Toward robustly extracting cosmological signals from ***PFS***: Lessons from ***BOSS***

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Kavli IPMU
(→ 2016年4月より Max Planck Institut für Astrophysik)

SS, Baldauf, Vlah, Seljak, Okumura, McDonald (2014)
SS, Leauthaud, Bundy et al., submitted to the BOSS ML
Leauthaud, Bundy, **SS** et al., submitted to the BOSS ML
Bundy, Leauthaud, **SS** et al., submitted to the BOSS ML

すばるPFSによるサイエンス検討会

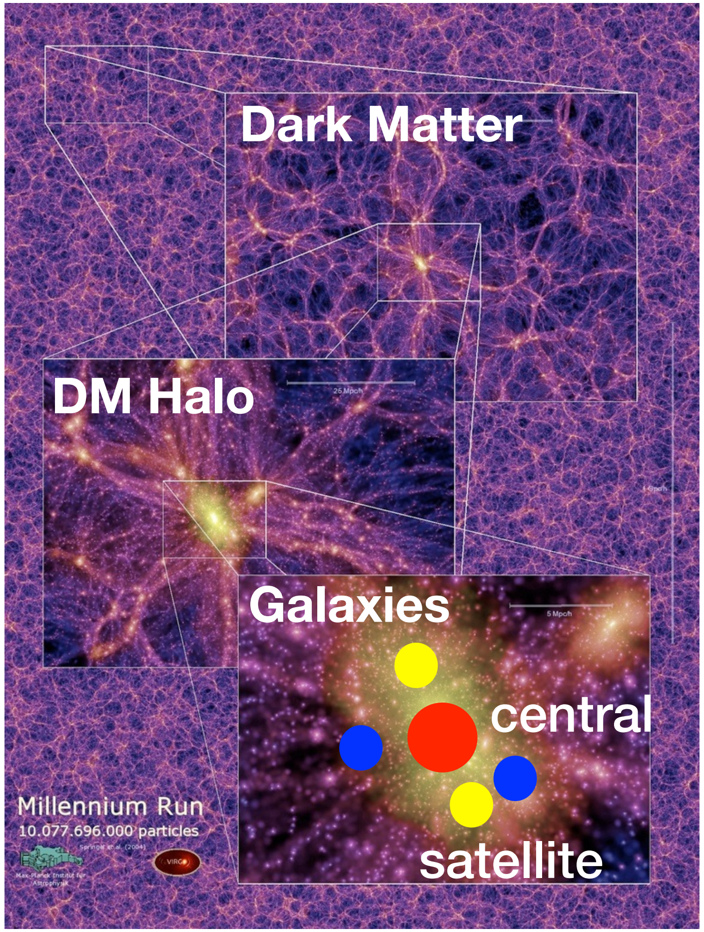
2015年7月9日(木)

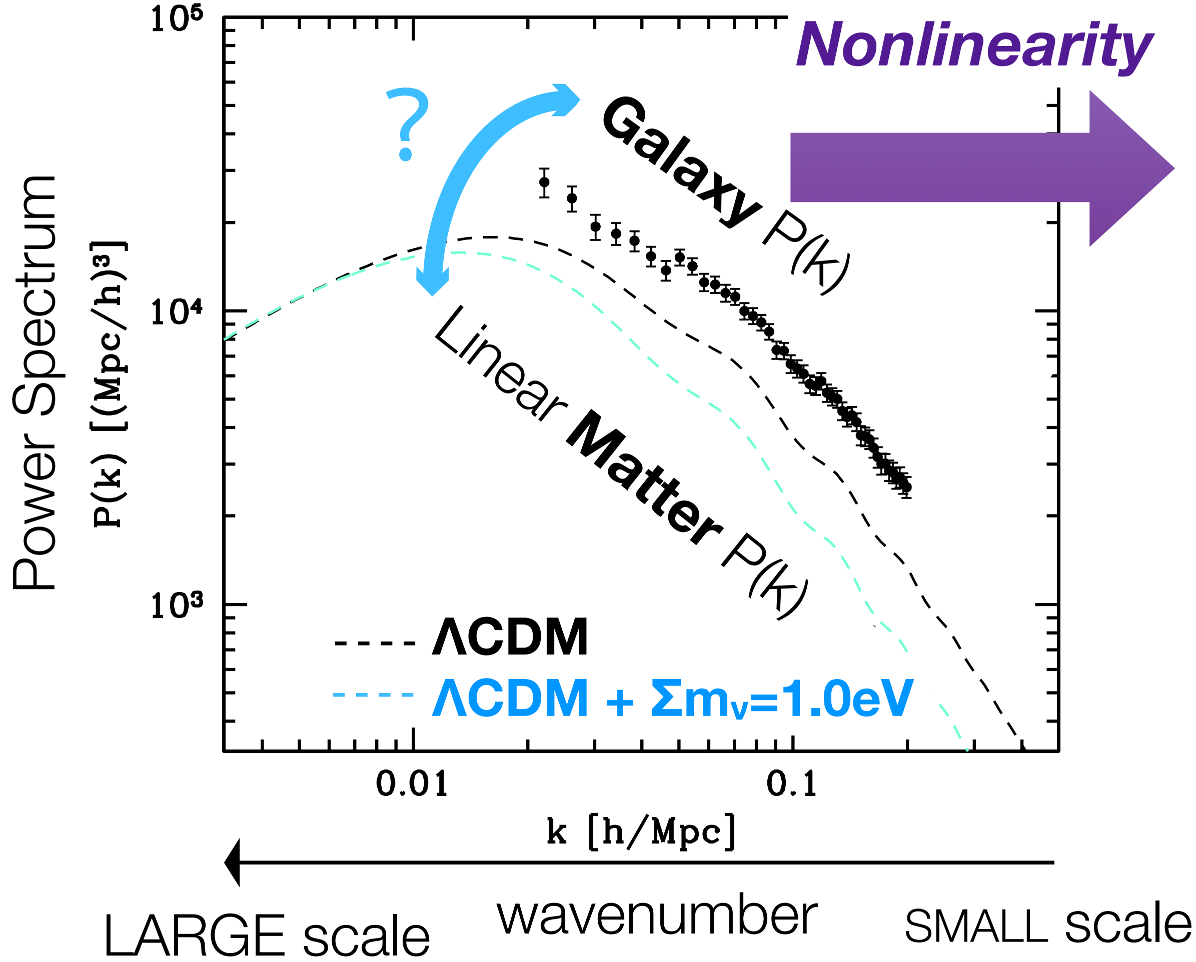
Cosmology ***BEYOND BAO***

✦ Galaxy traces underlying matter: $P_{\rm galaxy}(k) \approx b_1{}^2 P_{\rm matter}(k)$

- information on initial condition (**Inflation**) and **Neutrino mass**

e.g., Takada et al. (2006), **SS** et al. (2008,2009,2011), Zhao, **SS** et al. (2013)



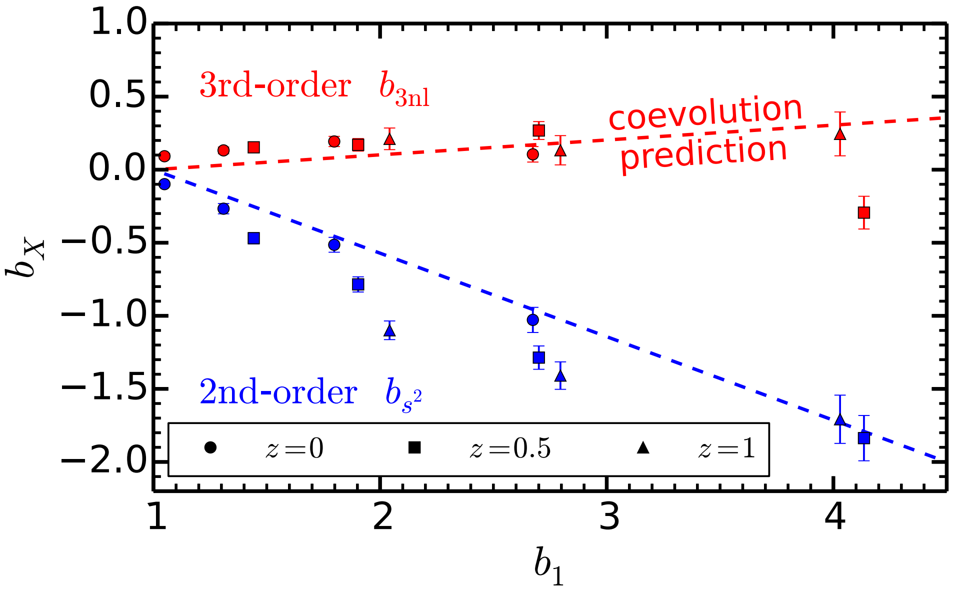


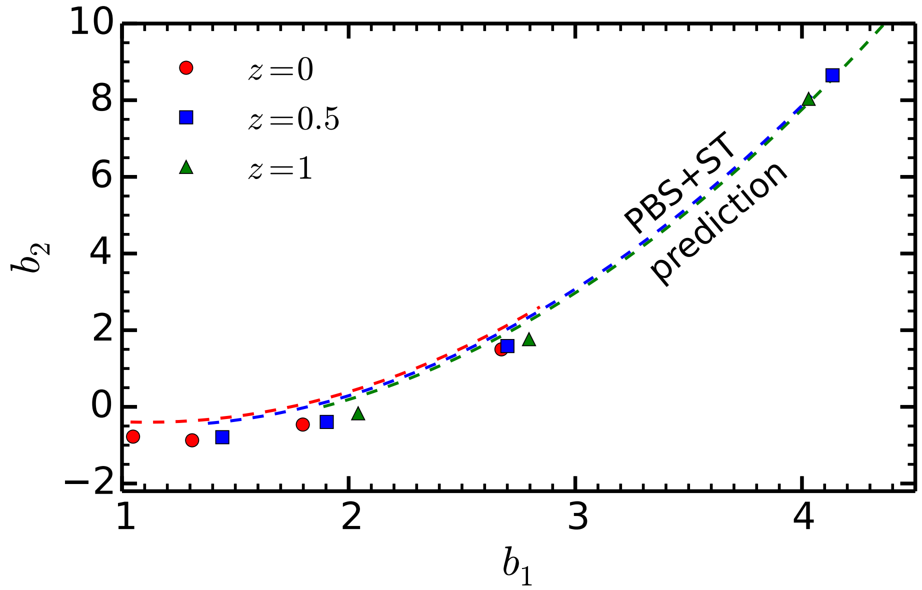
SS 天文月報 2011年8月号

Halo bias is hopefully predictable!

SS, Baldauf, Vlah, Seljak, Okumura, McDonald (2014)

✦ Even nonlinear bias, $b_X(M_{halo})$, could be modeled based on physics.





