Models to assign galaxy color to dark matter halos

extensions of the abundance matching method for galaxy-halo connection

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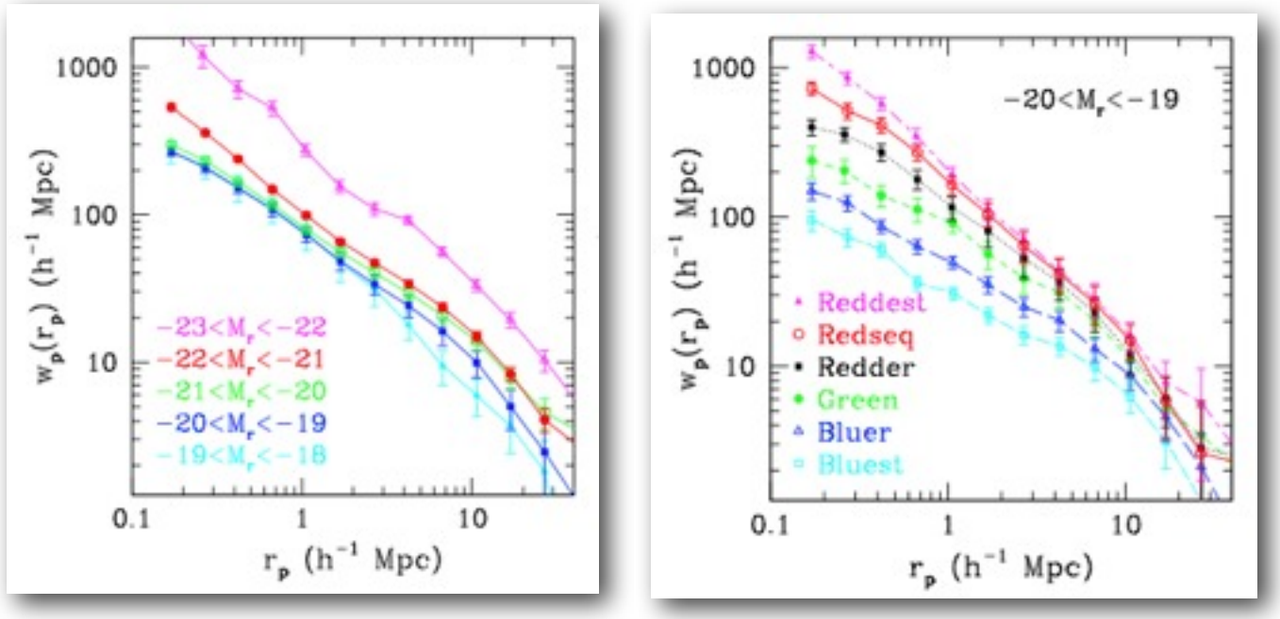
Aug. 2012 @Summer School 2012

Masaki, Lin & Yoshida, in prep.

