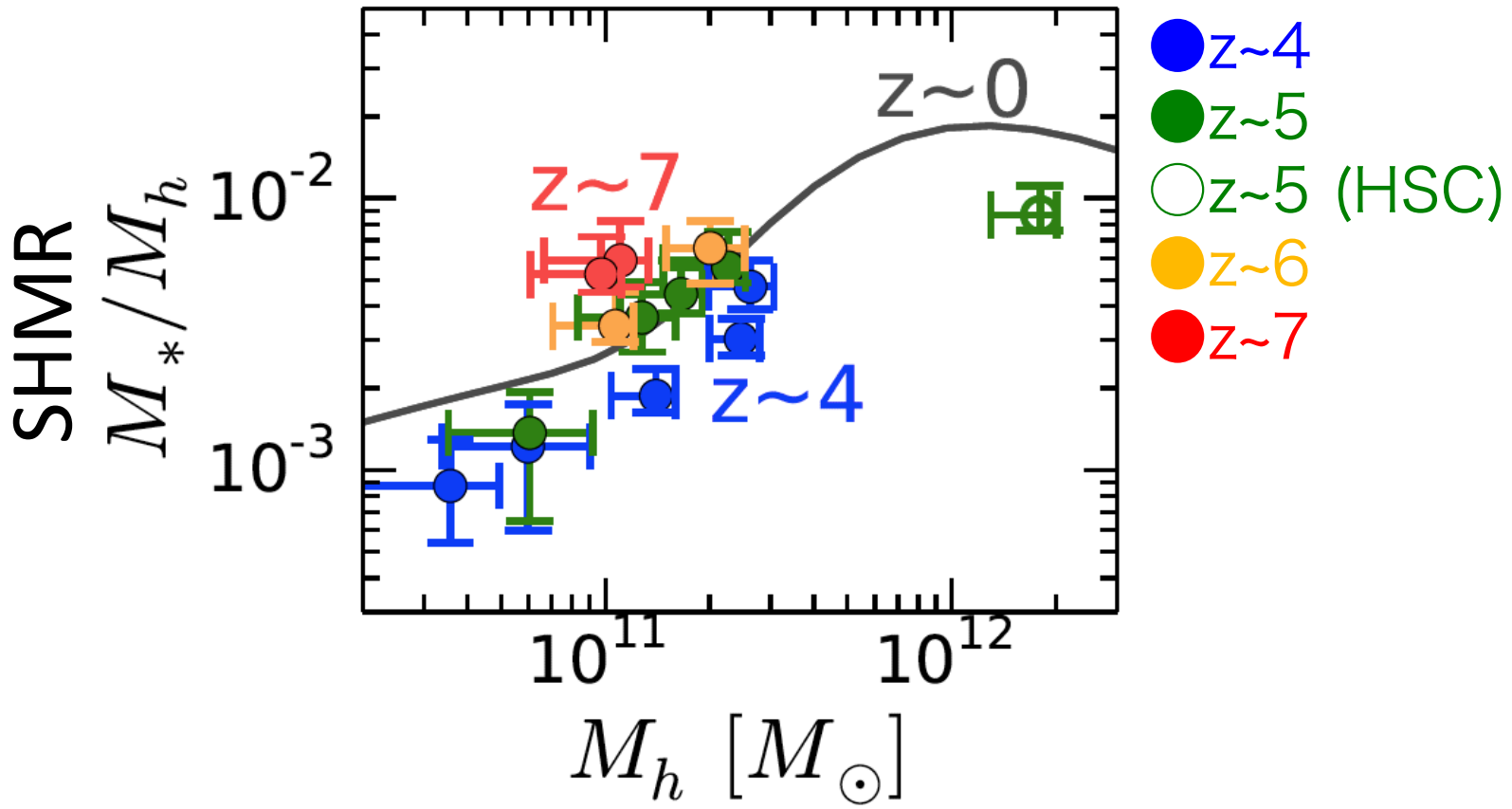
M_* from M_{UV} using the tight correlation at high-z



