The Galaxy-Halo Connection for the BOSS CMASS Sample

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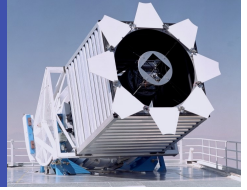
Leauthaud, **SS**+, MNRAS (2017).
SS, Leauthaud, Hearin+, MNRAS (2016).
Leauthaud, Bundy, **SS**+, MNRAS (2016).
Bundy, Leauthaud, **SS**+, ApJS (2015).

Quantifying and Understanding the Galaxy-Halo Connection
@KITP, UC Santa Barbara, USA
18th May 2017

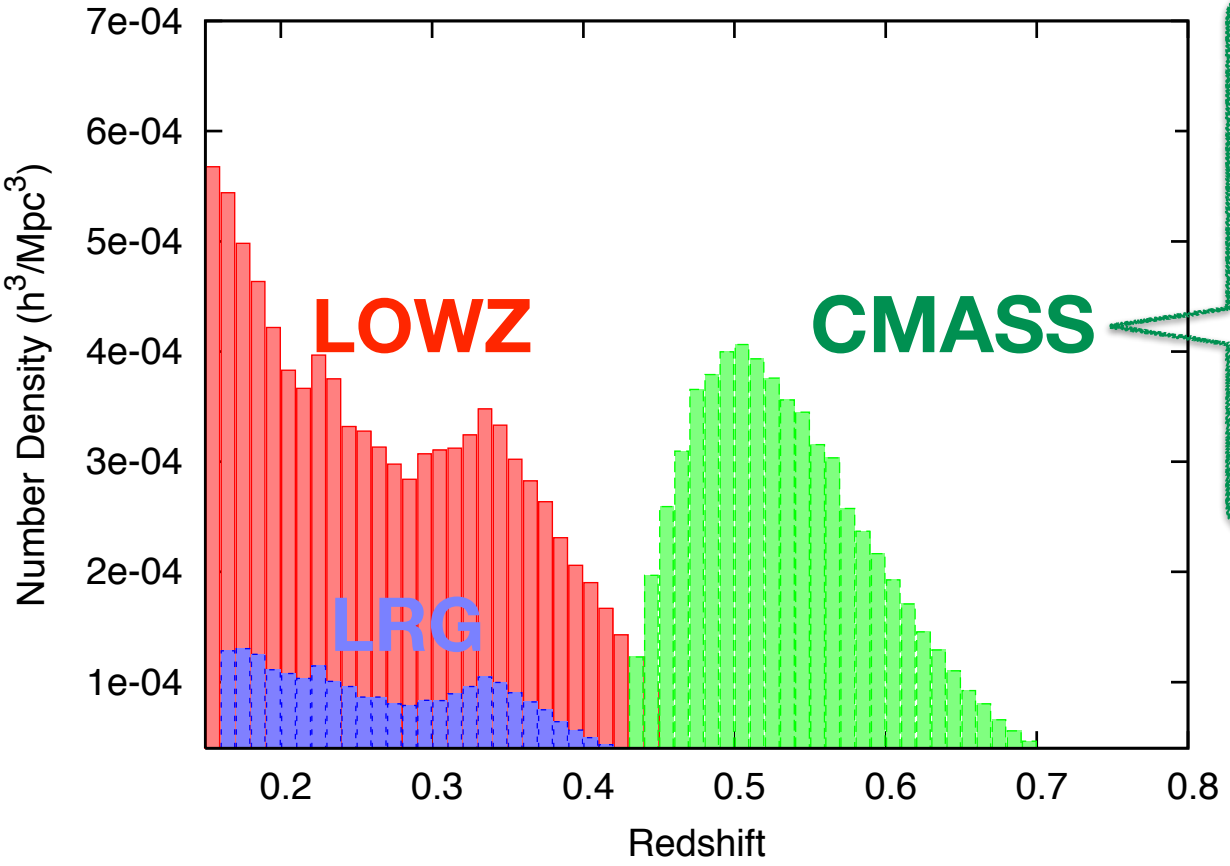
The BOSS CMASS sample



✦ The Baryon Oscillation Spectroscopic Survey (2009-2014)

Eisenstein+(2011)

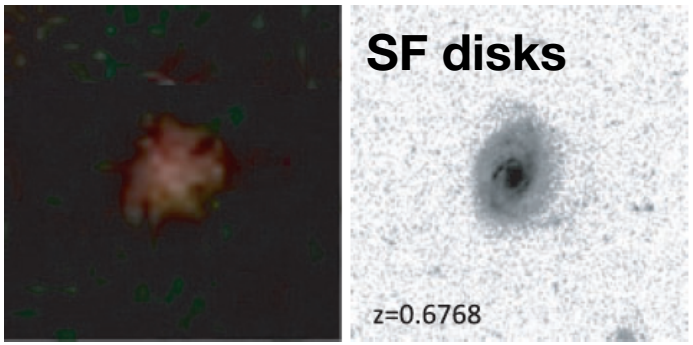
taken over **10,252deg²**



"Constant MASS"

- select $\log(M_*/M_\odot) \gtrsim 11.3$

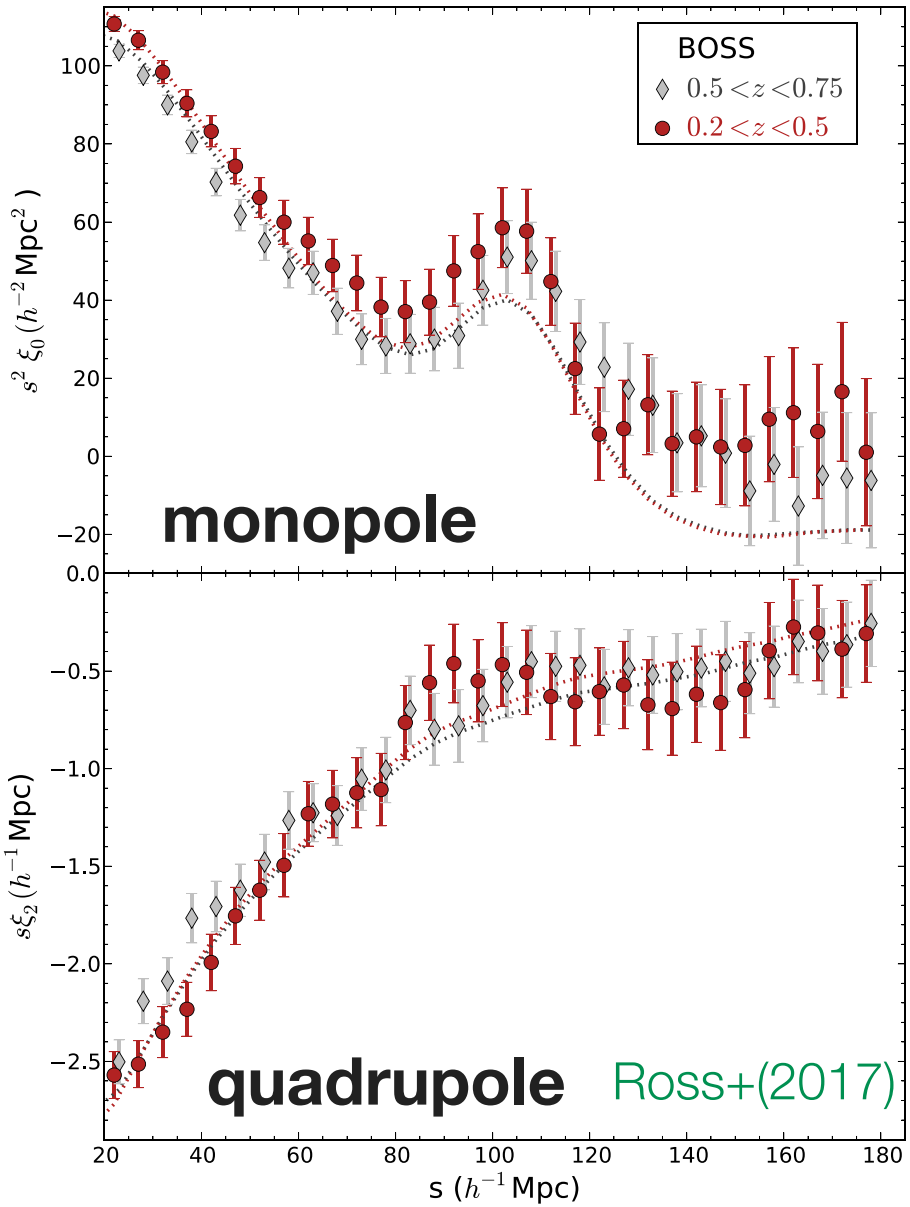
  Maraston+(2013)
- #: 836,347 (DR12)
- 0.43 < z < 0.7



Masters+(2011)

Montero-Dorta+(2014)

Rich Statistics from BOSS & Cosmology



- ***LARGE***-scale galaxy clustering
  - **BAO :** ~ **1%** distance
  - **RSD :** ~ **7%** growth of LSS

  Alam+(2017)

- How was the analysis validated?

→ extensively tested against **mocks**

which assumes a gal-halo connection

Let's ask ourselves & you

- Are Massive Galaxies simple enough?

- Do we even understand the galaxy-halo connection for massive galaxies ***at the statistical level of BOSS***?
  → highly relevant to both cosmology & galaxy evolution

- Stellar Mass, M* is probably the most relevant quantity
  → let's look at ***M* & its completeness*** for CMASS

CMASS-Halo Studies

Paper	Model	Statistics	sample/ completeness	comments
White+(2011)	HOD	W_p	full/ down-sampling	
Guo+(2014)	HOD	W_p	red subsample	
Reid+(2014)	HOD	$W_p + \xi_l$	full/ down-sampling	
Guo+(2015)	HOD	$W_p + \xi_l$	red subsample	Zheng's talk
More+(2015)	HOD	$W_p + \Delta\Sigma$	M*-limited subsample	cosmology
Rodriguez-Torres+(2016)	SHAM	ξ_l	full/ SDSS SMF	BigMDPL
SS+(2016)	SHAM	W_p, ξ_l	full/ *S82 SMF*	MDR1
Leauthaud+(2017)	-	$\Delta\Sigma$	full	comparison

＊incomplete list

Stripe 82 Massive Galaxy Catalog (S82MGC)

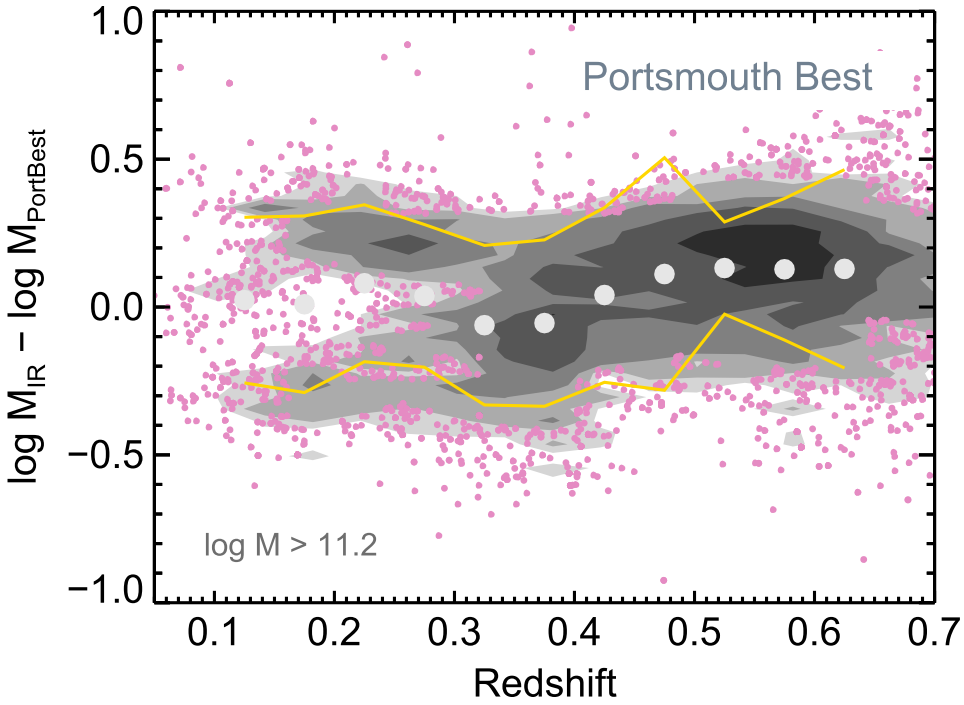
Bundy, Leauthaud, **SS**+ (2015)