PHYSICAL REVIEW D **90,** 123522 (2014)

Understanding higher-order nonlocal halo bias at large scales by combining the power spectrum with the bispectrum

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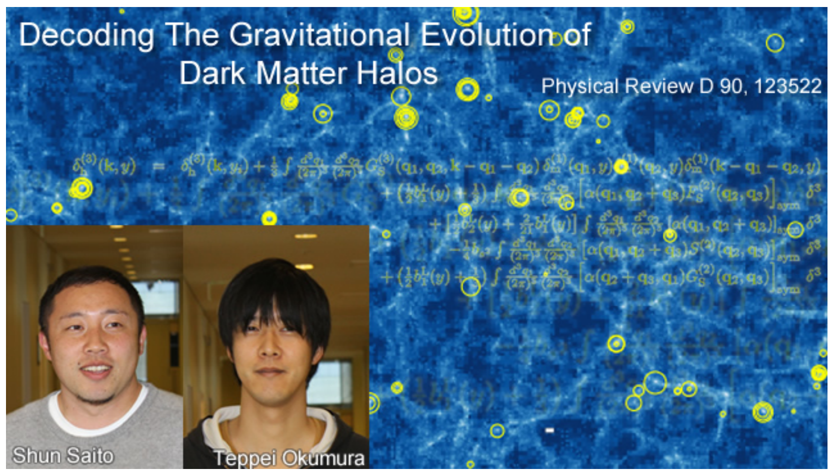
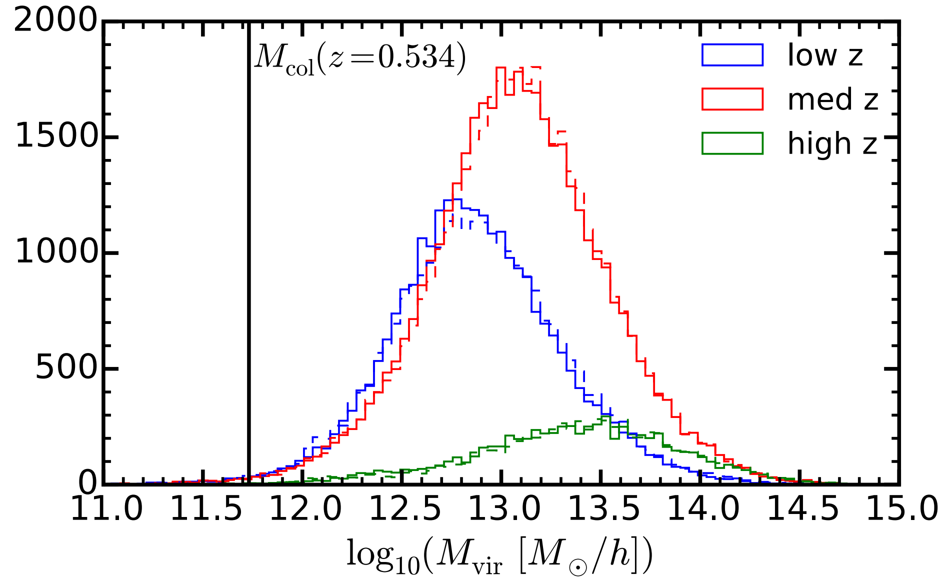


IPMU Press Release 2014年12月

Galaxy has a broad distribution

✦ Should know M_{halo} distribution

- broad range of M_{halo}



✦ *Stellar-to-Halo-Mass Relation (SHMR)*

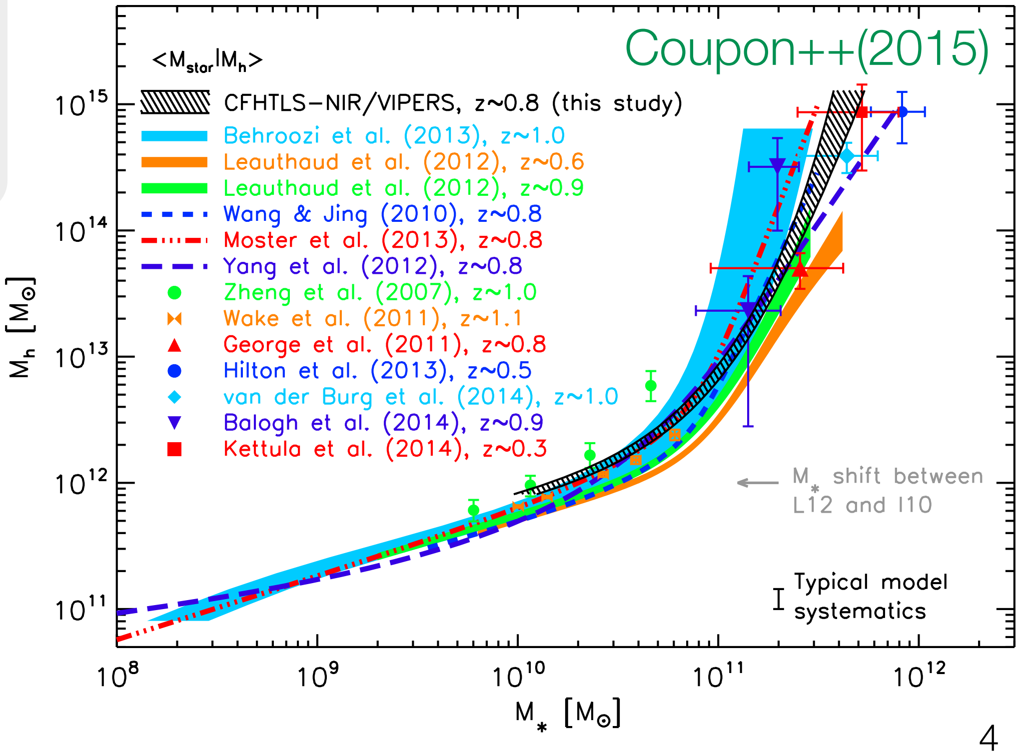
- tight correlation b/w M_* & M_{halo}

- desirable to obtain

Stellar-Mass-Limited Sample

&

halo-galaxy relationship

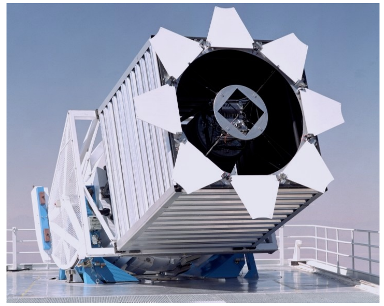


✦ Necessary to construct ***mocks***

✦ **Galaxy evolution science**

- Stellar Mass vs Halo Mass
- Color (SFR) vs Halo Assembly

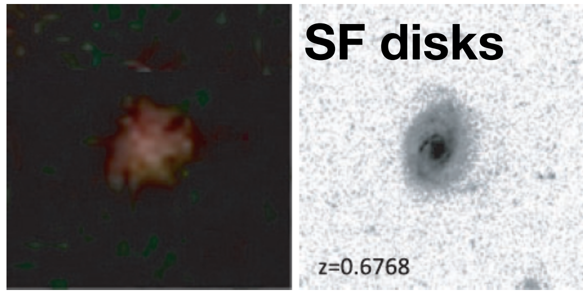
The BOSS CMASS sample



- **The Baryon Oscillation Spectroscopic Survey (BOSS)**
  - a part of SDSS-III (2009-2014) Eisenstein et al. (2011)
  - Two main cosmological samples: **LOWZ** (z~0.32) & **CMASS** (z~0.57)

- **CMASS** : ***"Constant Stellar Mass" sample***
  - redshift range: **0.43 < z < 0.70**
  - DR12: 836,347 galaxies over 10,252 deg^2
  - designed to be *complete* at $\log(M_*/M_\odot) \gtrsim 11.3$ Maraston et al. (2013)
  - not all dead and red
    - ~25% has a SF disk Masters et al. (2011)
    - ~37% belongs to an intrinsically blue cloud

Montero-Dorta et al. (2014)



- **Stripe82 Massive Galaxy Catalog (S82-MGC)** Bundy et al. (in prep)
  - SDSS Co-Adds photometric catalog (~2mag deeper) over 139.4 deg^2
  - Combined with UKIDSS NIR bands, obtained more robust M_* estimates

Halo Occupation Distribution

✦ The most popular method to link galaxies with halos. Berlind & Weinberg (2002) etc

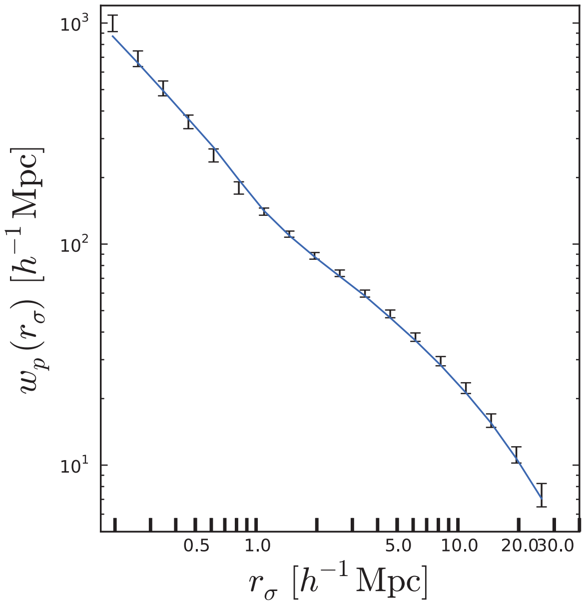
✦ focus on modeling the **full** CMASS sample.
c.f.) for subsample, see Miyatake et al. (2015), More et al. (2015), Guo et al. (2013,2014) etc

✦ How it works:

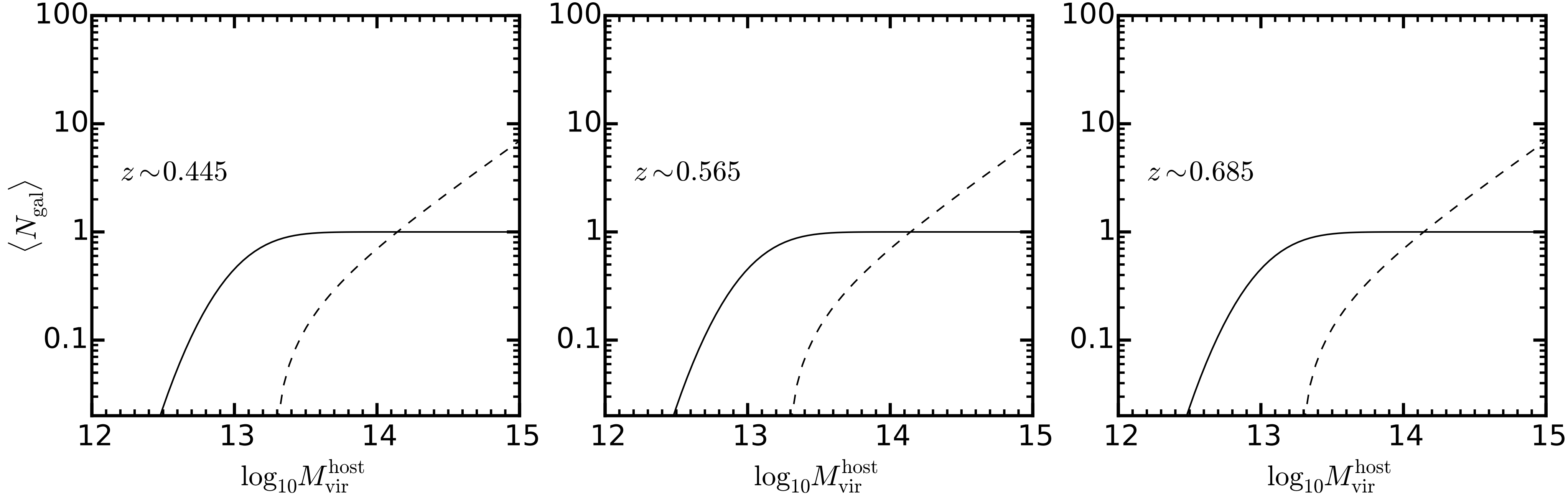
1) assume a functional form P(N_{gal}|M_{halo}) for central and satellite HODs
2) determine the HOD parameters to reproduce $w_p(r_p)$ or 3D correlation function or gal-gal lensing

$$w_p(r_p) = 2\int_0^{r_{\pi,\max}} dr_\pi \, \xi(r_p, r_\pi)$$

3) randomly down sample to reproduce dn/dz



Halo Occupation Distribution



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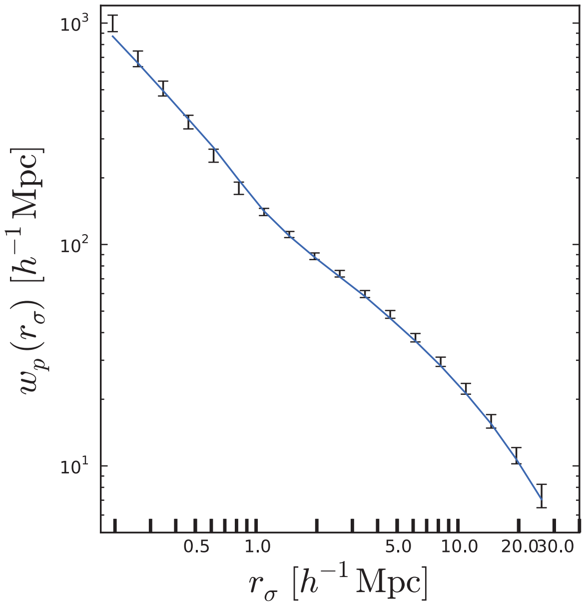