Shibuya, Ouchi & YH+15

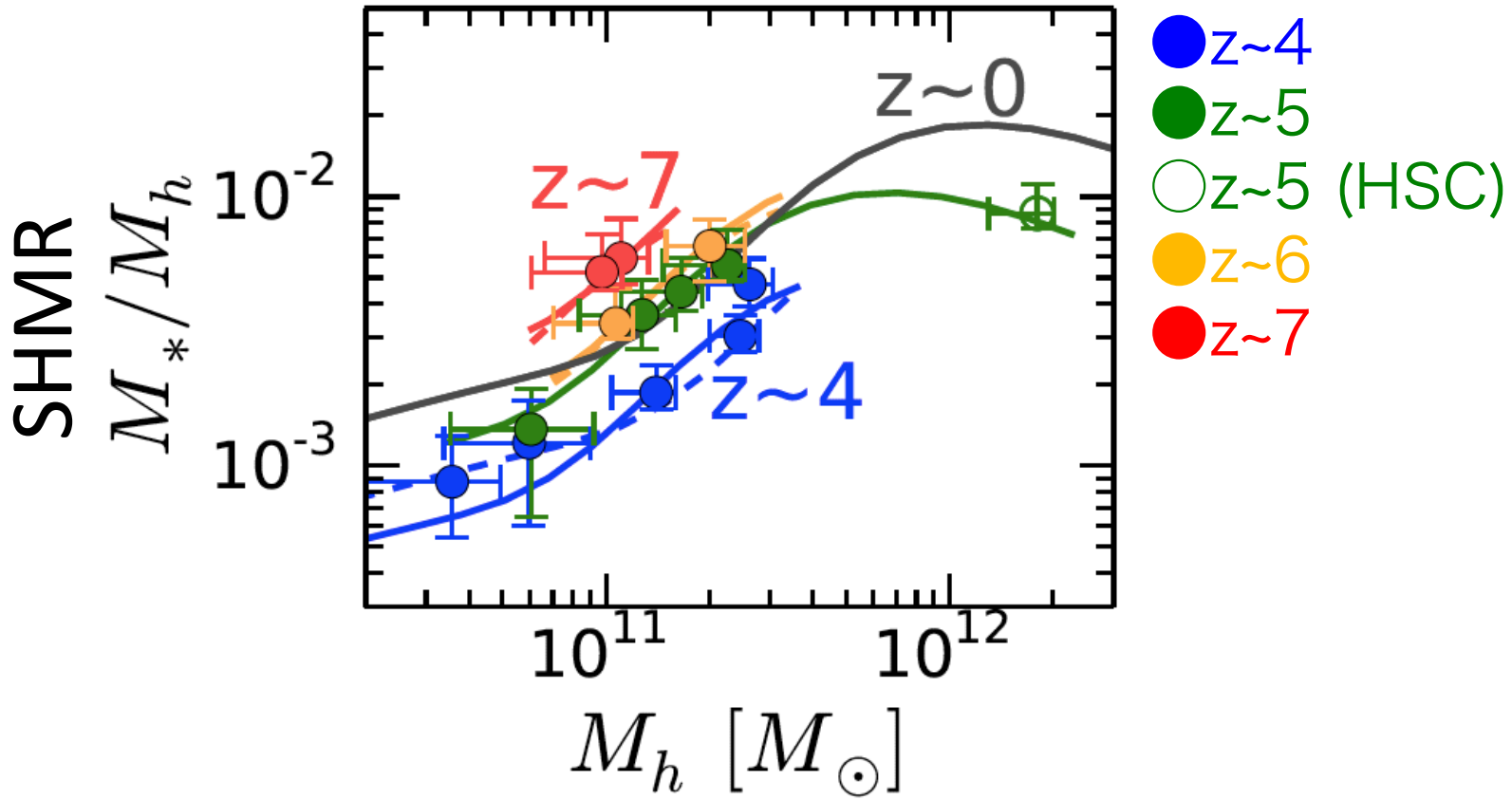
SHMR

- We estimate SHMR=M_*/M_h at z~4-7