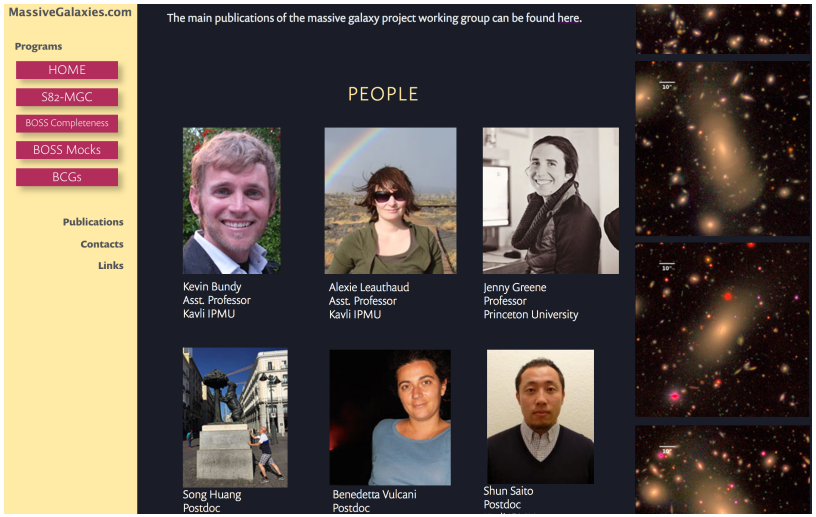
- SDSS photometry is shallow!

- SDSS ***Co-Adds*** photometry (~2mag deeper) over 139.4 deg^2

- Combined w/ UKIDSS NIR bands → more robust M_* estimates

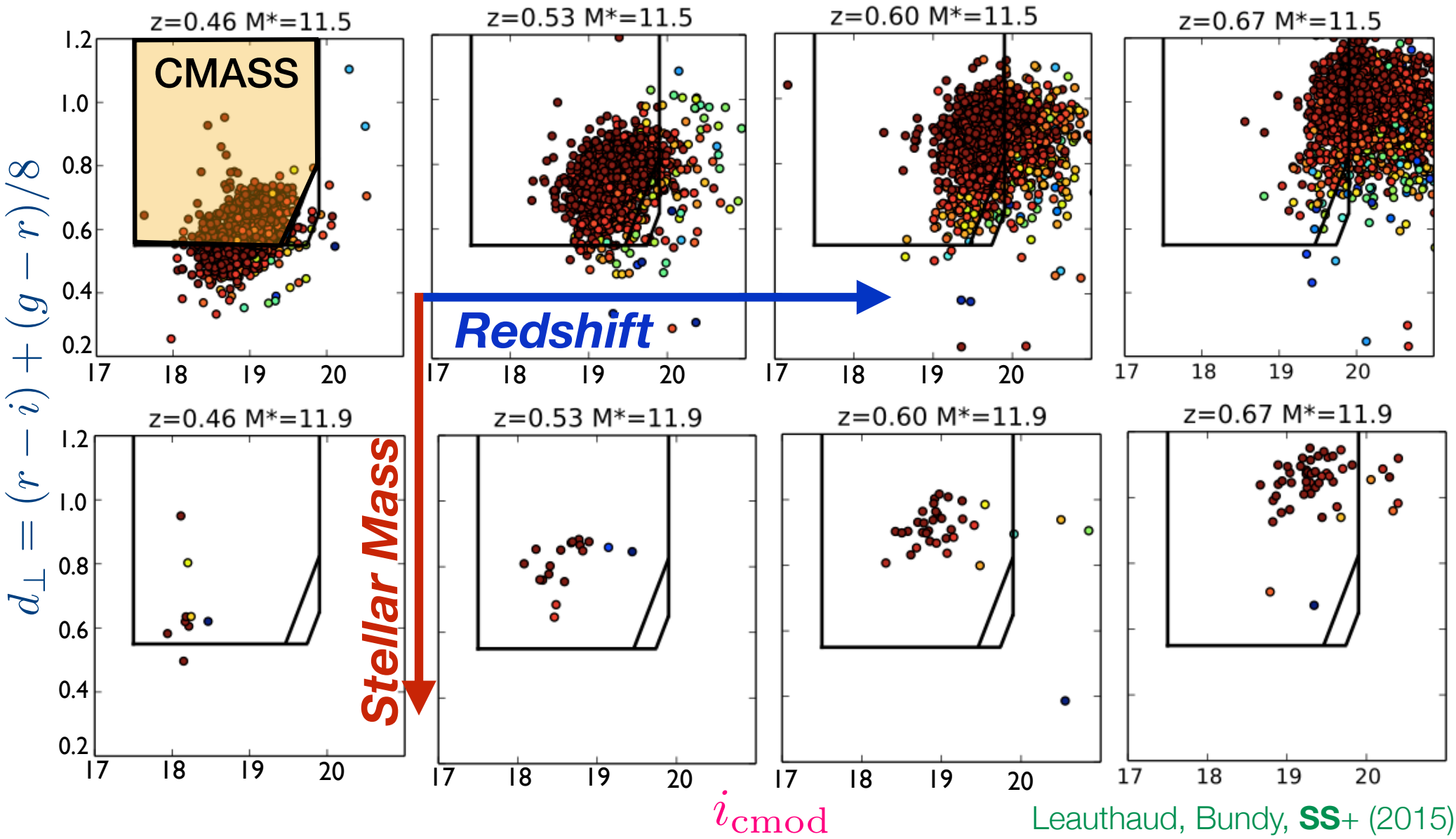
→ **0.1-0.2dex offset** in a ***redshift-dependent*** way





www.massivegalaxies.com

CMASS Selection Function



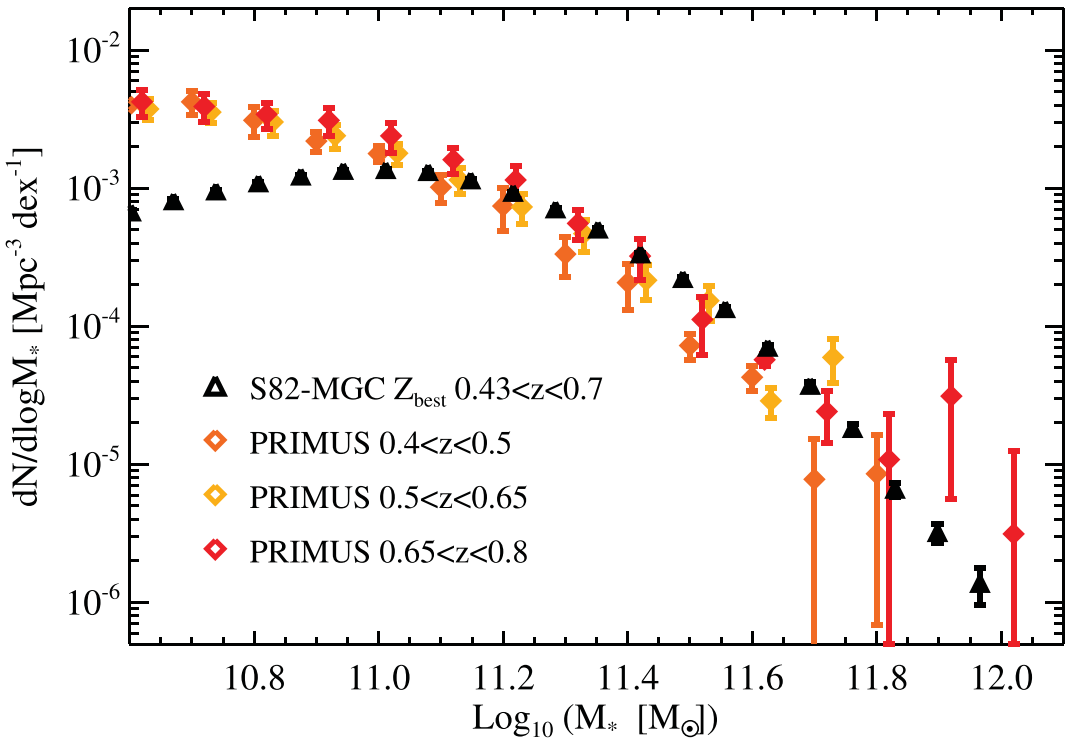
Leauthaud, Bundy, **SS**+ (2015)

low/**high** z dominated by **color**/**luminosity** selection.

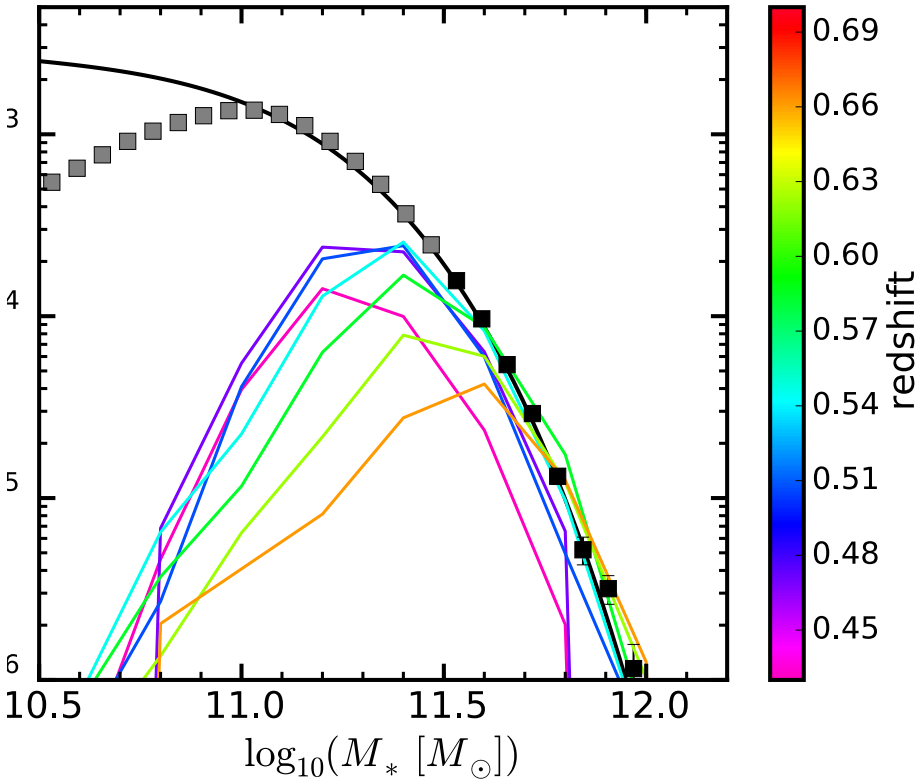
S82MGC SMF

SS, Leauthaud+ (2016)

All galaxies



CMASS z-dependence



✦ ***S82-MGC***: best constrain high-mass end, $\log(M_*/M_\odot) \gtrsim 11.5$

complete at $\log(M_*/M_\odot) \gtrsim 11.3$

✦ **CMASS ≠ Constant Mass!!** ***redshift-dependent*** M* completeness

S82MGC SMF

SS, Leauthaud+ (2016)