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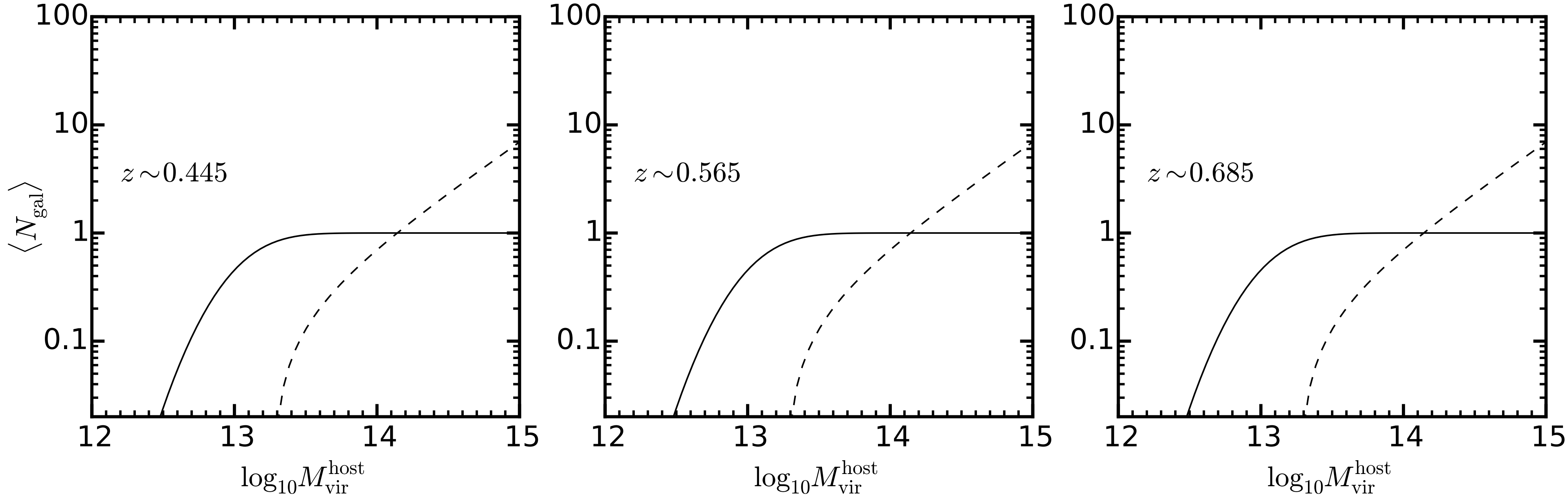

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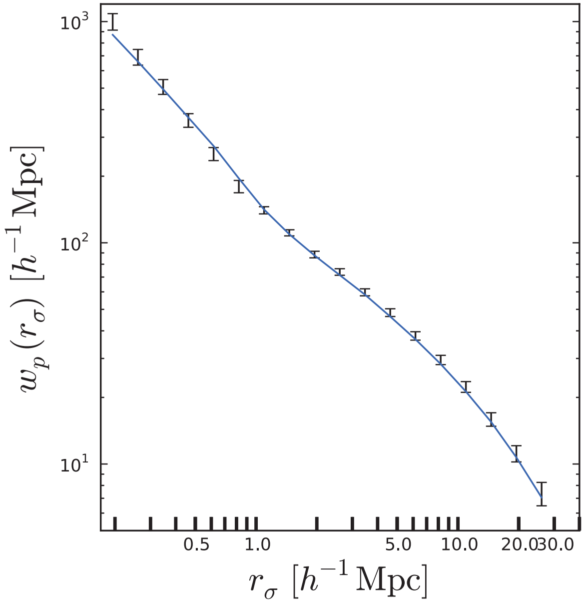

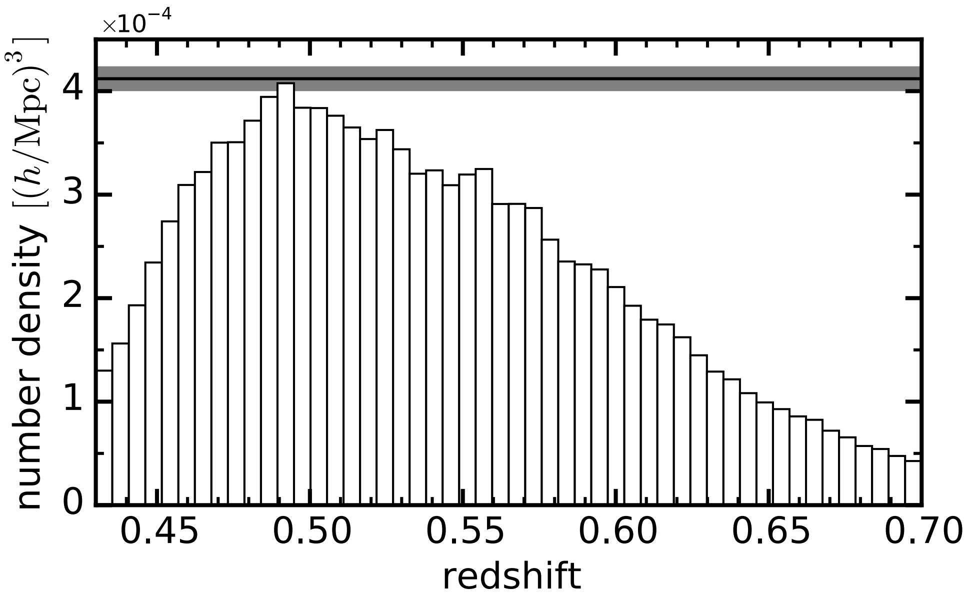

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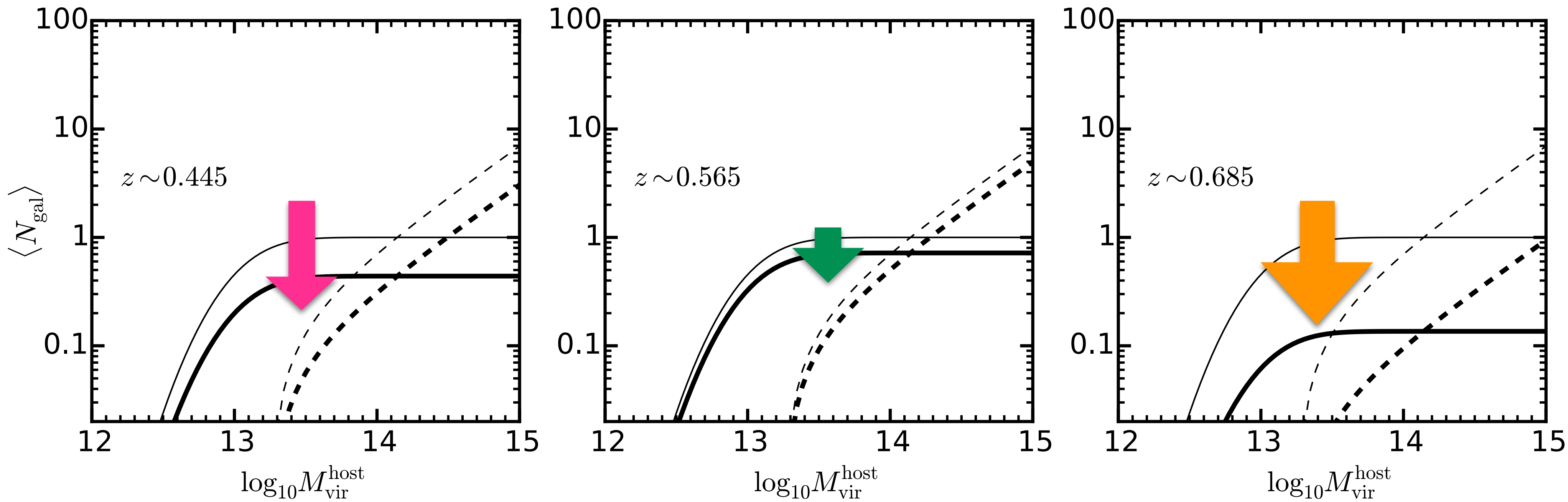