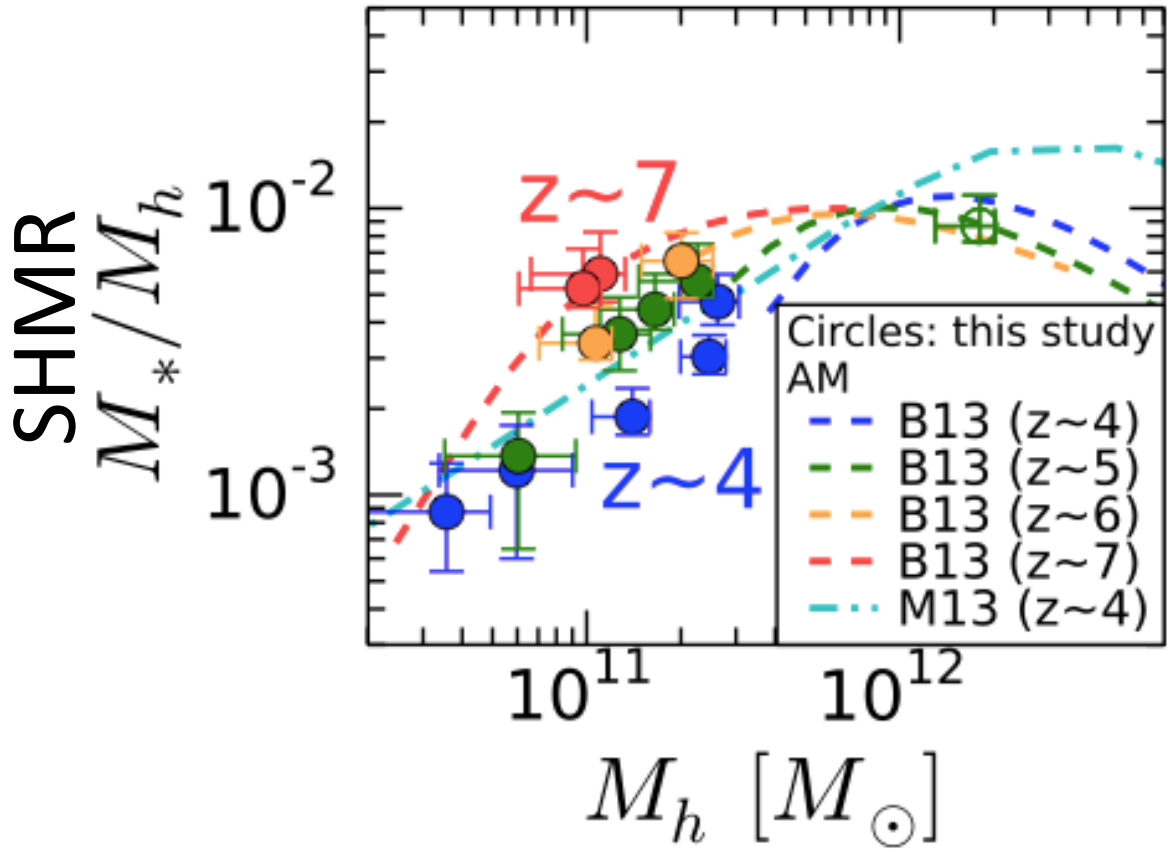


SHMR

- We estimate SHMR=M_*/M_h at z~4-7
- SHMR evolution w/ redshift is found (>98% CL)