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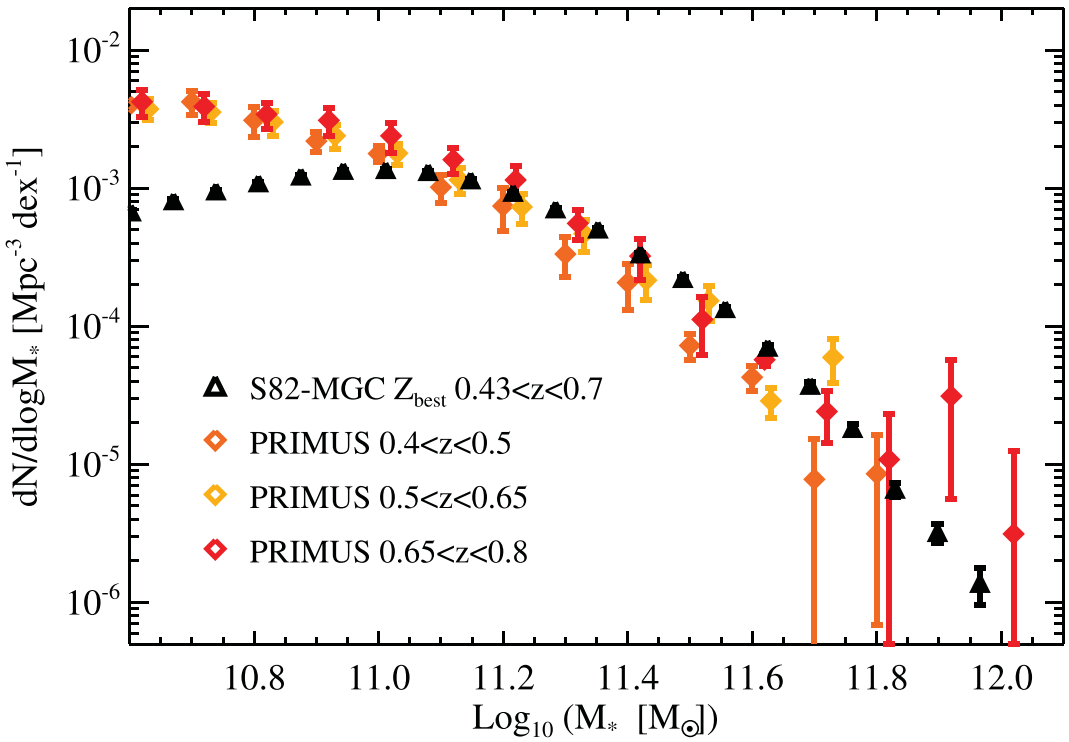

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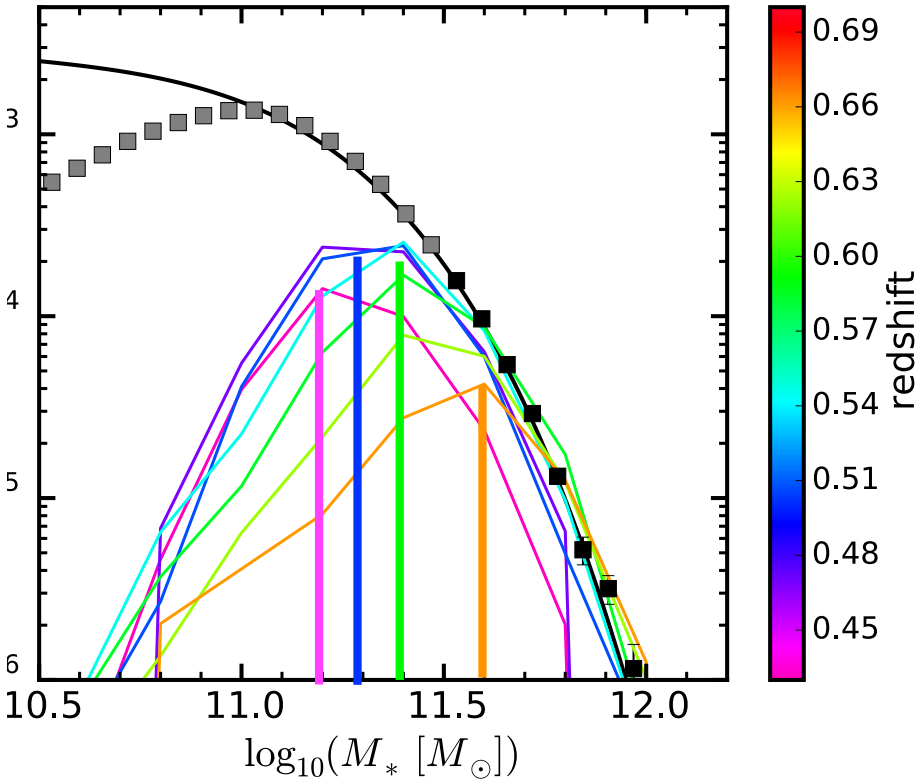

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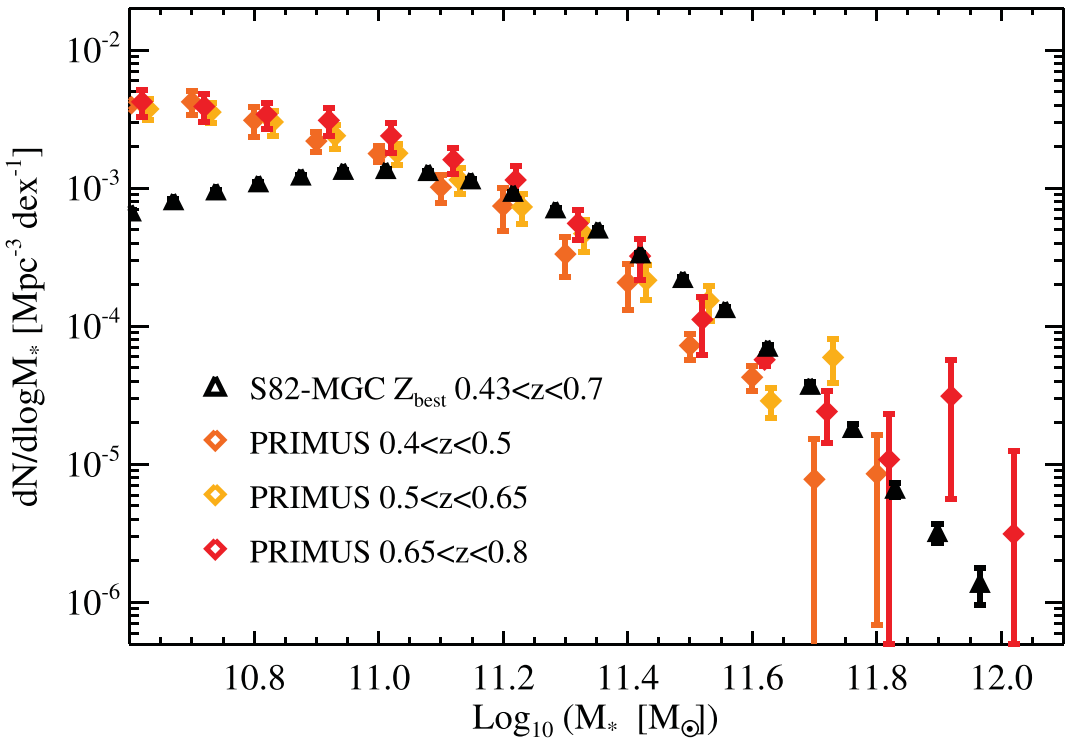
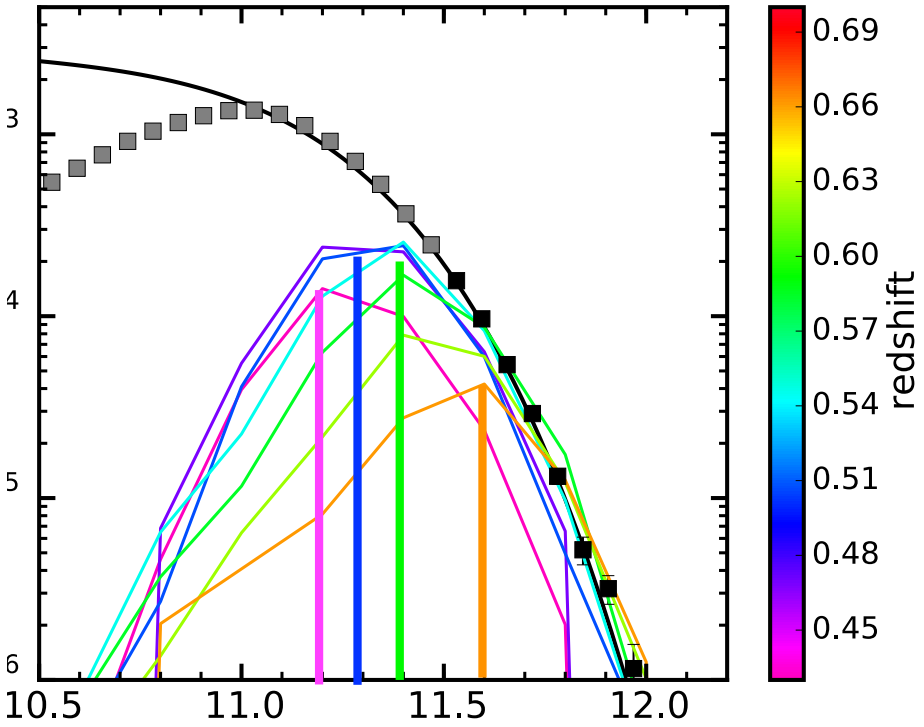


CMASS z-dependence



a factor of 1.8 increase in mean M*

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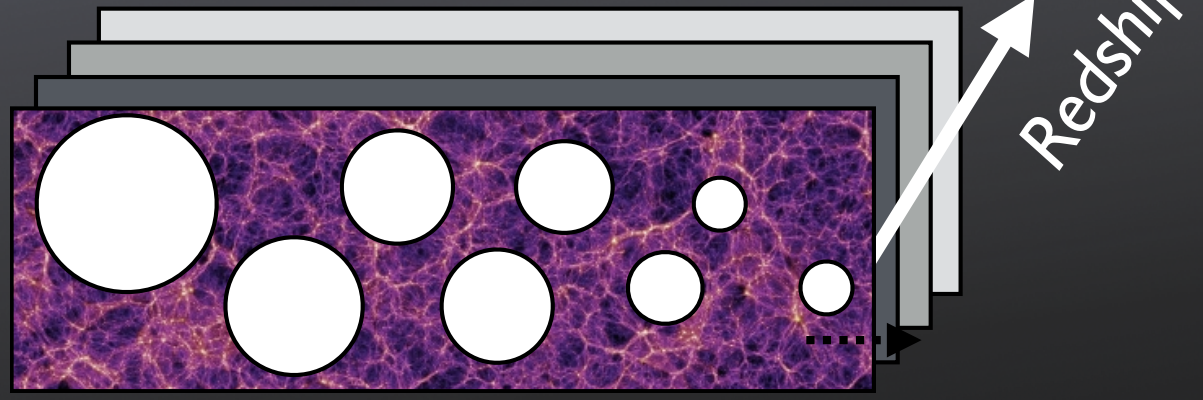
Subhalo Abundance Matching

halo

gal

1 (Gpc/h)^3 Multidark *N*-body (MDR1)