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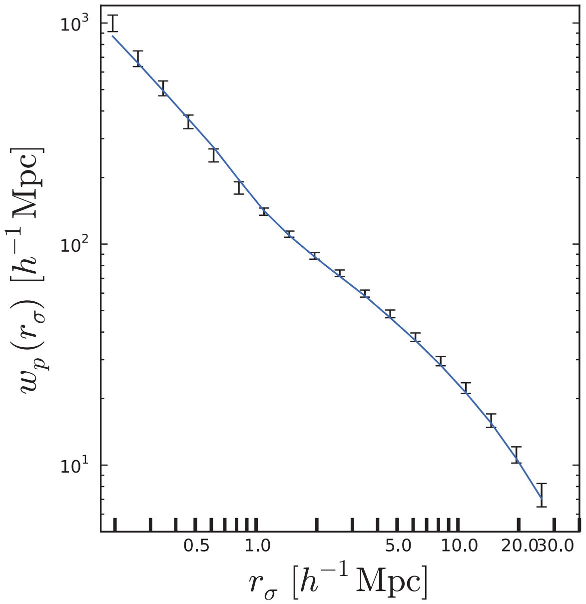
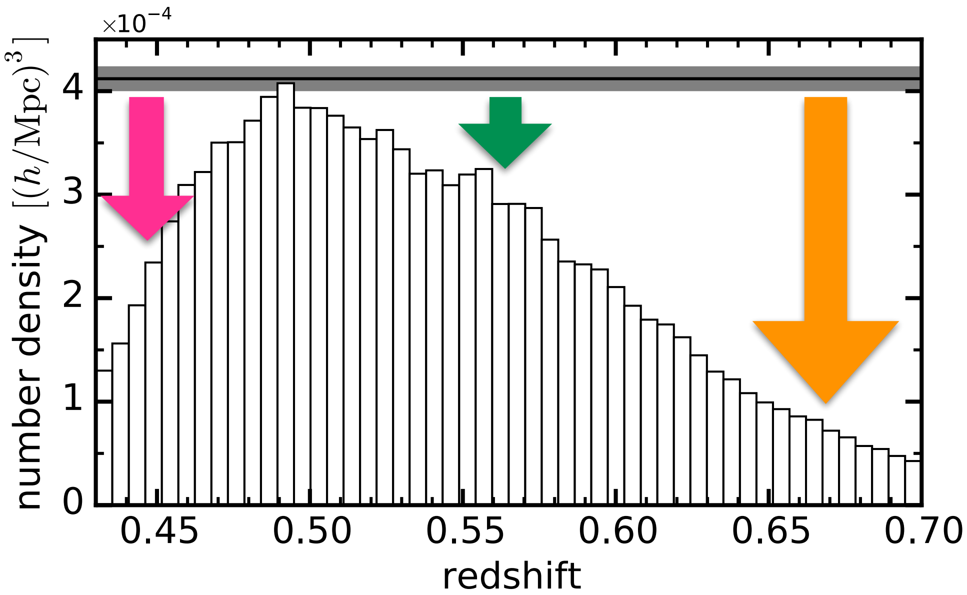
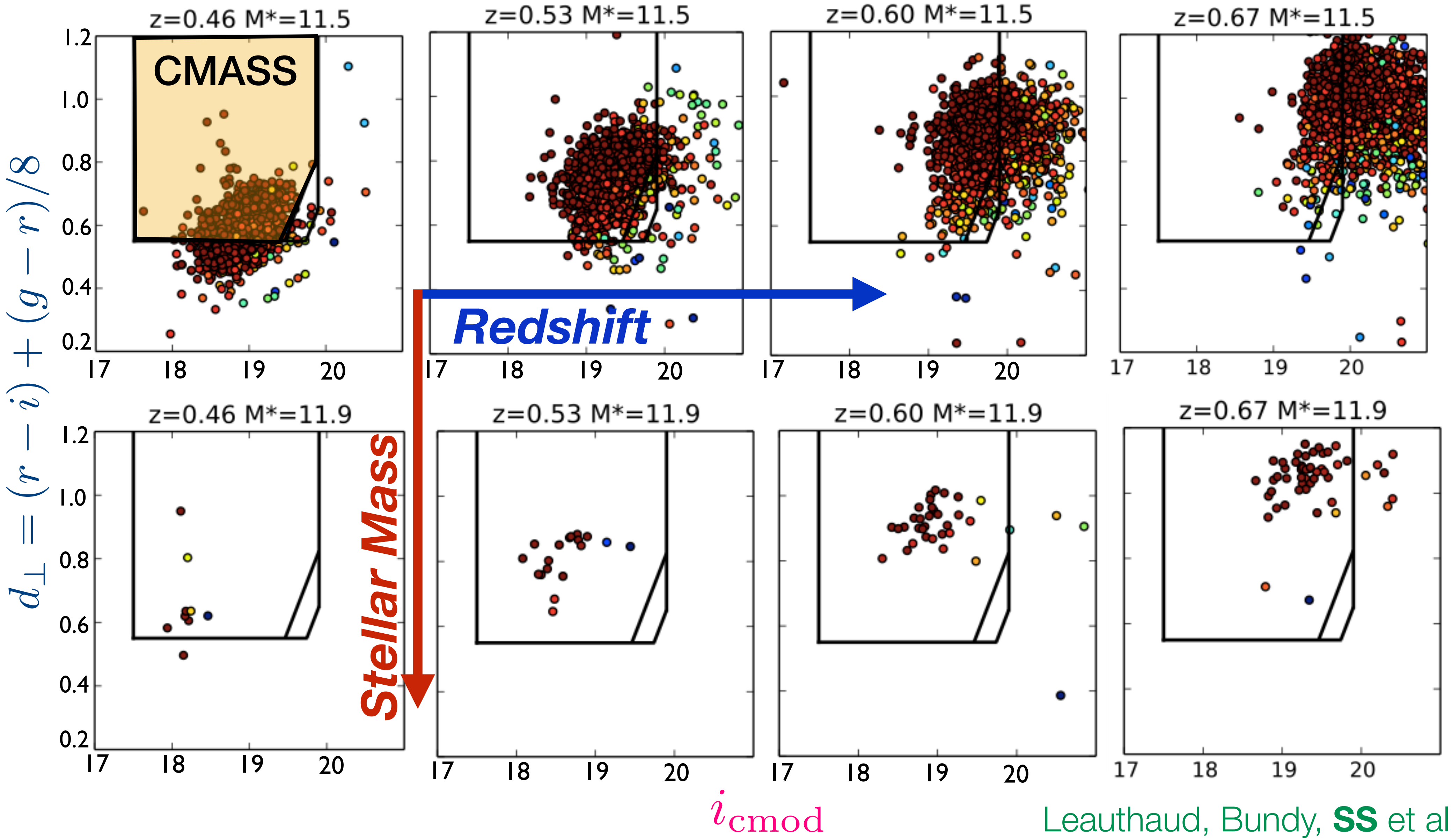




Incompleteness of the CMASS sample

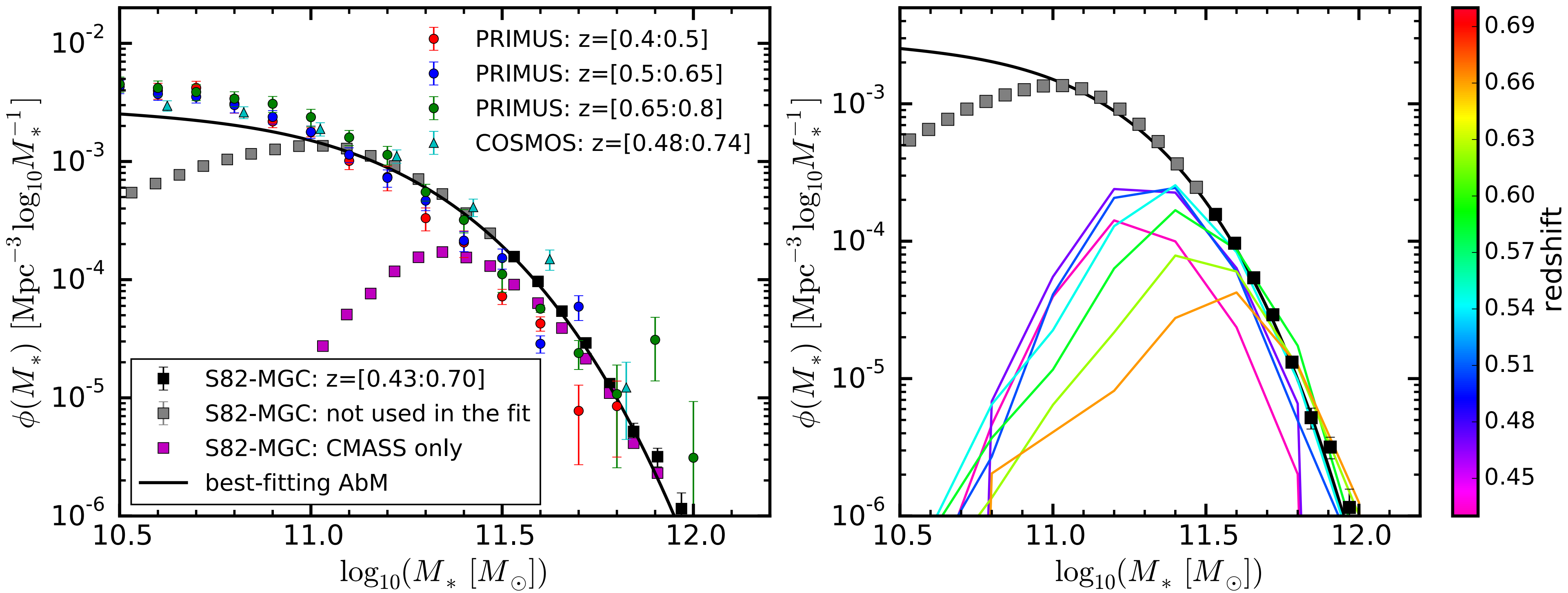


Leauthaud, Bundy, **SS** et al.

✦ The **color cut** dominates at **low z**, while the **luminosity cut** does at **high z**.

S82-MGC Stellar Mass Function

SS, Leauthaud, Bundy et al.



- ***S82-MGC*** provides the best constraint at high mass, $\log(M_*/M_\odot) \gtrsim 11.5$ and is complete at $\log(M_*/M_\odot) \gtrsim 11.3$

- The selection effect makes ***the CMASS SMFs redshift dependent***.

Our approach based on SHAM

✦ **The Subhalo Abundance Matching (SHAM)** e.g. Kravtsov et al. (2004) etc

*"a **brighter galaxy** tends to be hosted by a **more massive (sub)halo**"*

$$n_{\rm gal}(>M_*) = n_{\rm halo}(>V_{\rm peak})$$

Reddick et al. (2013)

Here we assume a global SMFs for "total" galaxies as

double Schechter function

$$\phi(M_*;\phi_1,\alpha_1,\phi_2,\alpha_2,M_0) = \left\{\phi_1 10^{(\alpha_1+1)(\log M_* - \log M_0)} + \phi_2 10^{(\alpha_2+1)(\log M_* - \log M_0)}\right\} (\ln 10) \exp\left[-\frac{M_*}{M_0}\right]$$

→

convolved with log-normal scatter

$$\phi_{\rm conv}(M_*;\phi_1,\alpha_1,\phi_2,\alpha_2,M_0,\sigma) = \int dm \frac{\phi(M_*;\phi_1,\alpha_1,\phi_2,\alpha_2,M_0)}{\sqrt{2\pi}\sigma} \exp\left[-\frac{(m-\log M_*)^2}{2\sigma^2}\right]$$

✦ Pros & Cons

◯ less free parameters, no need to calibrate the nonlinearities e.g. Tinker et al. (2012)

◯ straightforward to implement the selection effect

◯ can incorporate the conditional abundance matching dabbed ***Age Matching***
Hearin et al. (2013,2014) etc, see also Masaki et al. (2013) Yamamoto et al. (2015)

✖ need to rely on the subhalo catalog in *N*-body simulation

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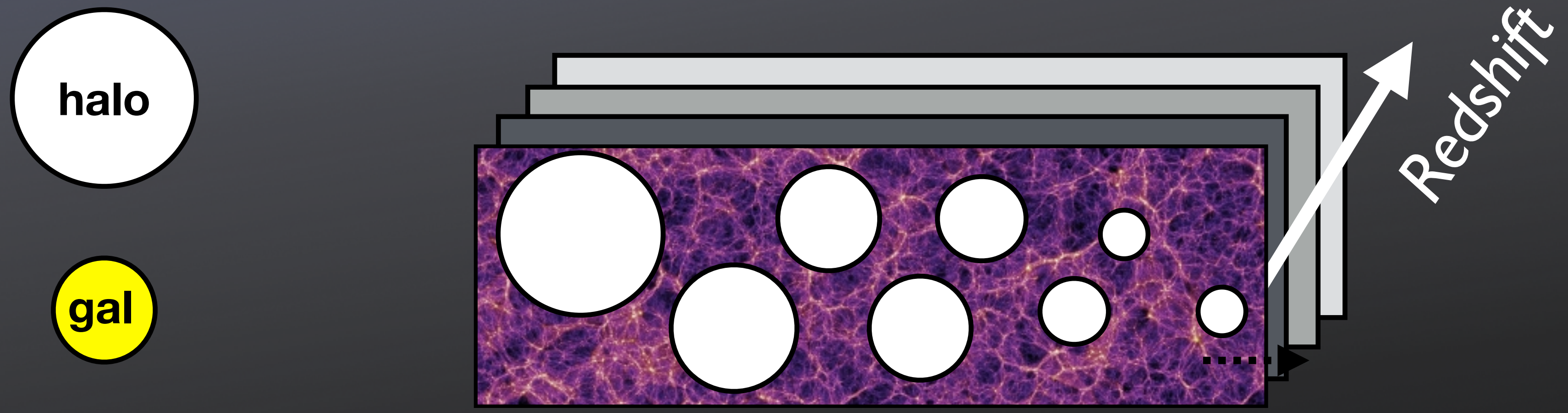
1 (Gpc/h)^3 Multidark *N*-body Simulation