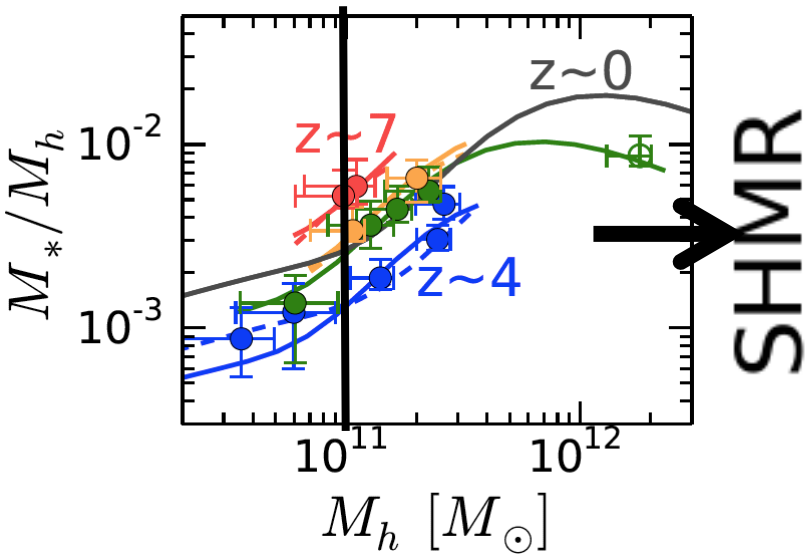
Comparison with AM



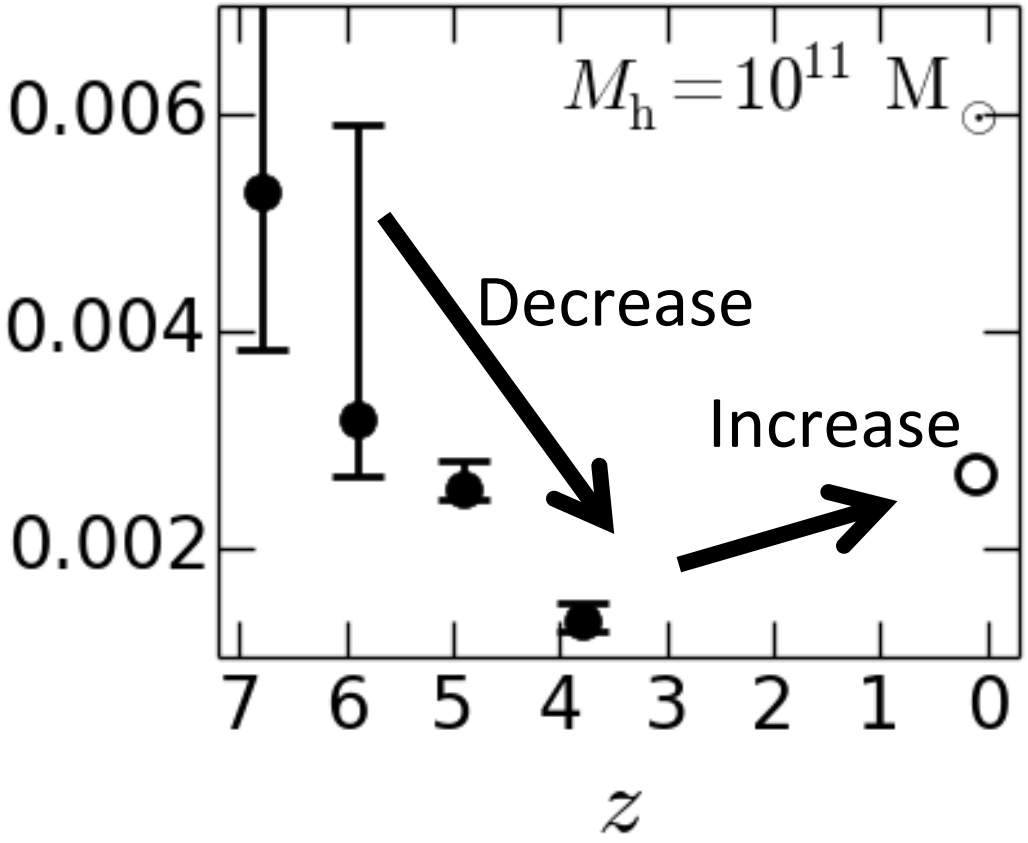
- The difference is up to a factor of ~3 in M_h.
  - AM is useful to estimate M_h of high-z galaxy, if one allows the systematic uncertainties up to a factor of 3.