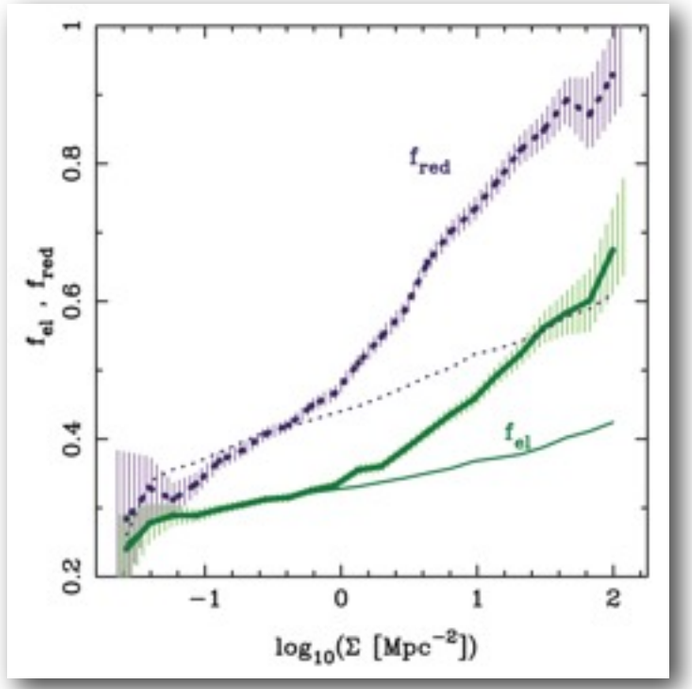
1. Introduction

Luminosity/color-dependence of 2pt. correlation function



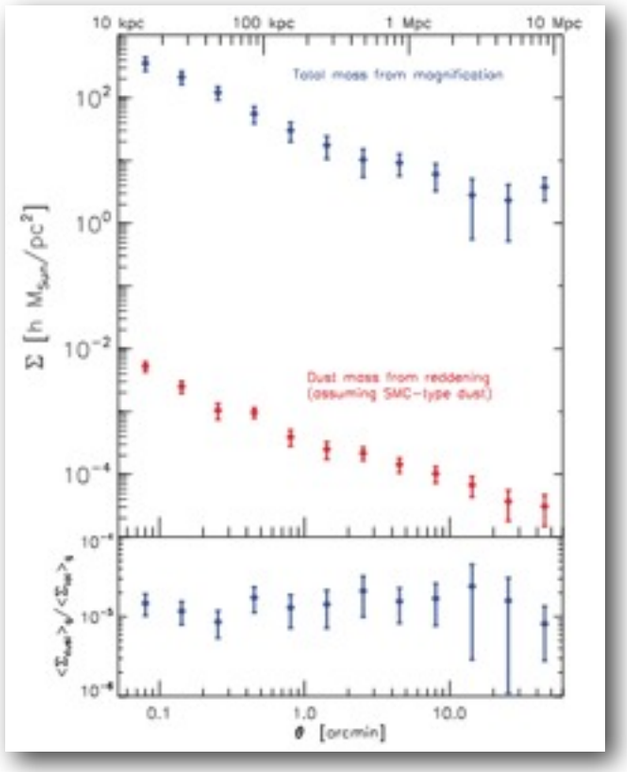
Zehavi+'12

Local density-galaxy type/color relation



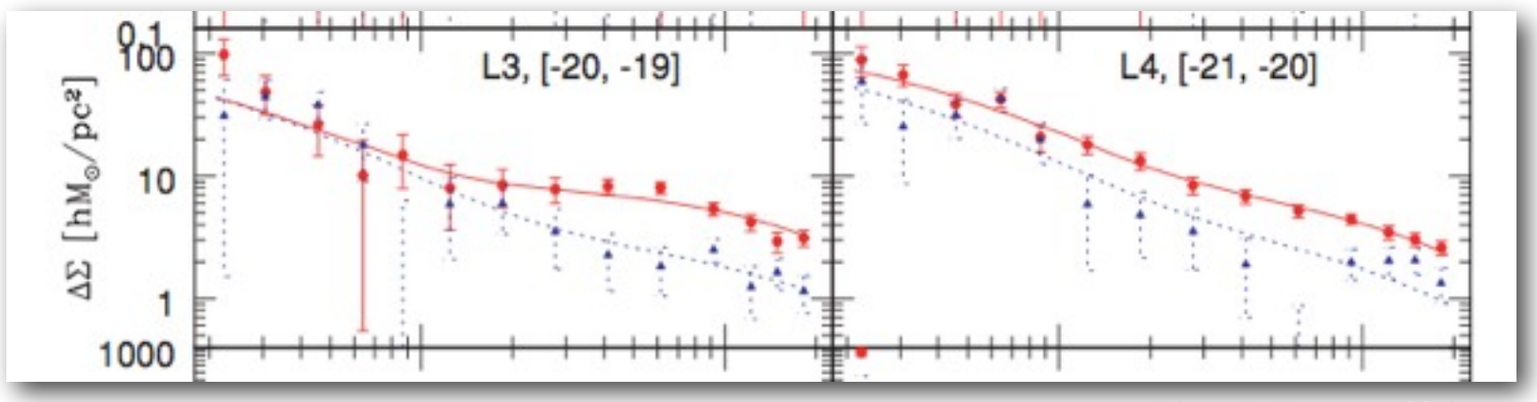
Bamford+'09