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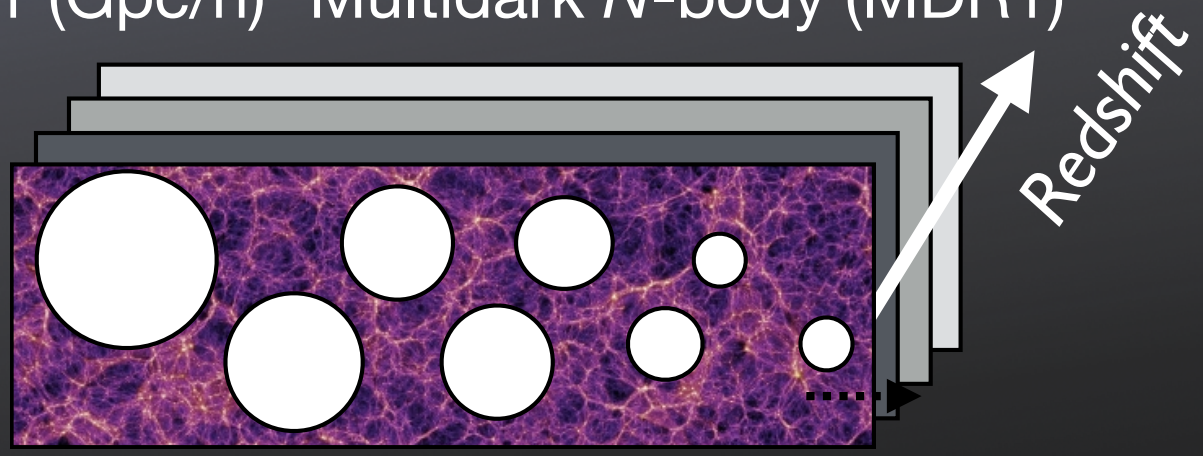
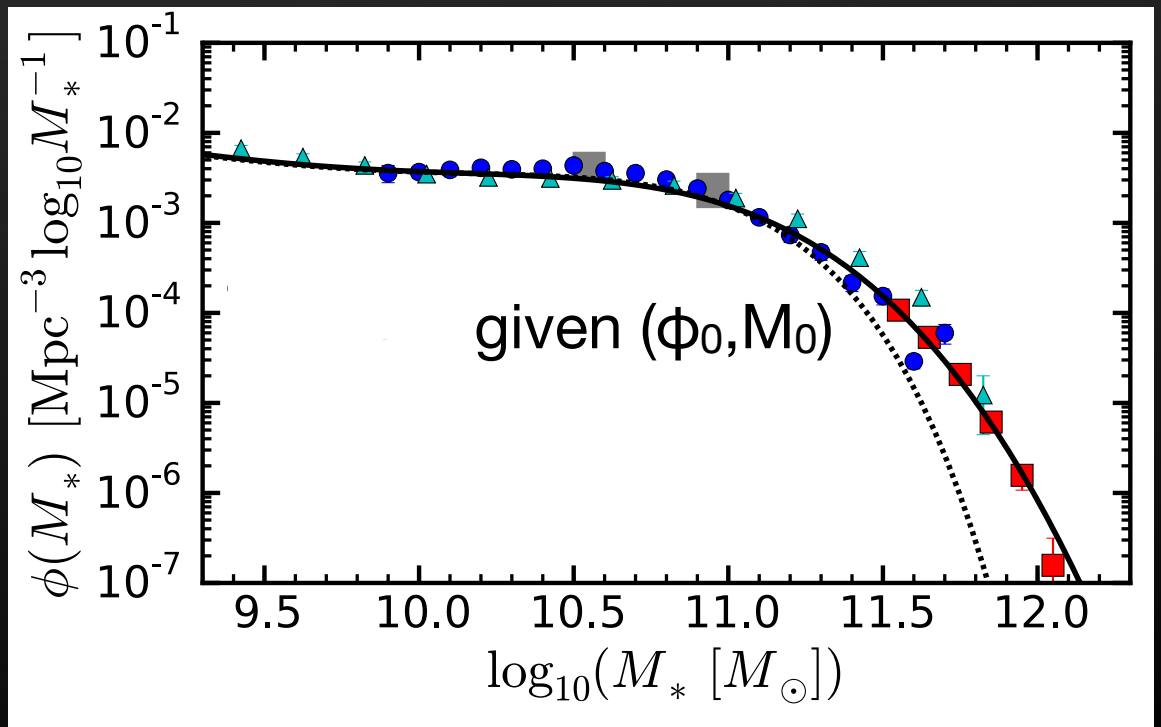


Step 1: Determine Mass Function and abundance match (V_{peak})



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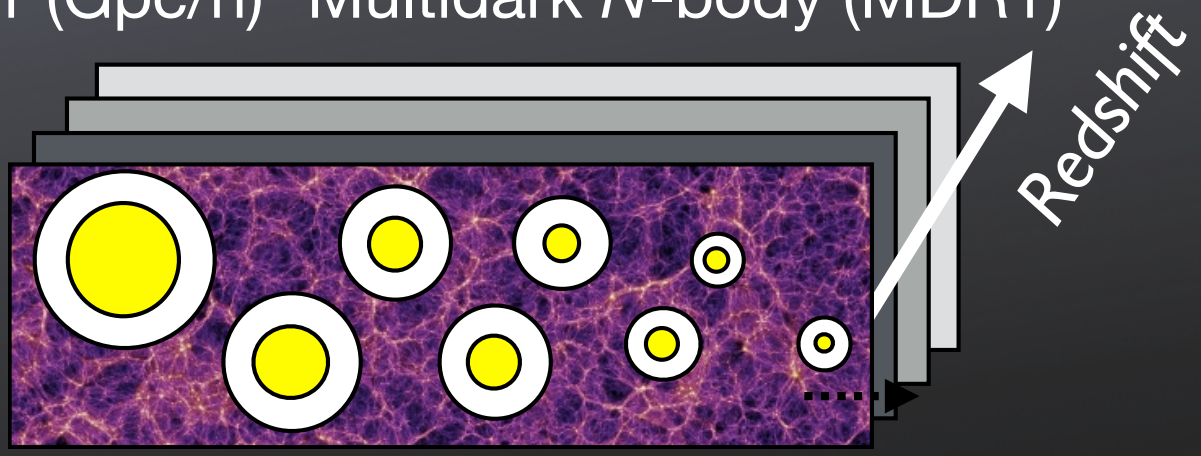

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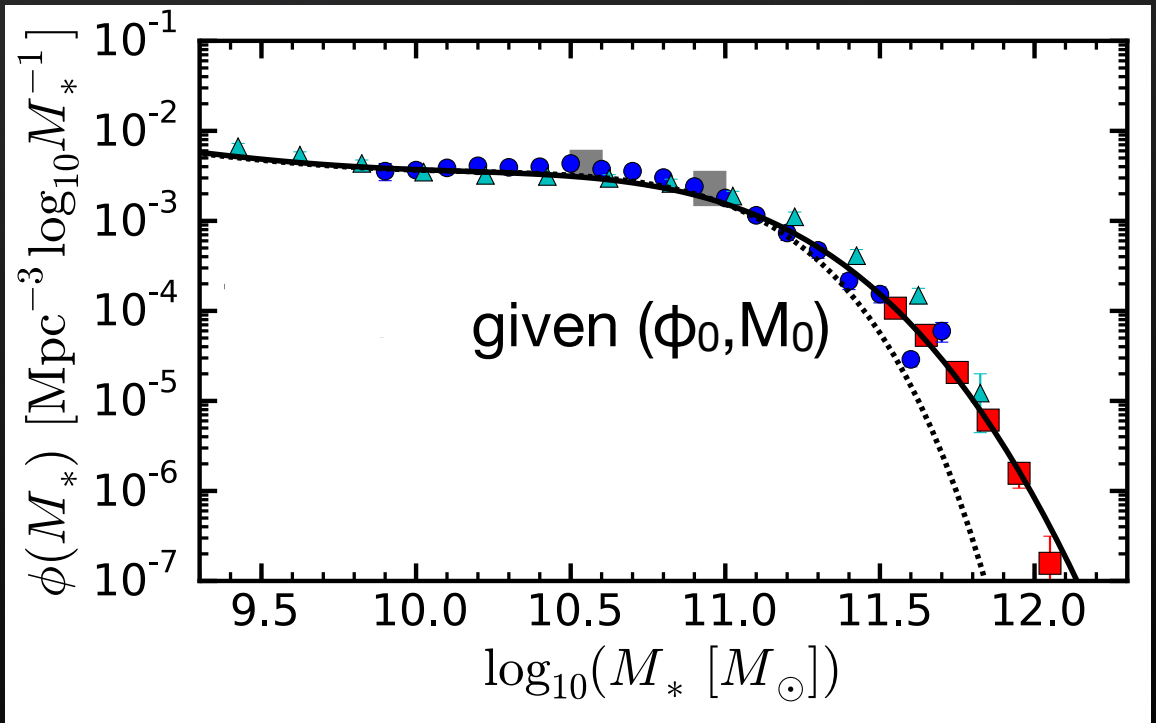

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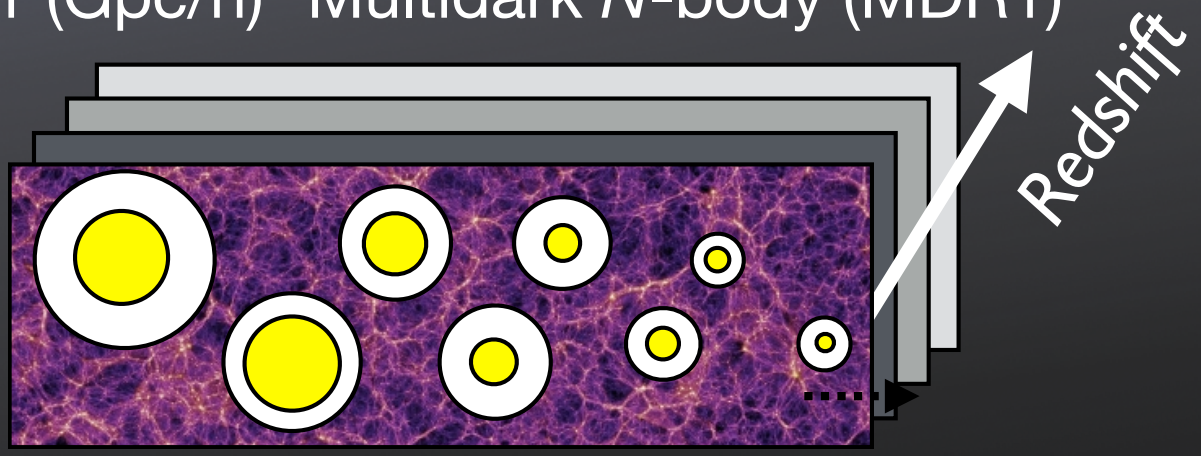