Evolution of SHMR

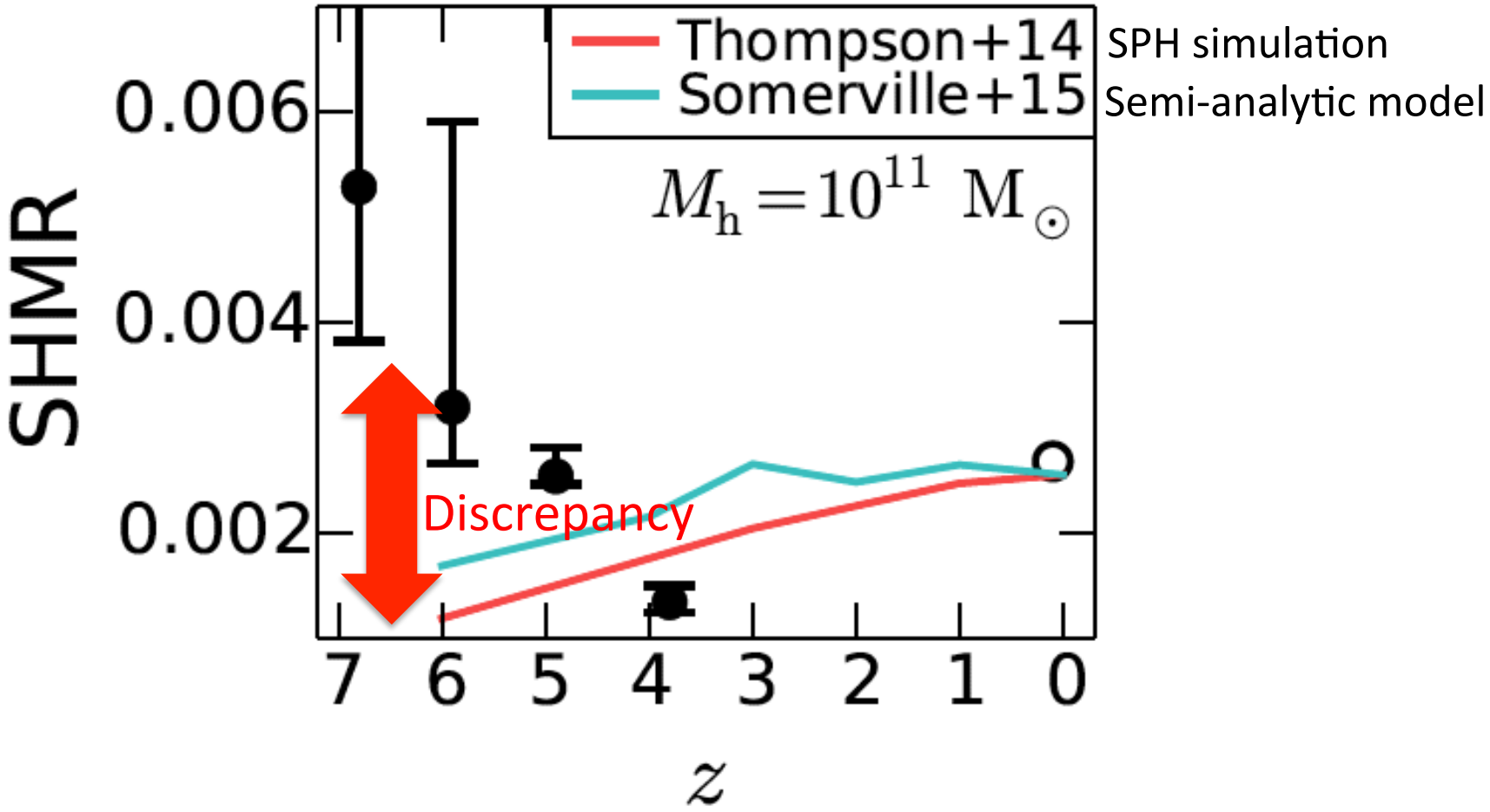
- SHMR (M_h=10^{11} M_{sun})
  - Decrease from z~7 to 4, increase from z~4 to 0



SHMR



Comparison with Theoretical Studies



- z~4->0: models reproduce our obs results
- z~7->4: models do not explain our obs results

Summary

1. SHMR evolution:
   decrease from z~7 to 4
   increase from z~4 to 0
   (>98%CL for M_h~$10^{11}M_{sun}$)
2. Our clustering results agree with the AM within a factor of 3 in M_h.
3. Theoretical models do not reproduce the SHMR evol at z~4-7.