Mass & dust profile around galaxy



Menard+'10

Luminosity/type-dependence of mass profile



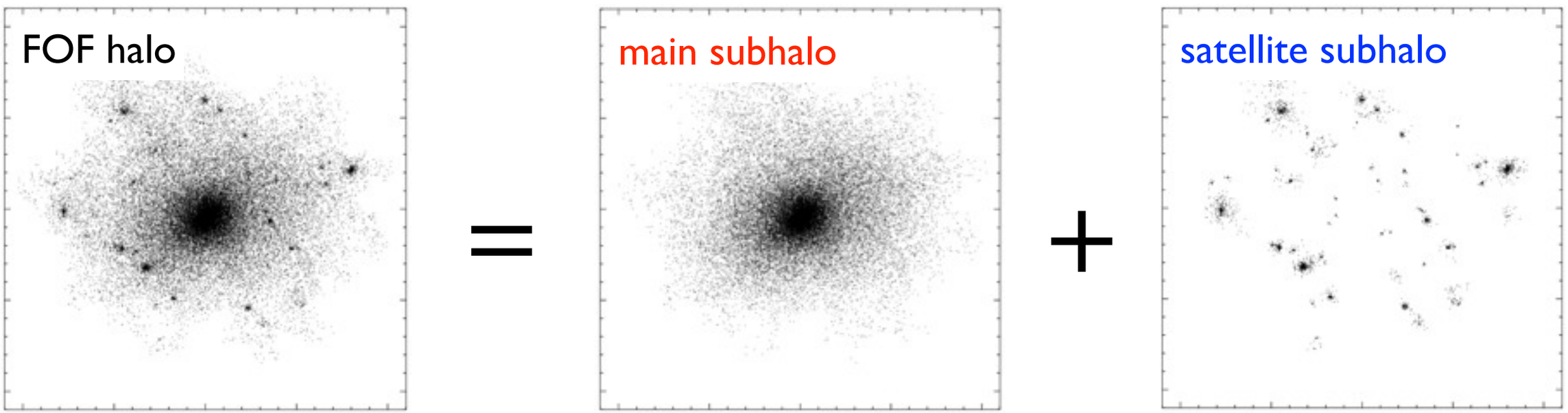
Mandelbaum+'06

- Understanding of various measurements in the cosmological context
  → *Galaxy-halo connection is highly important.*