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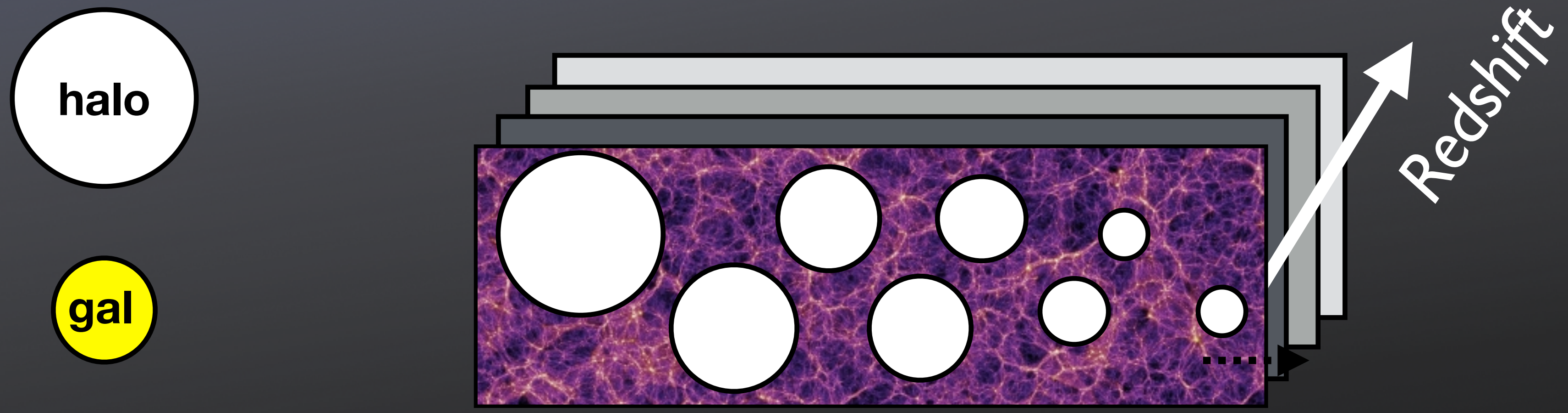
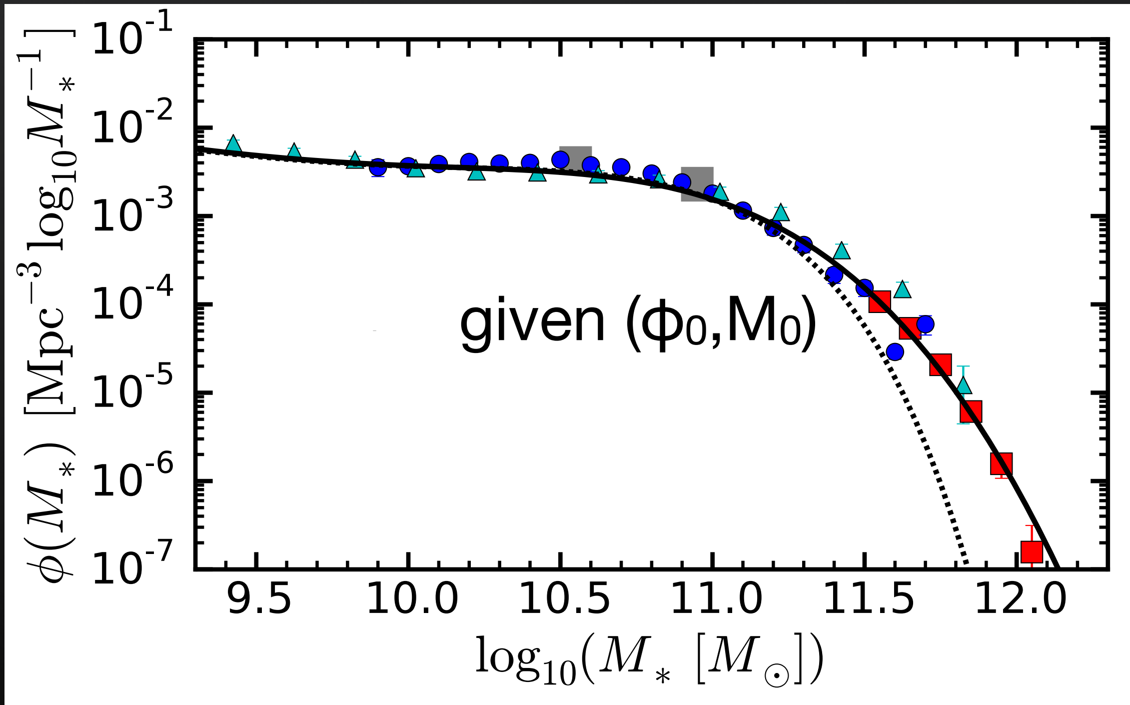


<u>Step 1</u>: Determine Mass Function and abundance match (V_{peak})



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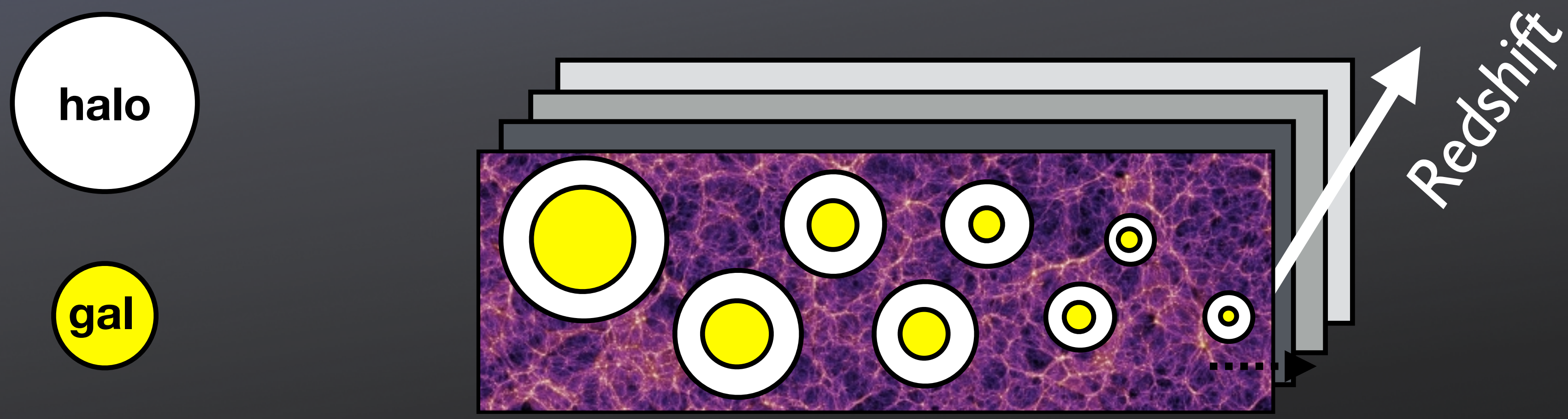

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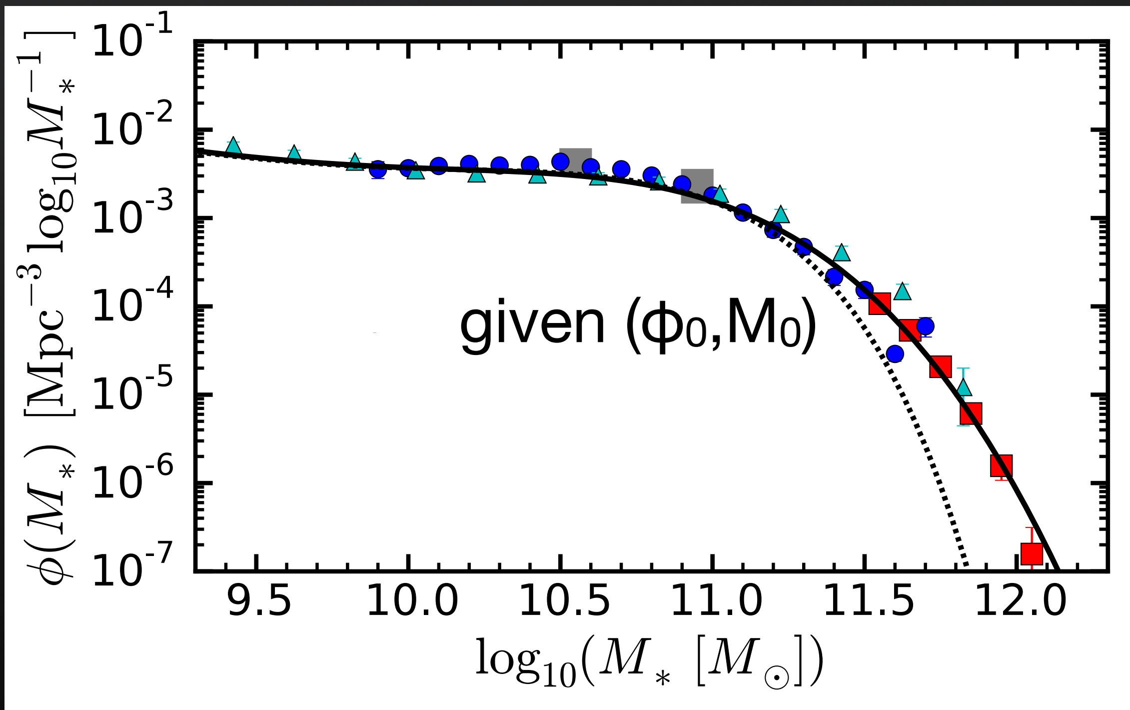

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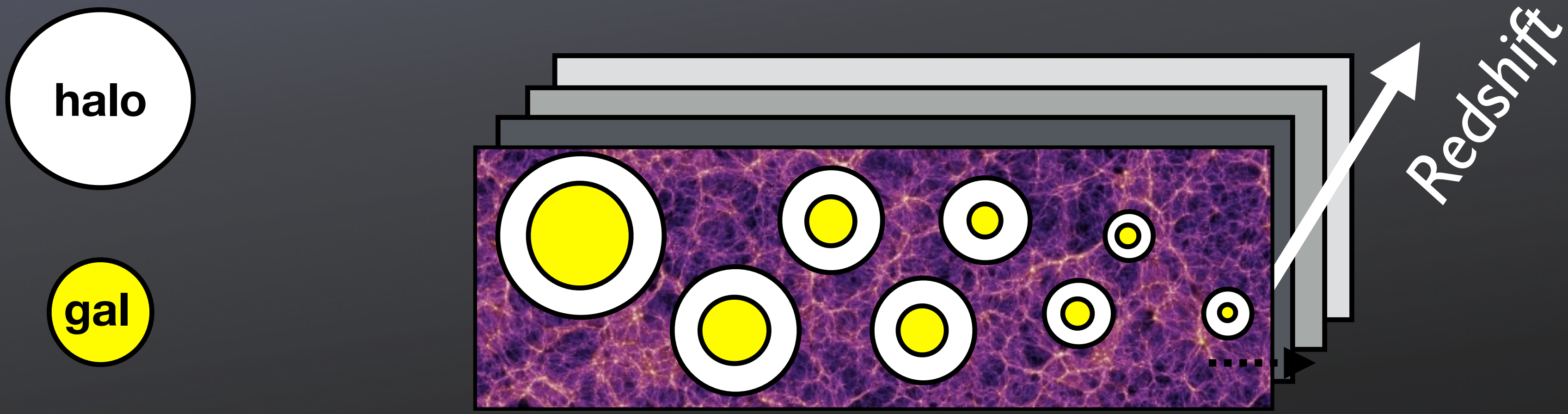