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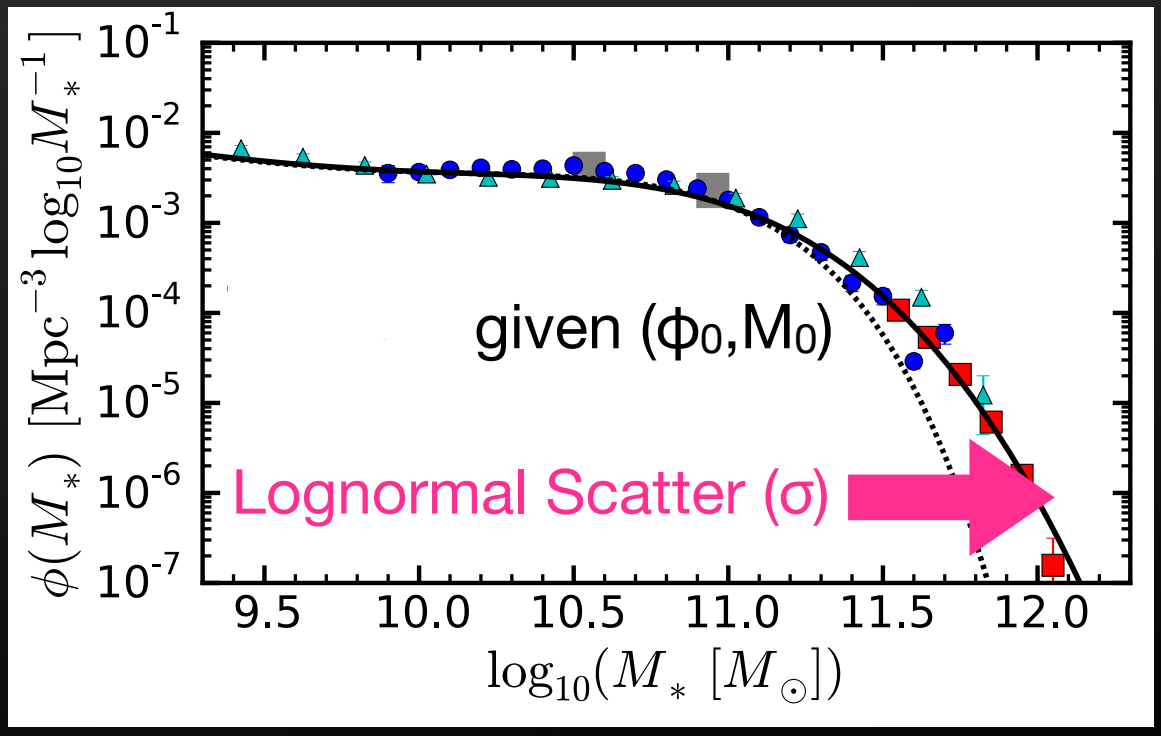
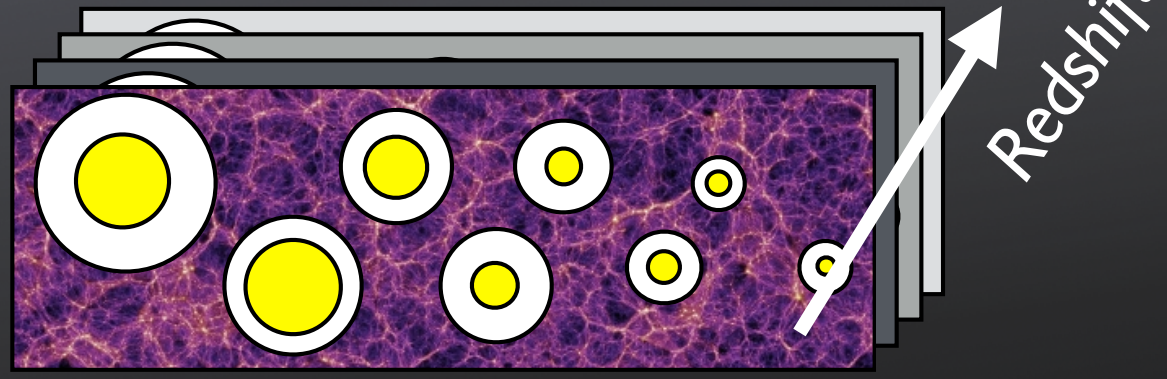


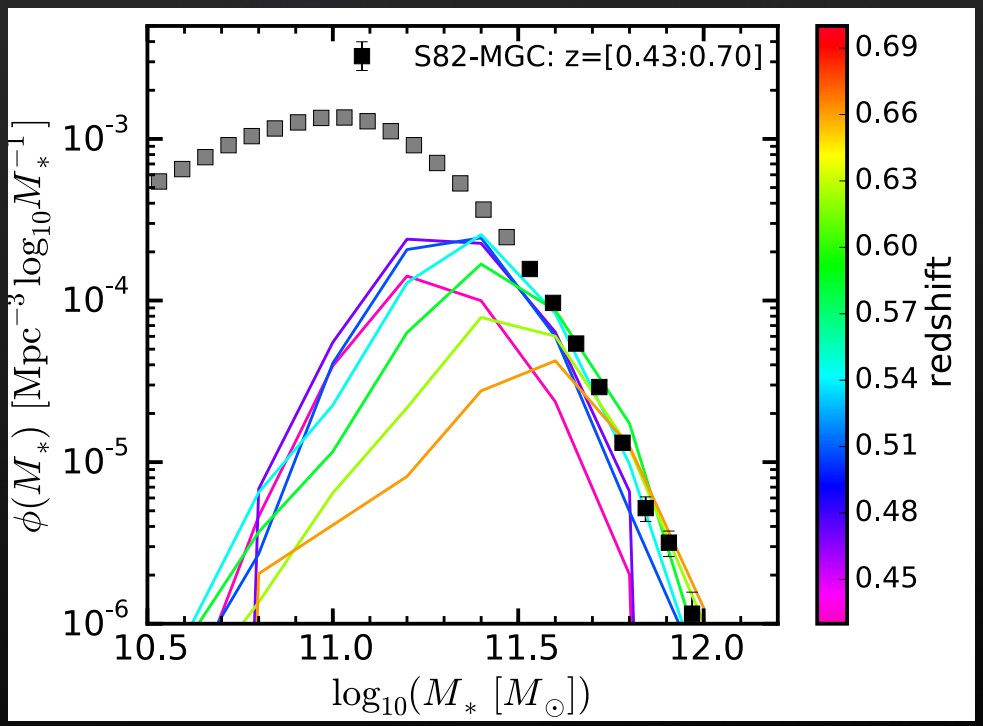
halo

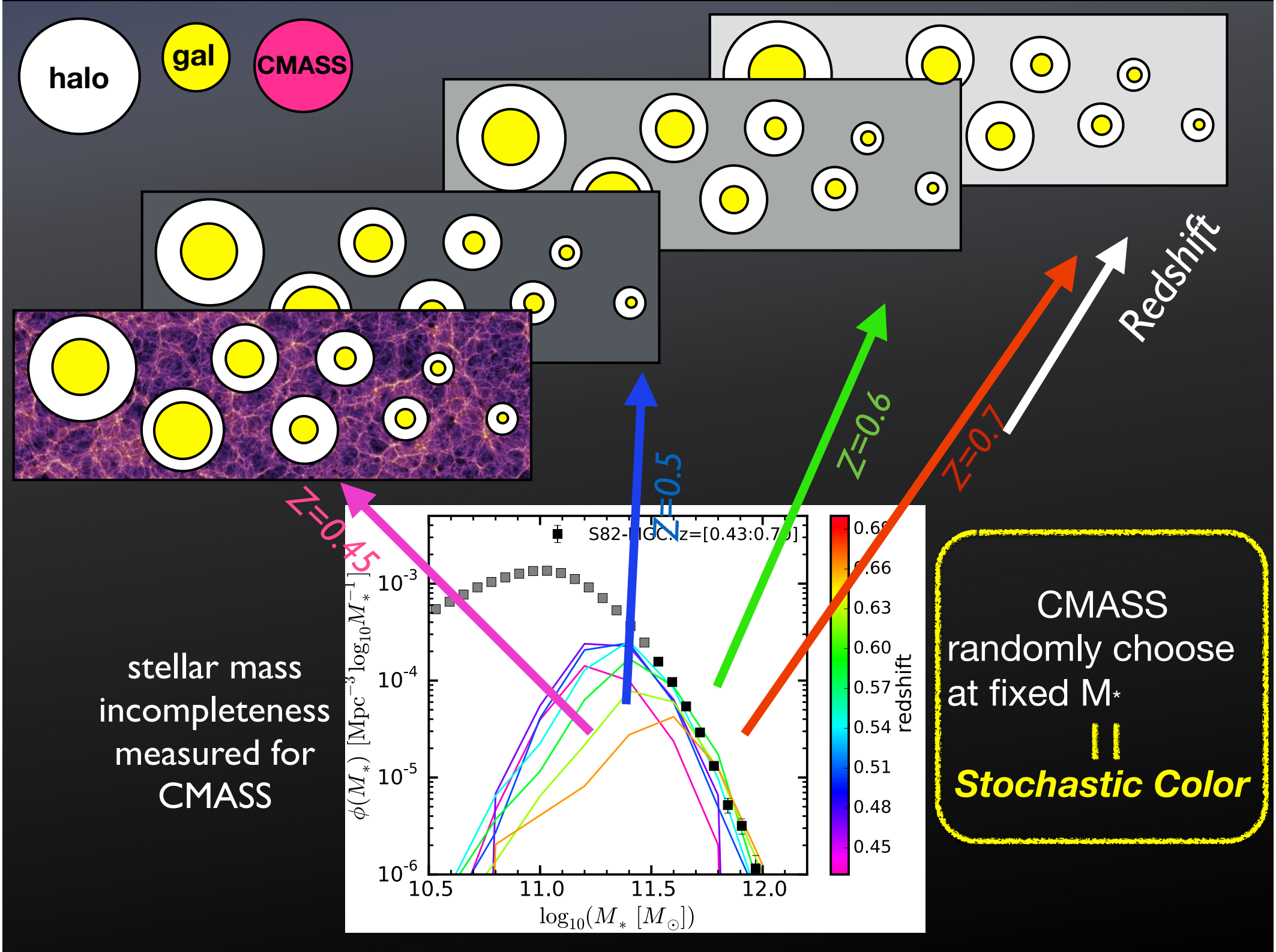
gal

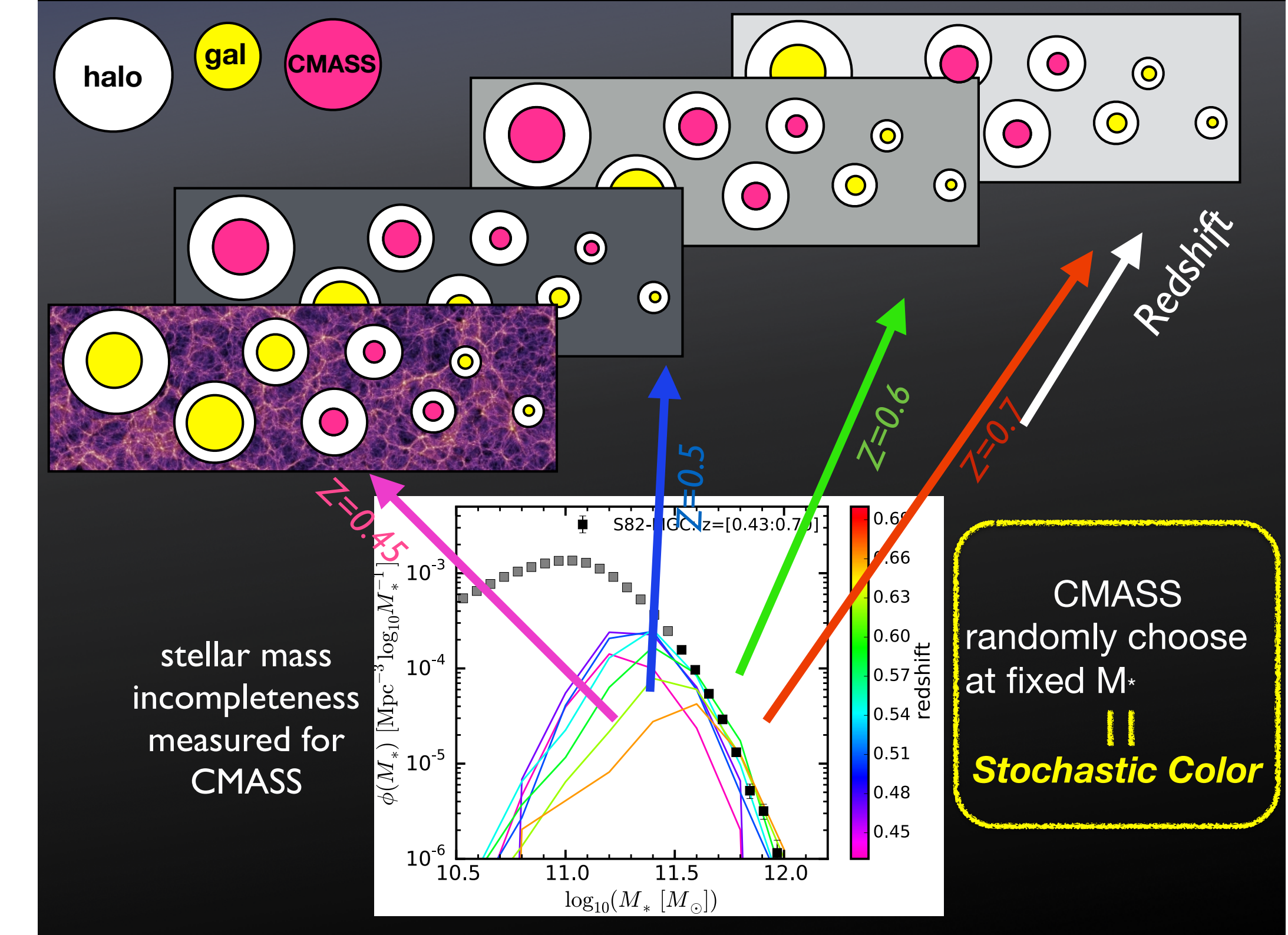
1 (Gpc/h)^3 Multidark *N*-body Simulation