Subhalo abundance matching (SHAM) for halo-galaxy connection

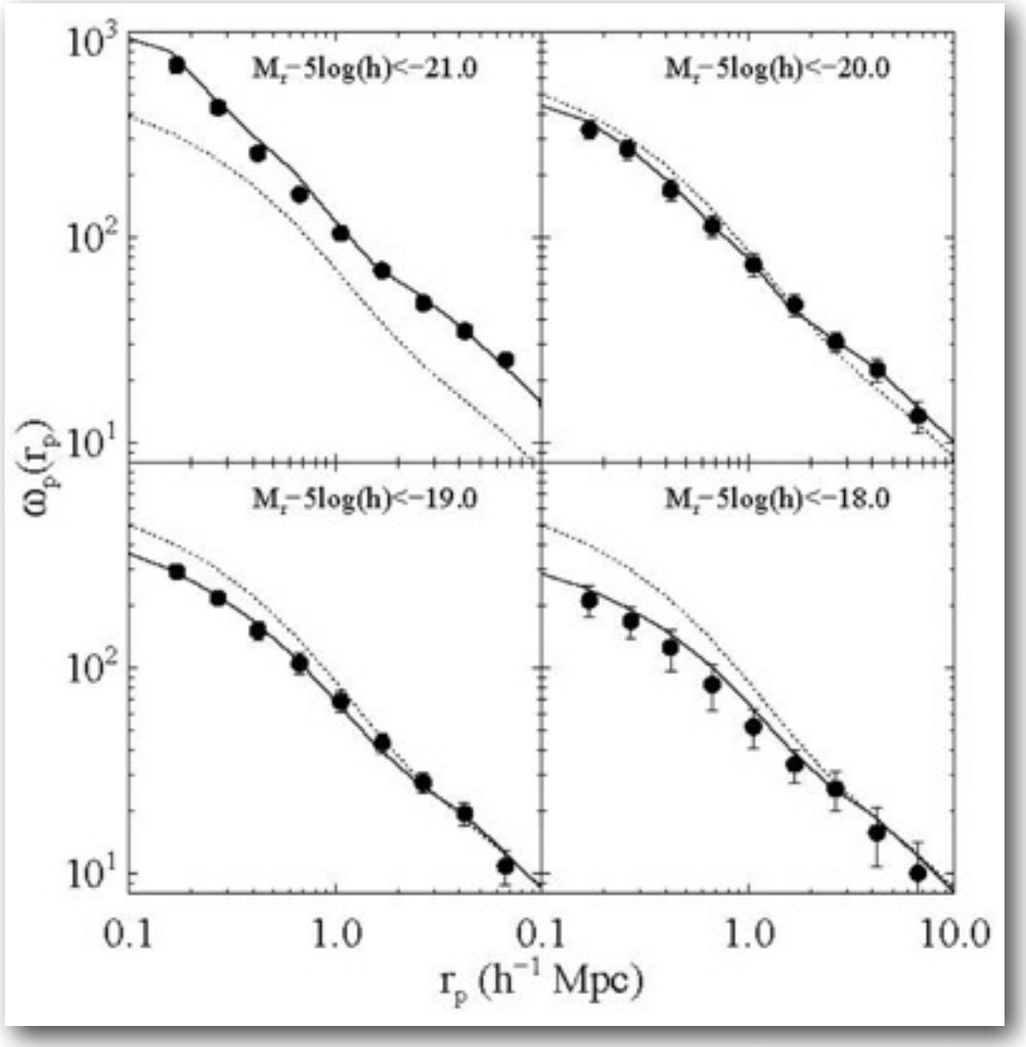
(e.g., Conroy+'06, Trujillo-Gomez+'12)

- assign central galaxies into *main subhalos*, satellite galaxies into *satellite subhalos*.
- subhalo: local density peak in halos, remnant of halo merger



Springel+'01

luminosity-dependent galaxy clustering from SDSS (points) vs. SHAM (solid lines)



Conroy+'06

SHAM works "very well" without free parameters.

- an assumption: monotonic relation between galaxy luminosity/stellar mass and subhalo circular velocity