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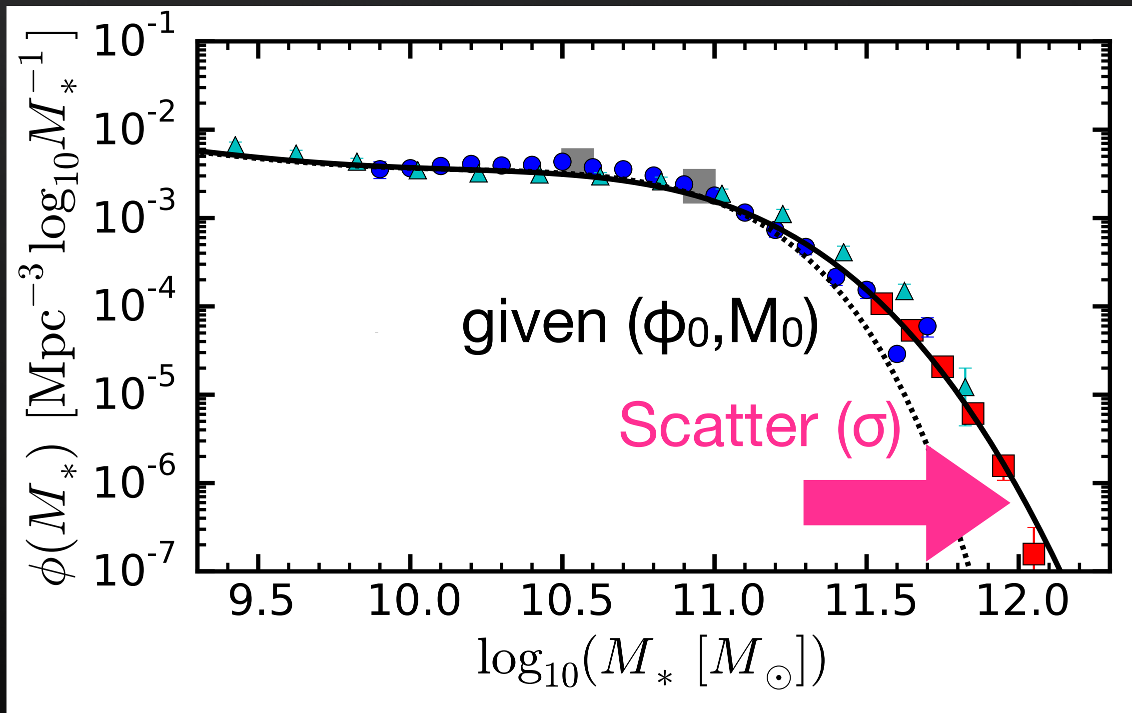

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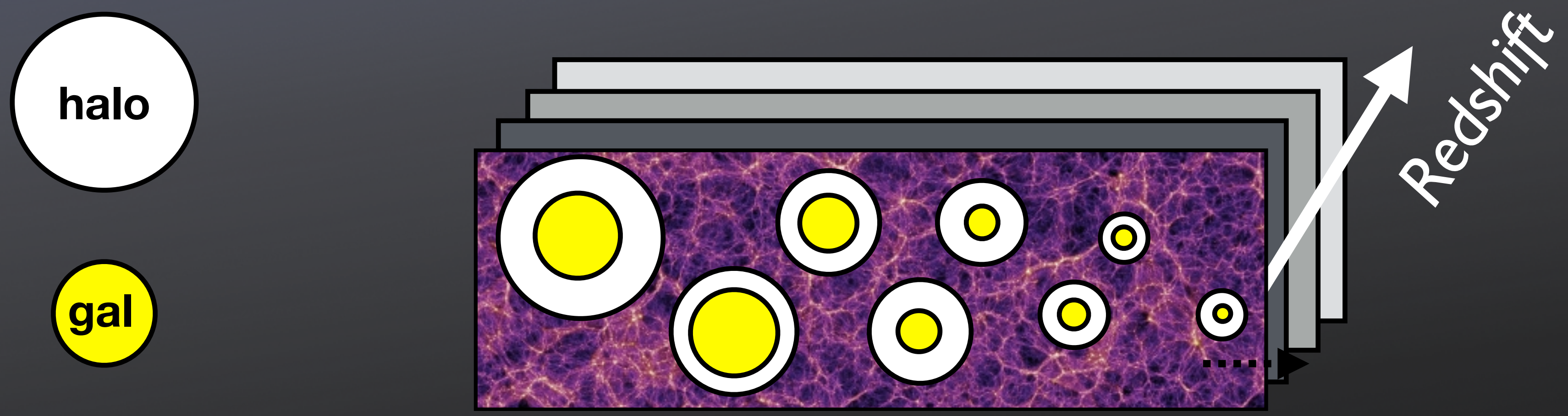

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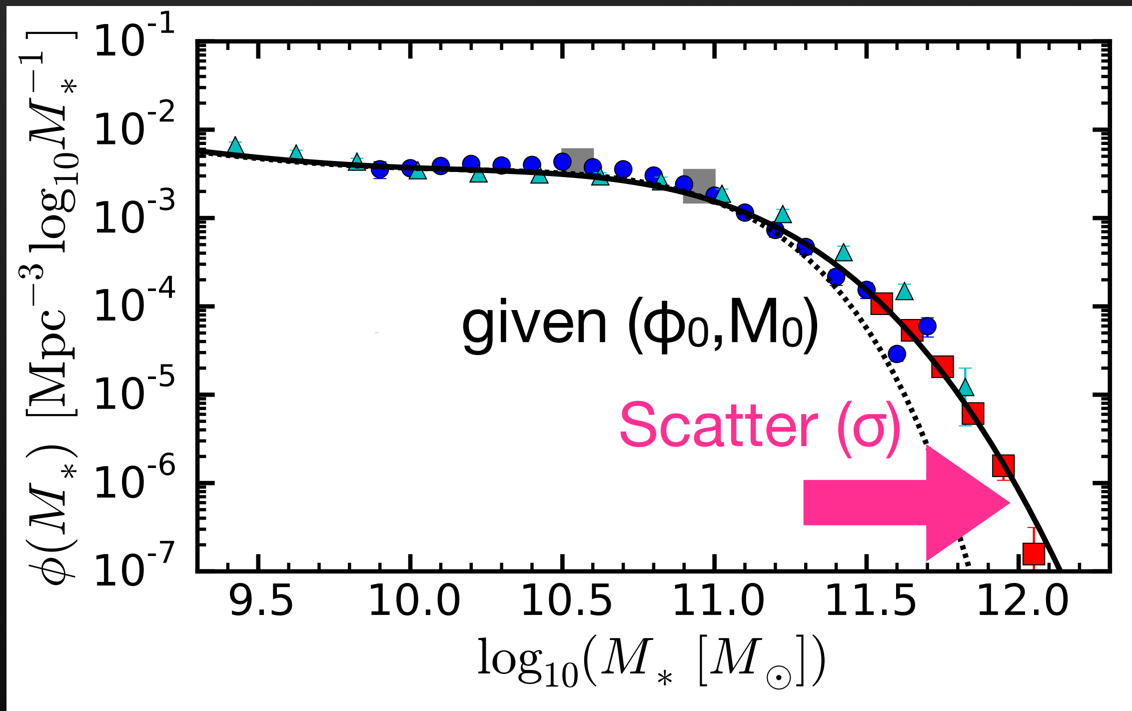