Step 2 : Redshift dependence of stellar-mass completeness




halo
gal
CMASS
Redshift
Z=0.45
Z=0.5
Z=0.6
Z=0.7
S82-[illegible]GC: z=[0.43:0.7[illegible]]
$\phi(M_*)$ [Mpc^{-3}log$_{10}M_*^{-1}$]
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10.5
11.0
11.5
12.0
log$_{10}(M_*$ [$M_\odot$])
redshift
0.69
0.66
0.63
0.60
0.57
0.54
0.51
0.48
0.45
stellar mass incompleteness measured for CMASS
CMASS randomly choose at fixed M*
=
Stochastic Color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gal

CMASS

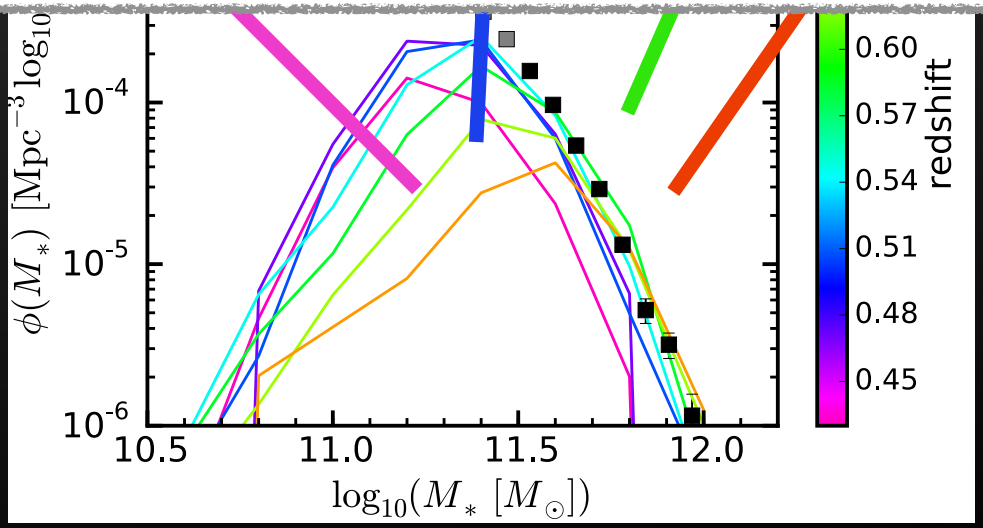
Redshift

MCMC fit (ϕ_0, M_0, σ) to

- S82MGC SMF

- BOSS CMASS w_p

stellar mass incompleteness measured for CMASS



CMASS randomly choose at fixed M_*

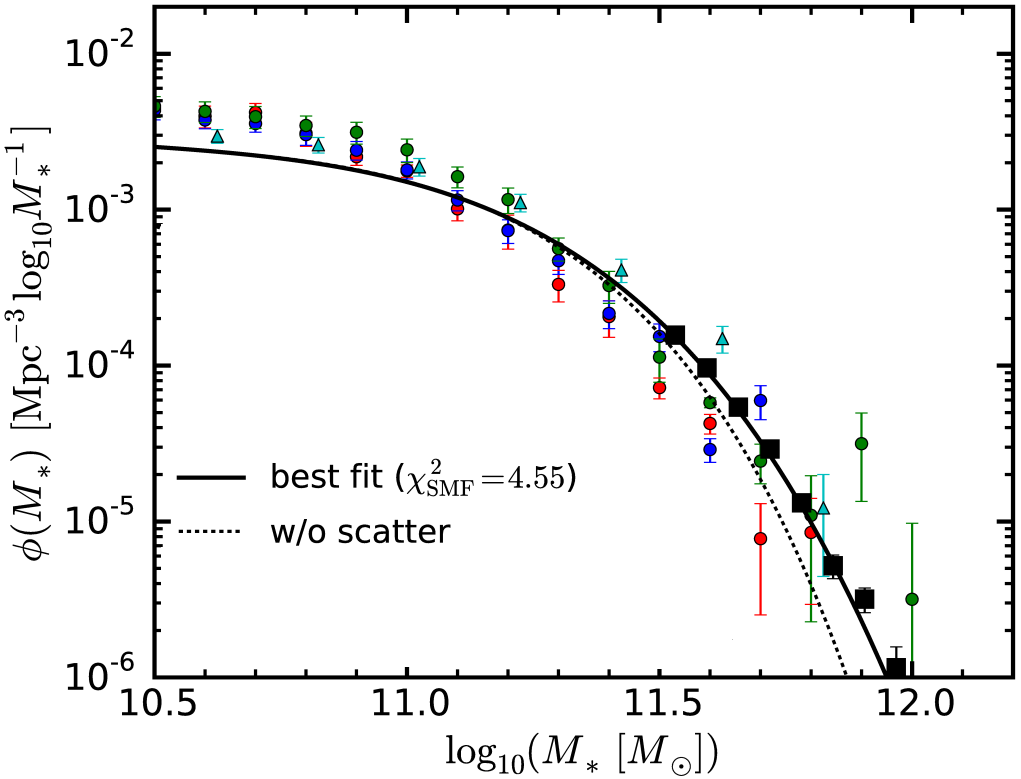
=

Stochastic Color

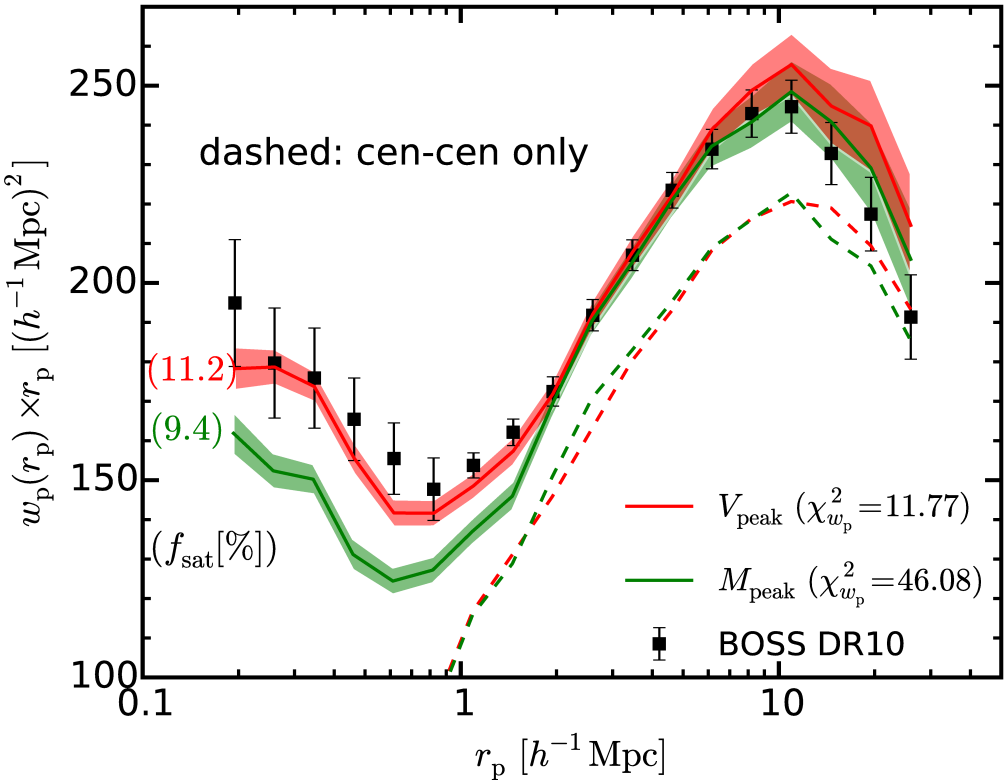
Results

SS, Leauthaud, Hearin+ (2016)

Stellar Mass Function

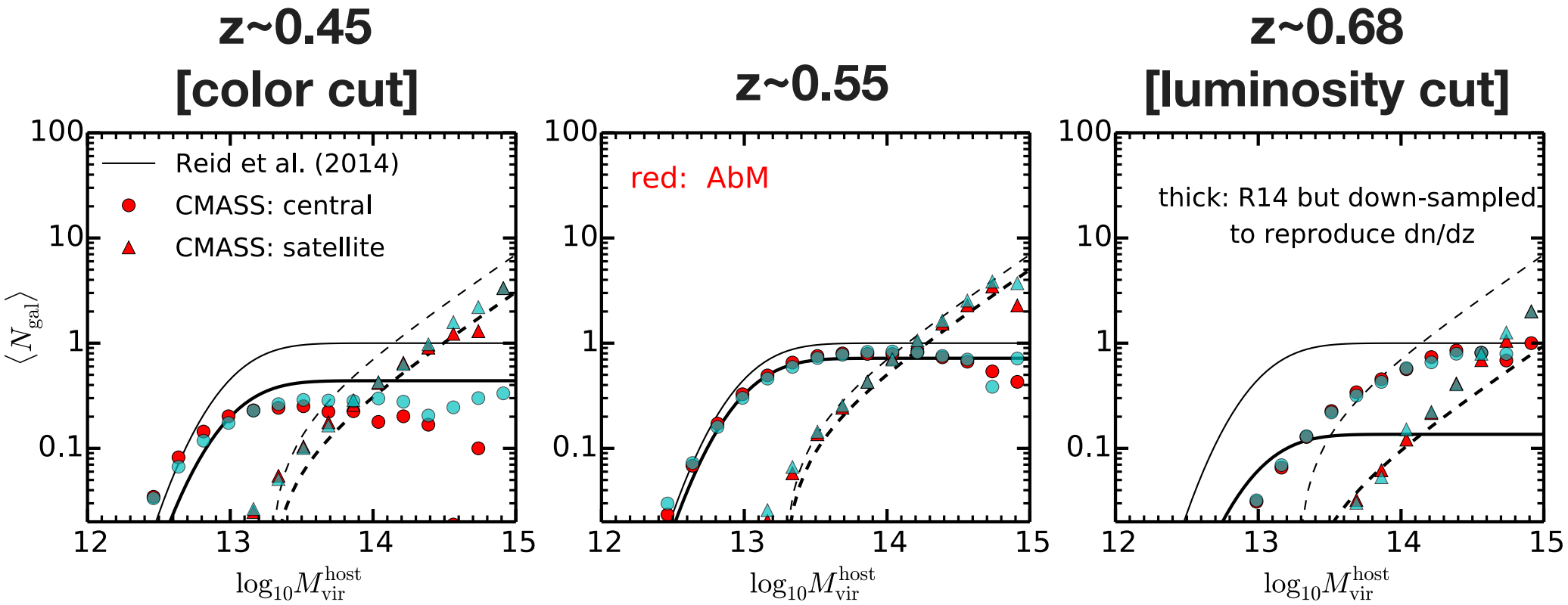


Projected Correlation Function



✦ surprisingly ***SMALL*** scatter: $\sigma(\log M * | V_{\rm peak}) = 0.105^{+0.024}_{-0.032}$