$$n_{\rm galaxy}(>L_i) = n_{\rm subhalo}(>V_{{\rm max},i})$$

- halo circular velocity

$$V_{\rm cir} = \sqrt{GM(<r)/r}$$

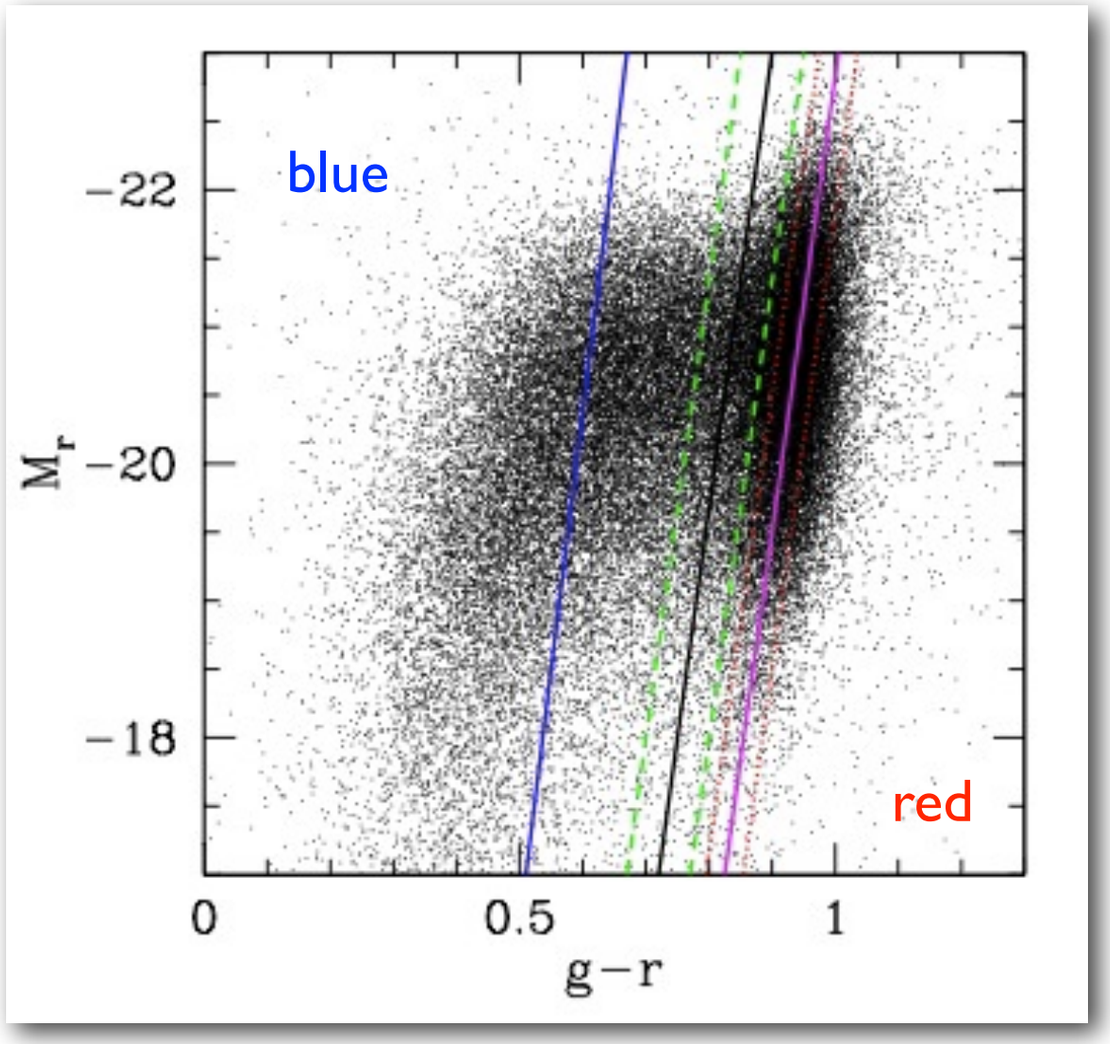
$$V_{\rm max} = \begin{cases} V_{\rm max}^{\rm acc} & \text{for satellite} \\ V_{\rm max}^{\rm now} & \text{for main} \end{cases}$$