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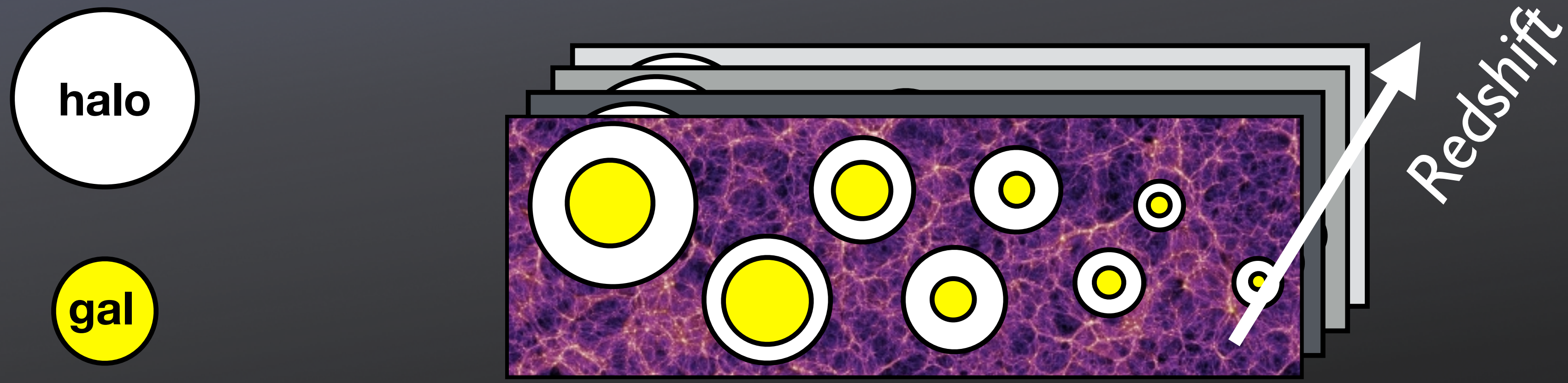
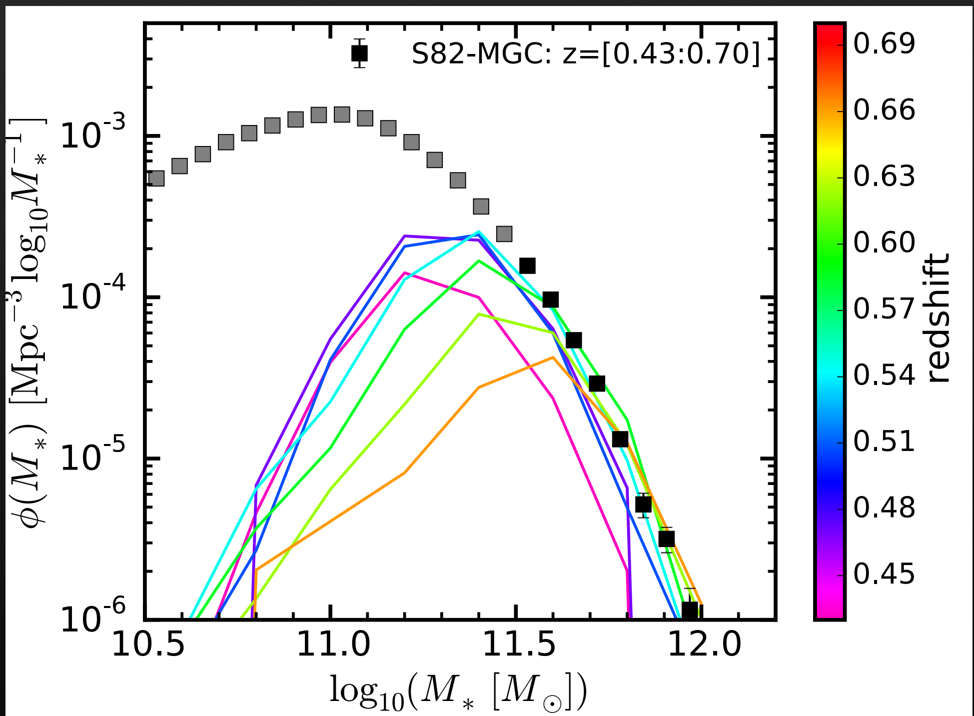
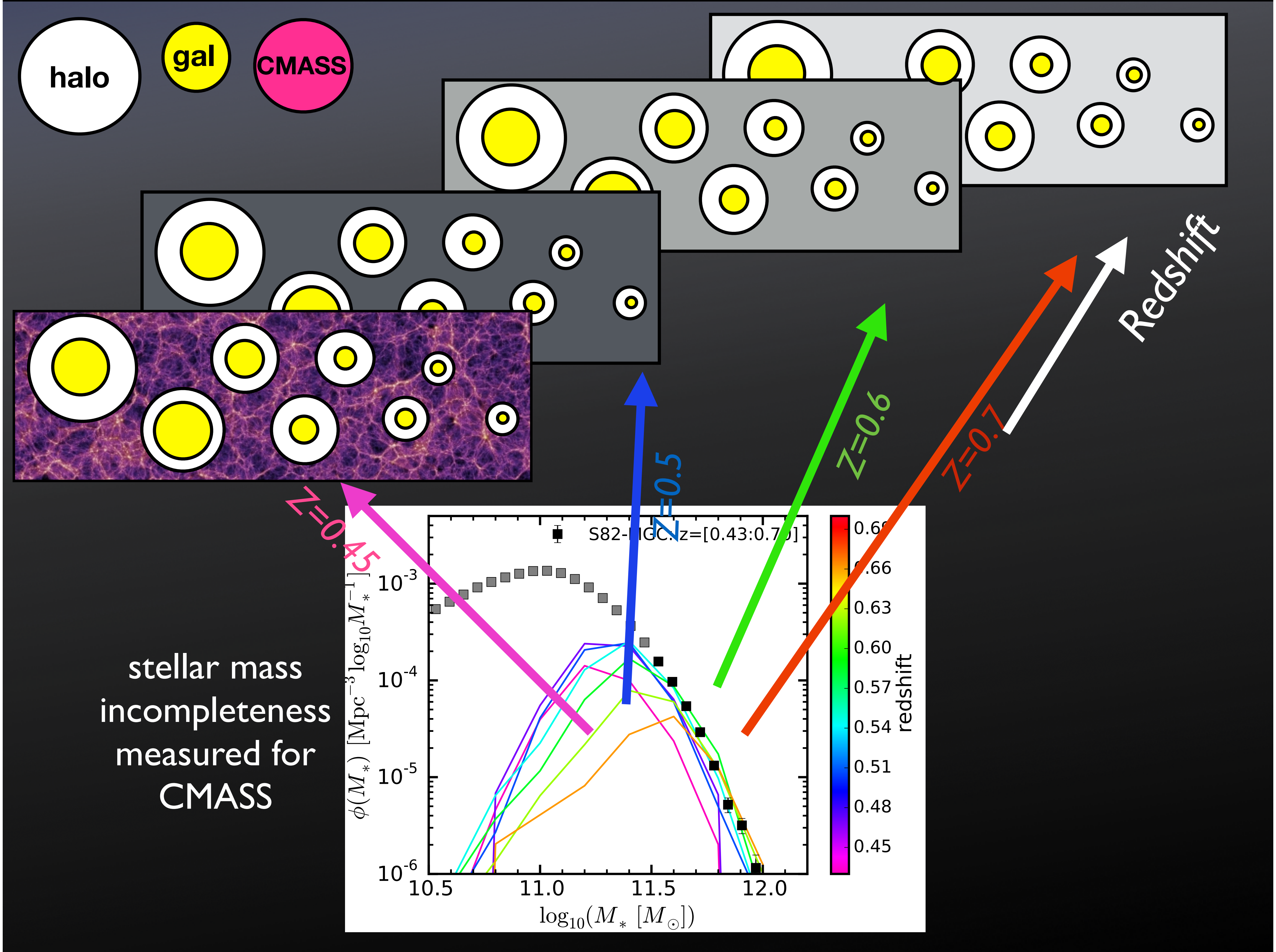
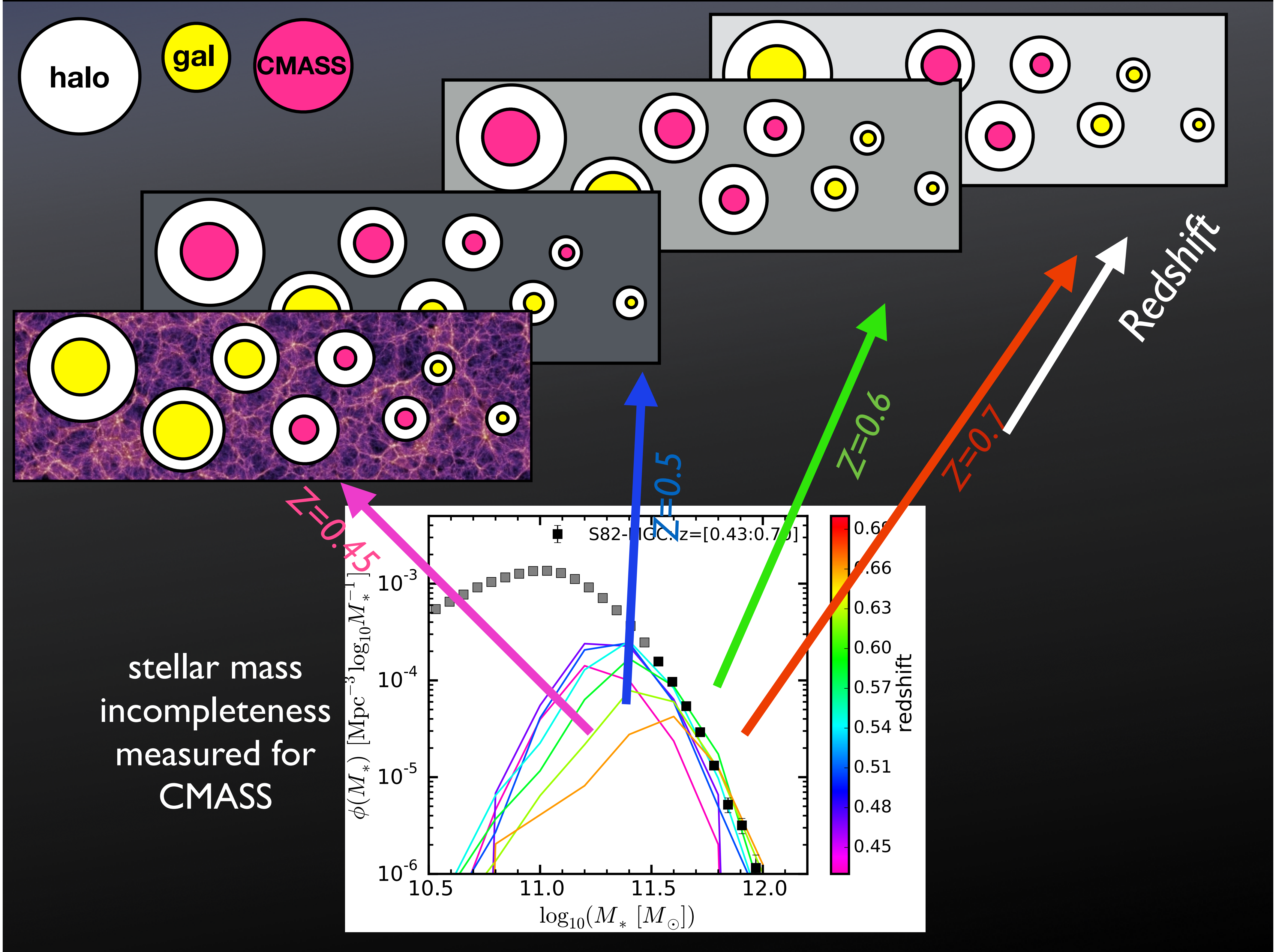


Step 2 : Redshift dependence of stellar-mass completeness




halo
gal
CMASS
Redshift
Z=0.45
Z=0.5
Z=0.6
Z=0.7
stellar mass incompleteness measured for CMASS
S82-NGC: z=[0.43:0.70]
$\phi(M_*)$ [Mpc^{-3} log$_{10}M_*^{-1}$]
$\log_{10}(M_*\ [M_\odot])$
redshift



halo
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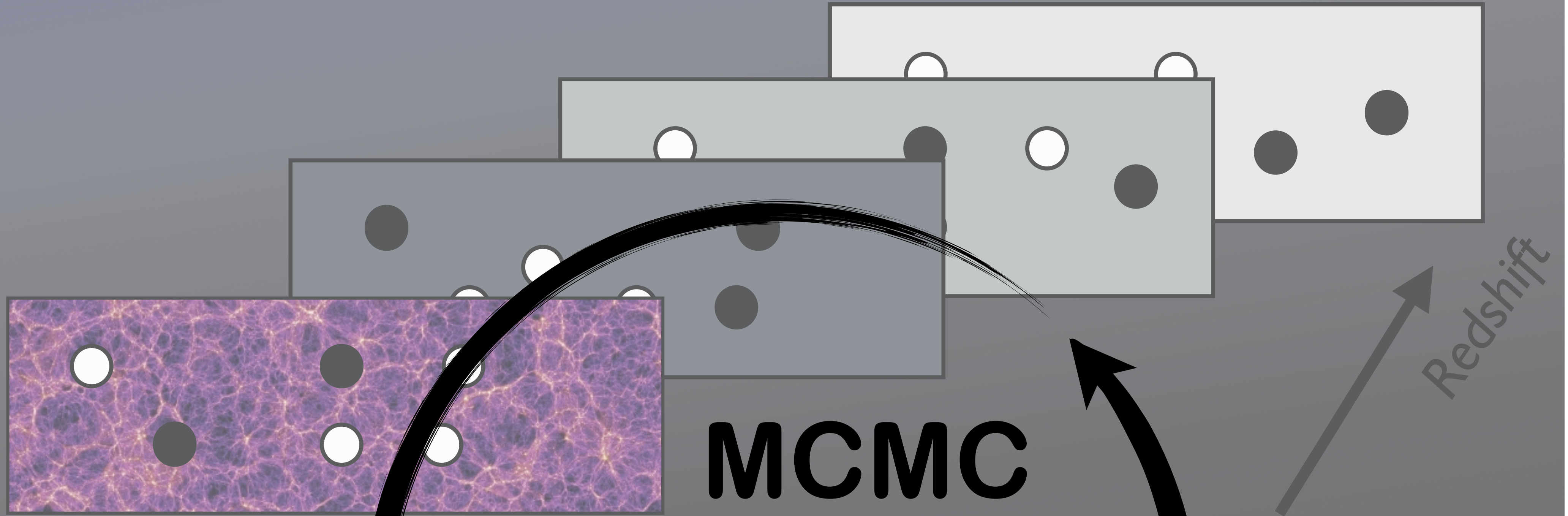
Z=0.6
Z=0.7
S82-
GC: z=[0.43:0.7
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$\phi(M_*)$ [Mpc^{-3} log$_{10}M_*^{-1}$]
10.5
11.0
11.5
12.0
$\log_{10}(M_*\ [M_\odot])$
.66
0.63
0.60
0.57
0.54
0.51
0.48
0.45
redshift
stellar mass
incompleteness
measured for
CMASS