Redshift Evolution of HOD



✦ excellent agreement with the HOD model at z ~ 0.55

✦ at high redshift, z > 0.6, very distinct HODs

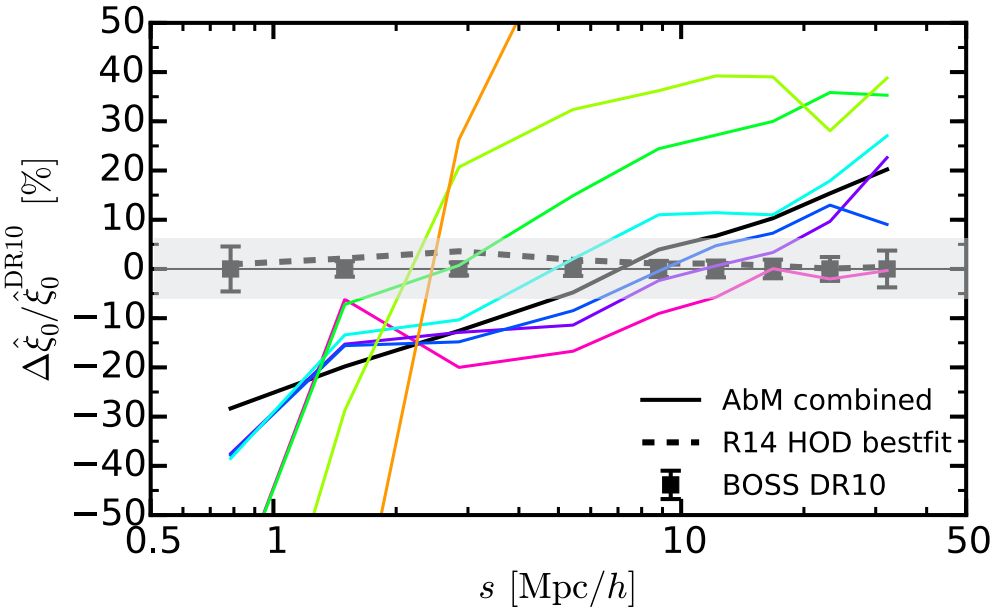
- random down-sample HOD model vs luminosity cut

SS, Leauthaud, Hearin+ (2016)

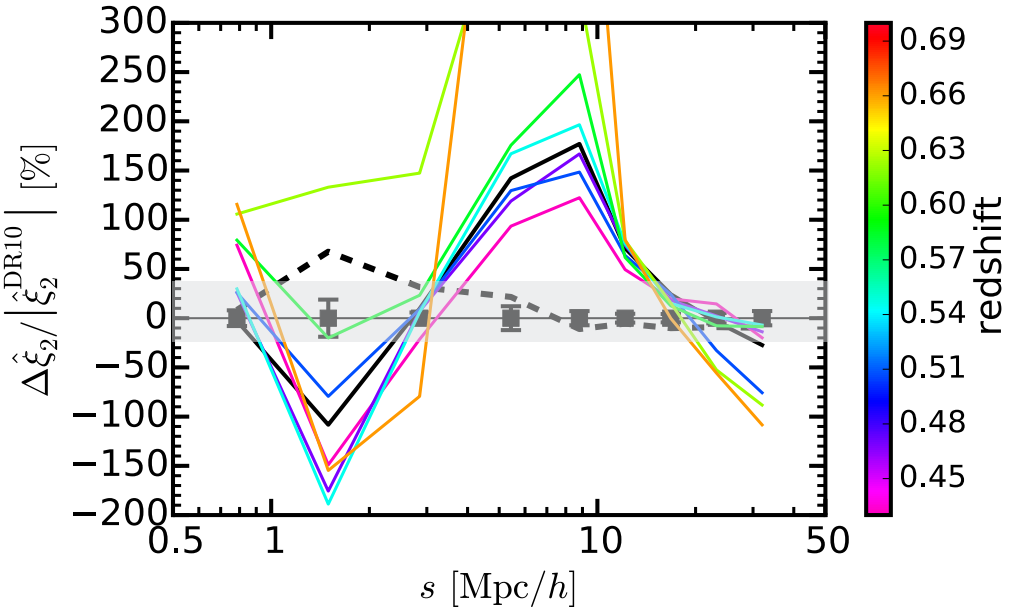
But…**Failure** of 3D Clustering Evolution

SS, Leauthaud, Hearin+(2016)

monopole



quadrupole



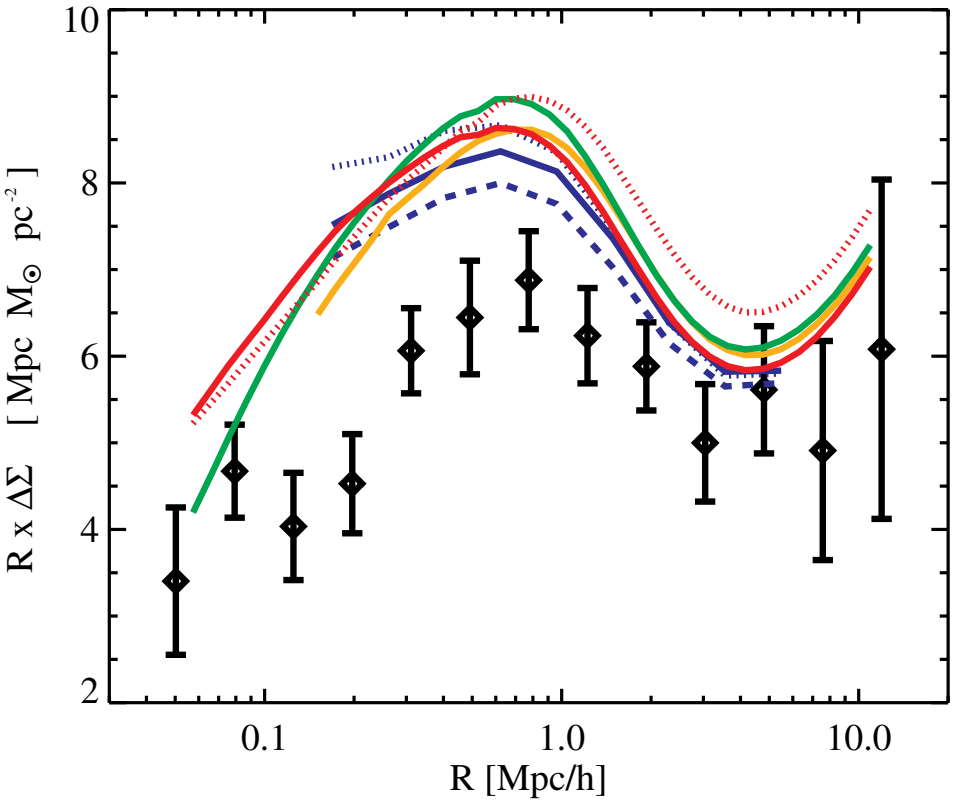
✦ The measurements show **NO** redshift evolution within

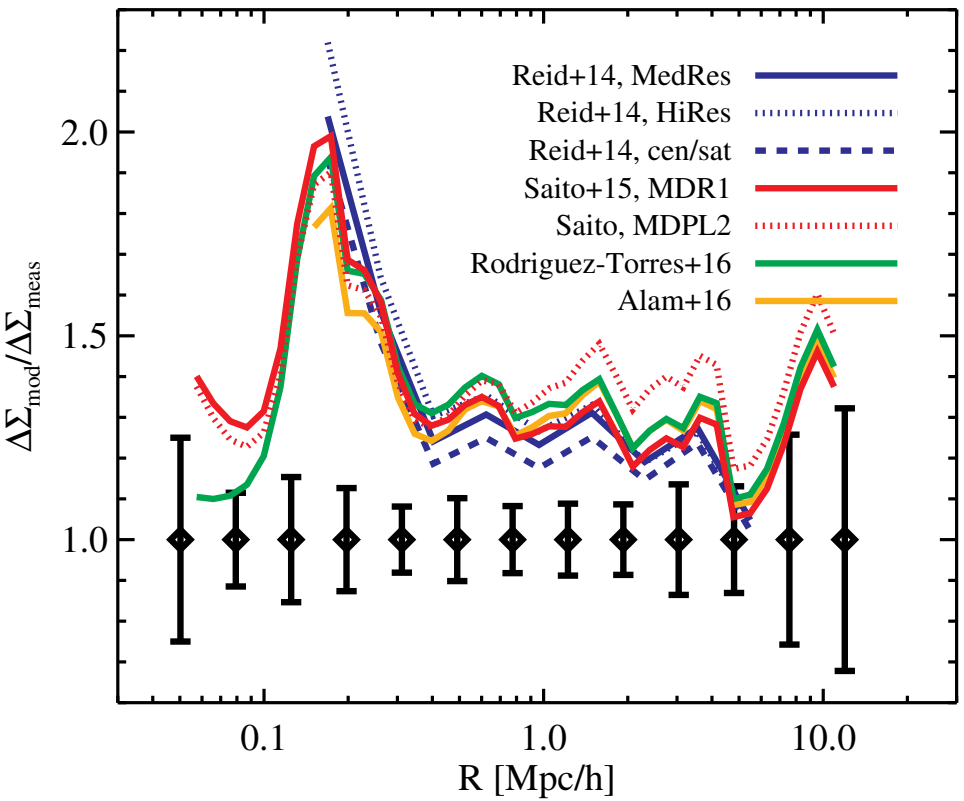
✦ Our SHAM model predicts a strong evolution:

x3.5 increase in mean M_{halo} ⇐ x1.8 increase in mean M*

Failure of galaxy-galaxy lensing

✦ CMASS galaxy-galaxy lensing over 250 deg^2 Leauthaud, **SS**+ (2017)





✦ **NONE** of the CMASS mocks explain our lensing signal.

Possible Reasons

✦ Galaxy-Halo connection?

See more details in Leauthaud, **SS**+ (2017)

- assembly bias & color selection
- baryonic effect: AGN feedback
- mass-dependent scatter

✦ Cosmology?