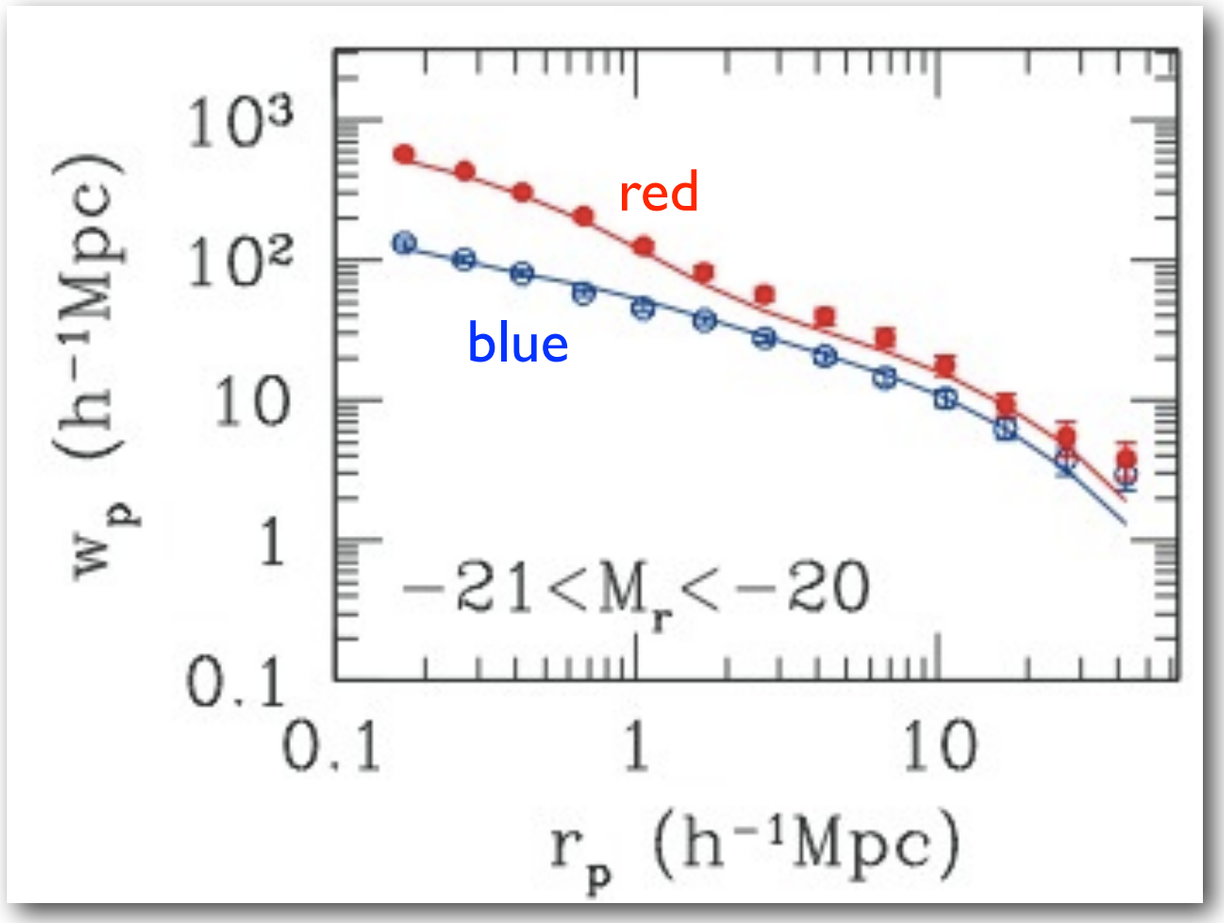
- **need to track subhalo assembly history**

Is SHAM enough...??

- SHAM only assigns luminosity in a band or stellar mass to subhalos
- However galaxies have various properties (e.g., other bands, color, SFR, etc.)
- To make galaxy-halo connection concrete, assigning multiple properties is clearly important.

an example: color-dependence of 2pt. correlation function





Zehavi+'12

- It is known that red galaxies are more clustered than blue ones.
- **In this work, we extend SHAM to assign galaxy color.**