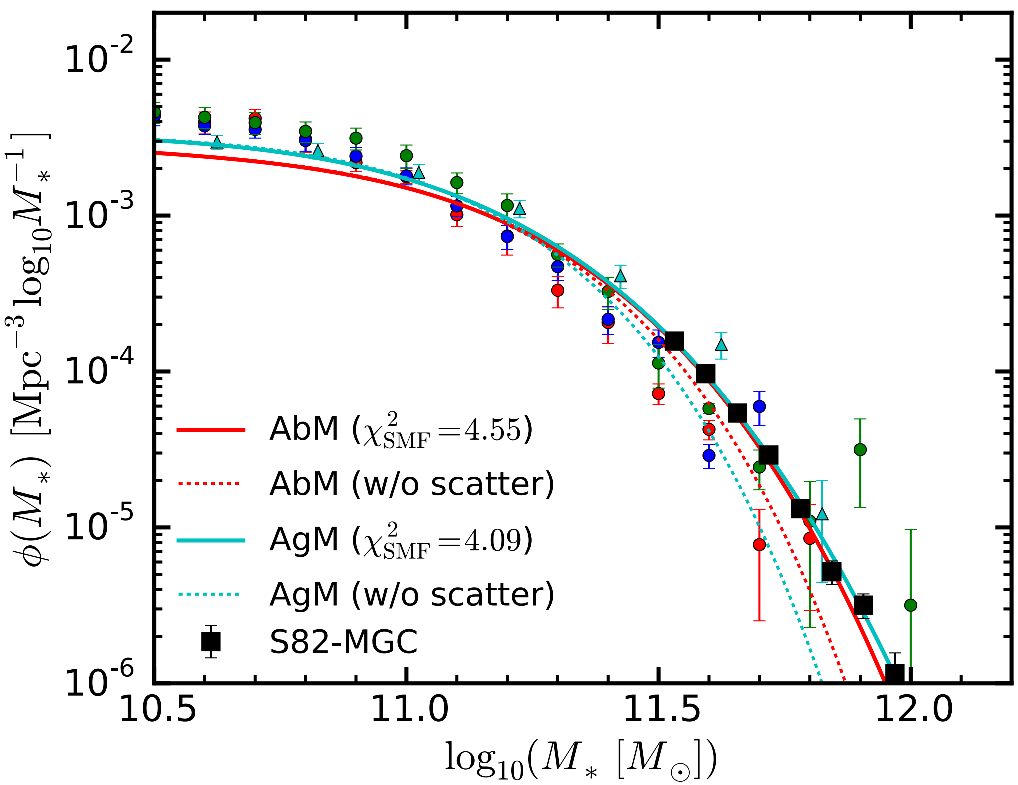


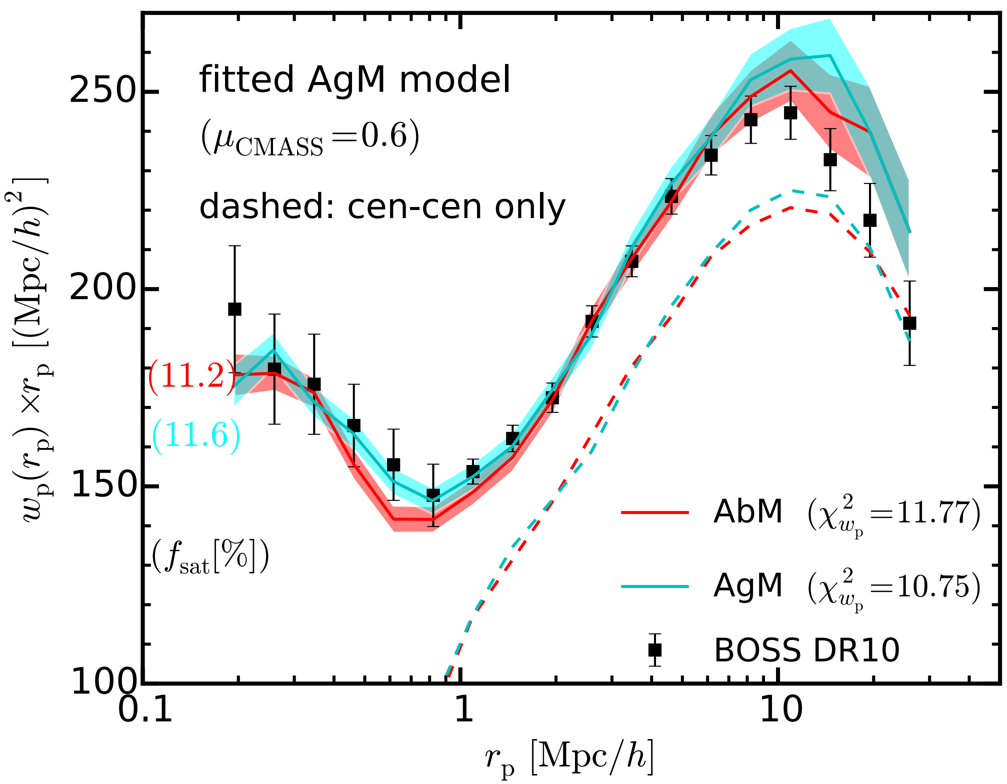
Step 1 : Determine Mass Function and abundance match

Step 2 : Redshift dependance mass completeness

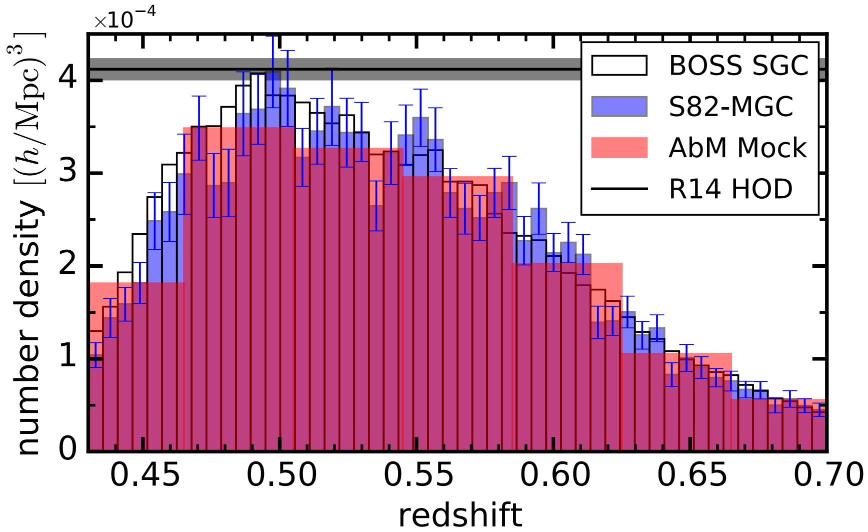
1 Galaxy color in high mass halos is a stochastic process
"AbM" Model

Results





- ✦ Our SHAM can simultaneously explain S82-MGC SMF & BOSS CMASS w_p.
- ✦ The CMASS SMFs and dn/dz should be reproduced by construction.

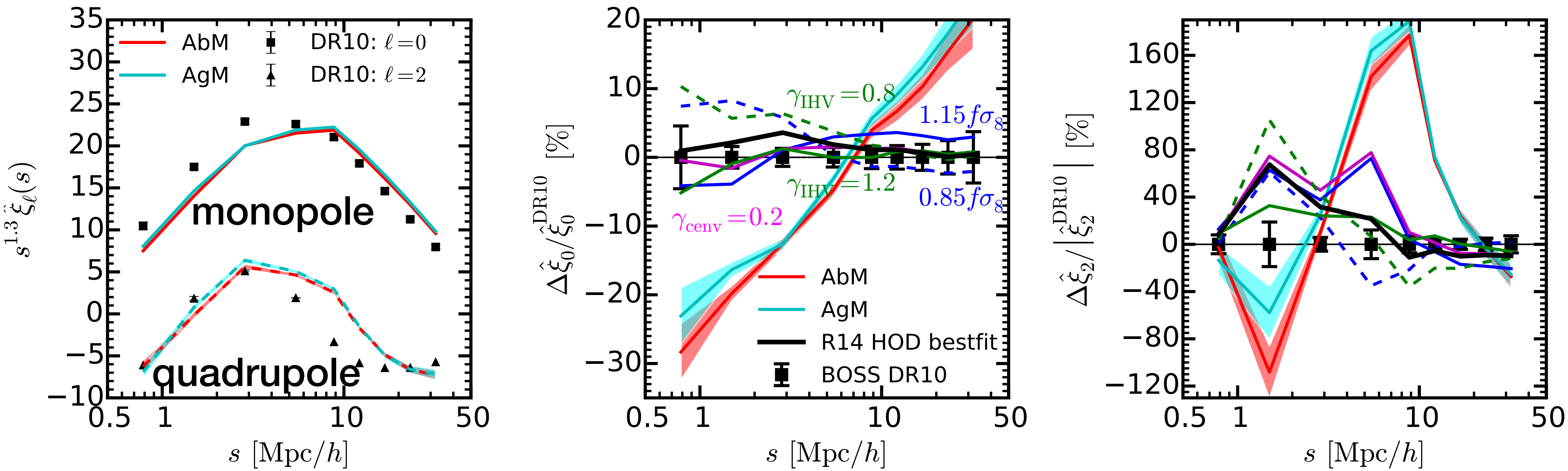


3D Clustering Signal

pseudo multipole

$$\hat{\xi}_\ell(s) = (2\ell+1)\int_0^{\mu_{\max}(s)} d\mu\, \xi(s,\mu)\mathcal{L}_\ell(\mu)$$

less sensitive to **fiber collision**
Reid et al. (2014)



✦ Even though our **AbM** model can reproduce the CMASS dn/dz, SMFs, and w_p, it **dramatically fails** to reproduce the pseudo multipole.

✦ The velocity effects are not likely to mimic the difference.

Summary: CMASS-Halo connection

	HOD [Reid et al. 2014]	SHAM	SHAM + age matching
CMASS dn/dz	down sample	○	○
CMASS SMF(z)	X	○	○
2D clustering, w_p	○	○	○
3D clustering, ξ_l	○	X	Hopefully ○
gal-gal lensing	X	△	Hopefully ○

✦ We are still looking for a perfect description of the galaxy-halo connection.

Towards PFS: (personal) lessons from BOSS

- ✦ To obtain **Stellar-Mass-Limited** sample
  1) Should be calibrated with ***deeper survey***. Is "HSC deep" sufficient?
  2) Spec-Z is key. The deep field should be observed in early phase.

- ✦ To better control **fiber collision**
  1) 30 arcsec ~ 0.4 Mpc/h @ z~1.4
  2) In particular for RSD, ***uniform tiling*** is desirable.

- ✦ For theory people (even within a ΛCDM model)
  1) find a good model ***to predict*** $b_X(M_{halo})$
  2) understand ***halo assembly bias*** Miyatake et al. (2015)
  3) understand ***velocity relation b/w galaxy & halo*** Wu et al. (2013)