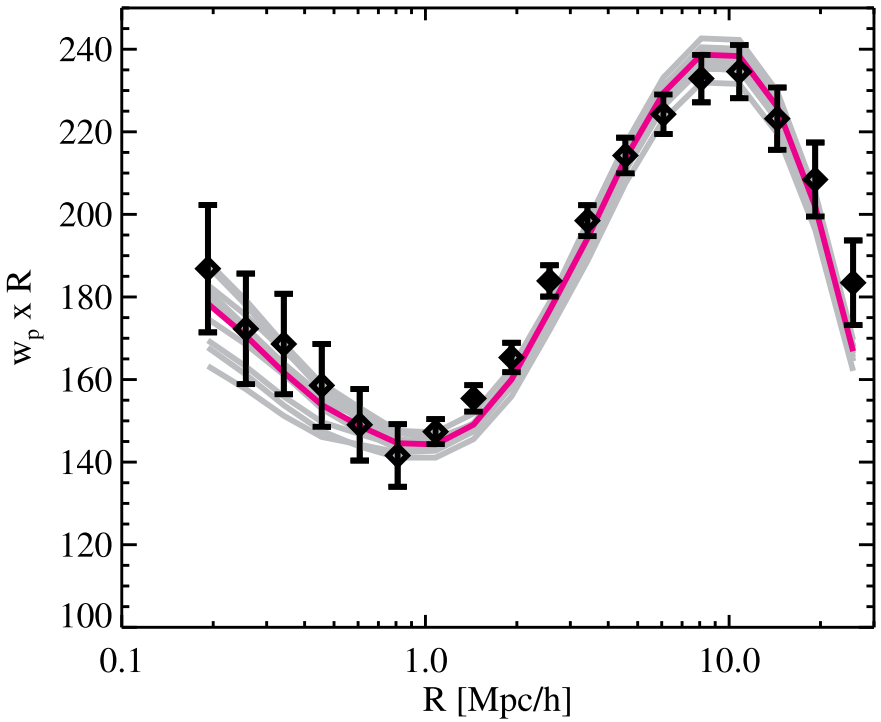
- Ω_m, σ_8
- neutrino mass
- modified gravity

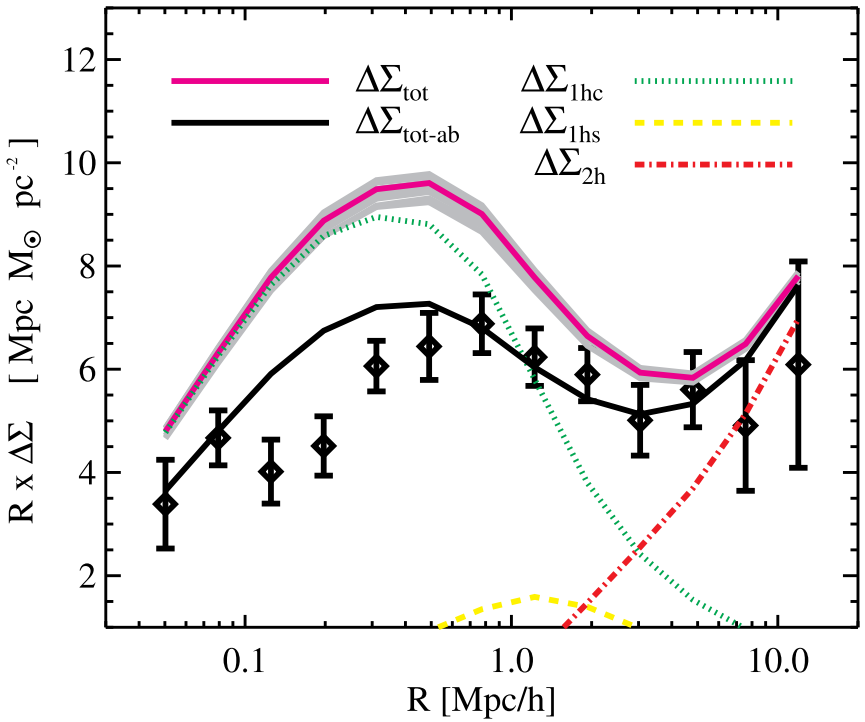
✦ Observational systematics?

- Song's HSC results on missing light at outer radii

Possible Reasons: *assembly bias?*

HOD fit to w_p ⟶ **predict $\Delta\Sigma$**





✦ necessary condition for assembly bias

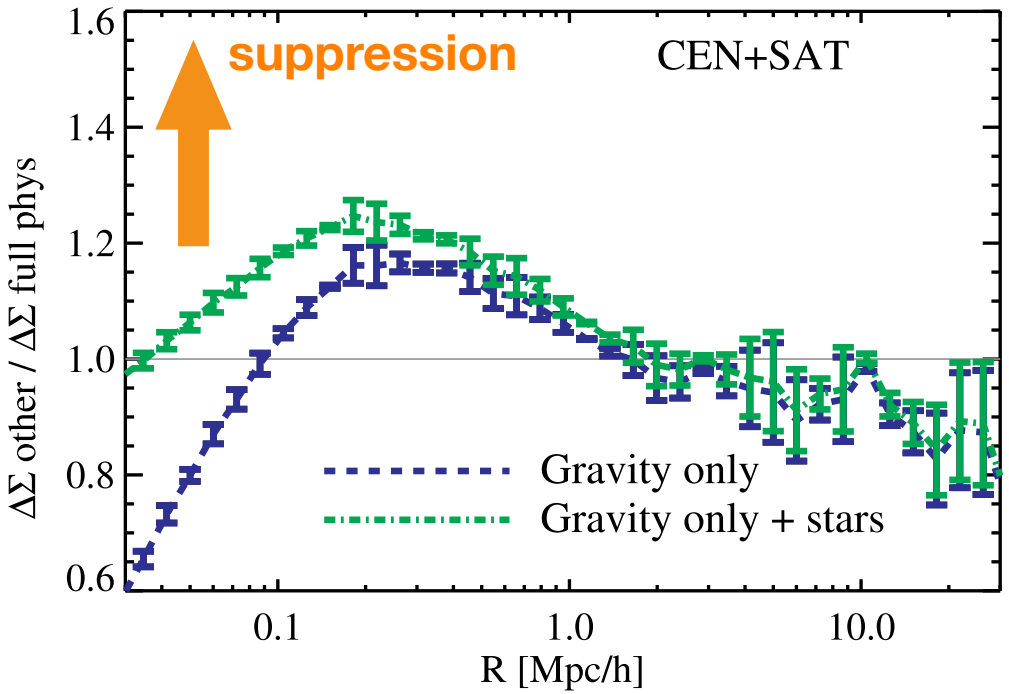
- need to make $\Delta\Sigma_{1hc}$ lower by **~25%** (c.f. 35% lower M_{halo})

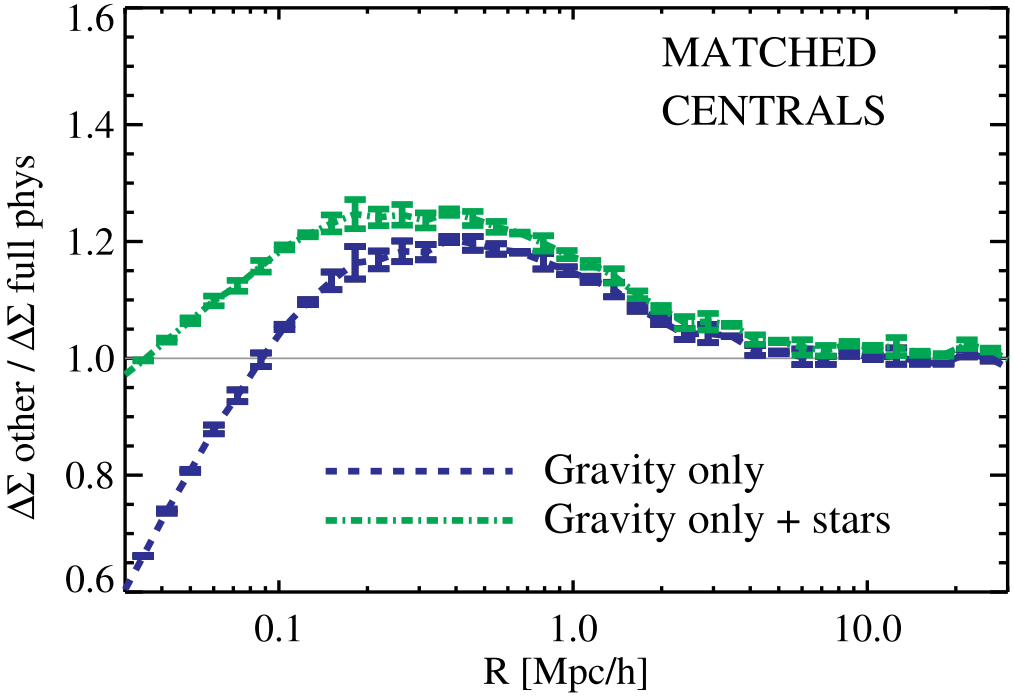
✦ tricky to perform age-matching at high-mass end

SS, Leauthaud, Hearin+(2016)

Possible Reasons: *Baryonic Effect?*

✦ sample with n_g=4x10^{-4} [(h/Mpc)^3] in ***Illustris (not TNG)***





- the impact of baryonic effect is important with a caveat of the aggressive AGN feedback in Illustris

Let's ask ourselves & you

- Do we even understand the galaxy-halo connection for massive galaxies ***at the statistical level of BOSS***?

  → highly relevant to both cosmology & galaxy evolution

- Stellar Mass, M* is probably the most relevant quantity

  → let's look at ***M* & its completeness*** for CMASS

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CMASS is NOT M*-complete!

Summary & Discussion

✦ **We revisit the M* completeness for the BOSS CMASS sample**

- **CMASS is NOT M*-complete NOR Constant MASS!**
- **a simple SHAM model**
  - **explains 'entire' SMF & w_p**
  - **fails to reproduce evolution of ξ_l and $\Delta\Sigma$**

✦ **BOSS offer challenges for a simple galaxy-halo modeling**

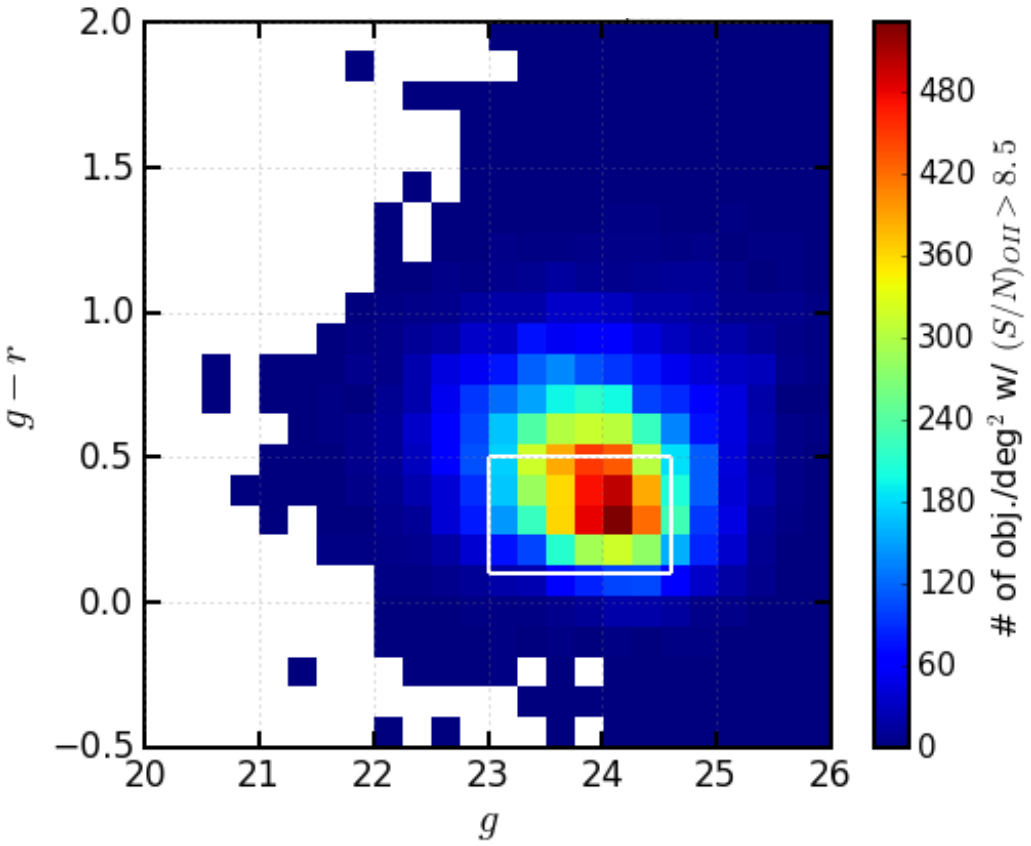
unlike e.g., SDSS Main sample.

- ***very precise* statistics**
- **selection effect: can be f(M*, SFR/color, ….)**

Future Prospects

✦ ***Selection effect*** **is a huge issue for** ***spectroscopic*** **galaxy surveys!**

- Emission Line Galaxies selected by color cut
- example in ***Subaru Prime Focus Spectrograph (PFS, 2020-2025)***



SMF at z~1.5 from Cosmos Mock