2. Color assignment: models & results

N-body simulation

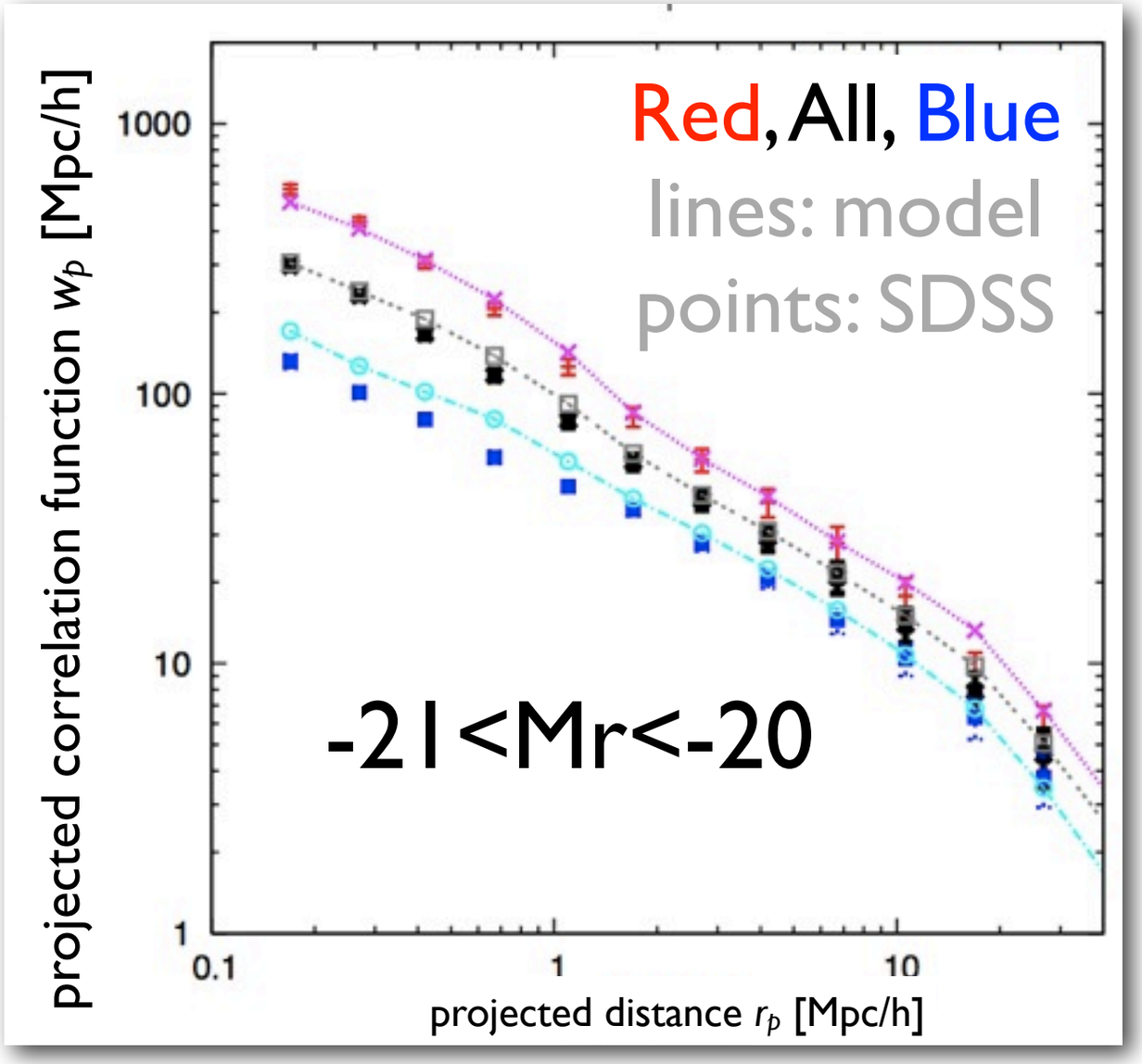
- *WMAP* 7-yr cosmology
- $L_{box}=200Mpc/h$, $N_{part}=1024^3$
- $m_{part}=5.8e8M_{sun}/h$, $\varepsilon=10kpc/h$
- 50 snapshots from $z=10$ *to* $z=0$ with equal $dln(1+z)$
- have both resolution and volume

Models

- After the original SHAM, we further divide subhalo catalog by a subhalo property into 2 groups (they correspond to red/blue).
- The observed red/blue fraction is matched.
- an assumption: color is a proxy for galaxy age
  - hints from assembly bias studies (e.g., *Gao+'05,'07, Wechsler+'06*)
    - subhalo age
    - local DM density around subhalos
    - concentration parameters (we have tried but failed)

subhalo age

- motivation:
  direct relation between subhalo and galaxy age
- subhalo age?
  → subhalo formation epoch z_{form}
- definition: $V(z=z_{form})=f\times V_{max}$, f should be tuned
- subhalos with higher z_{form} ⇔ redder galaxies

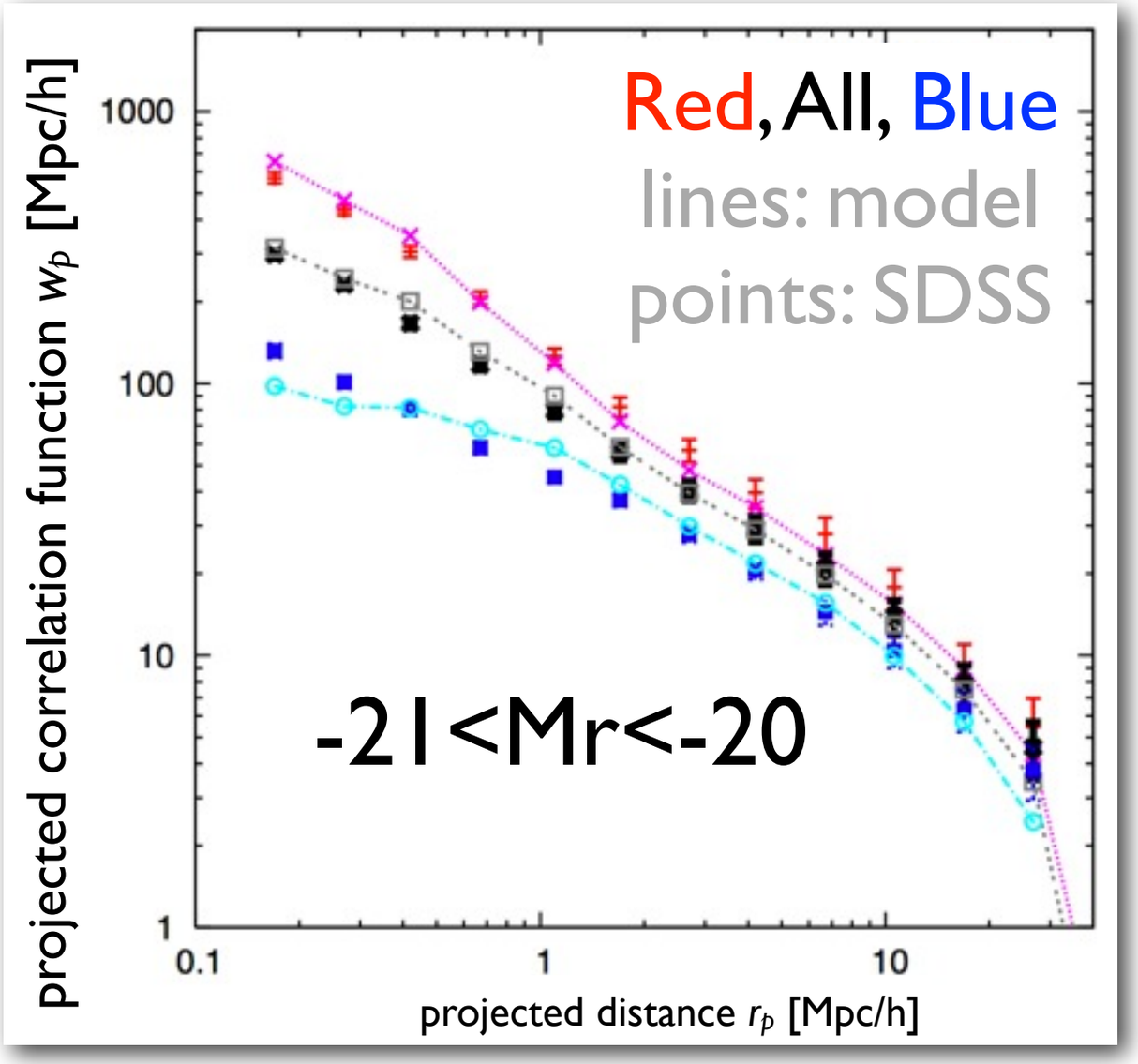


observation from *Zehavi+'12*

- We found the "color split" depends on f-value in the definition.
- The higher f-value gives larger split.
- $V(z=z_{form})=0.8V_{max}$ gives good agreement.
- w_ps of other magnitude bins (-22<Mr<-21, -20<Mr<-19) are also reproduced well.

local DM density

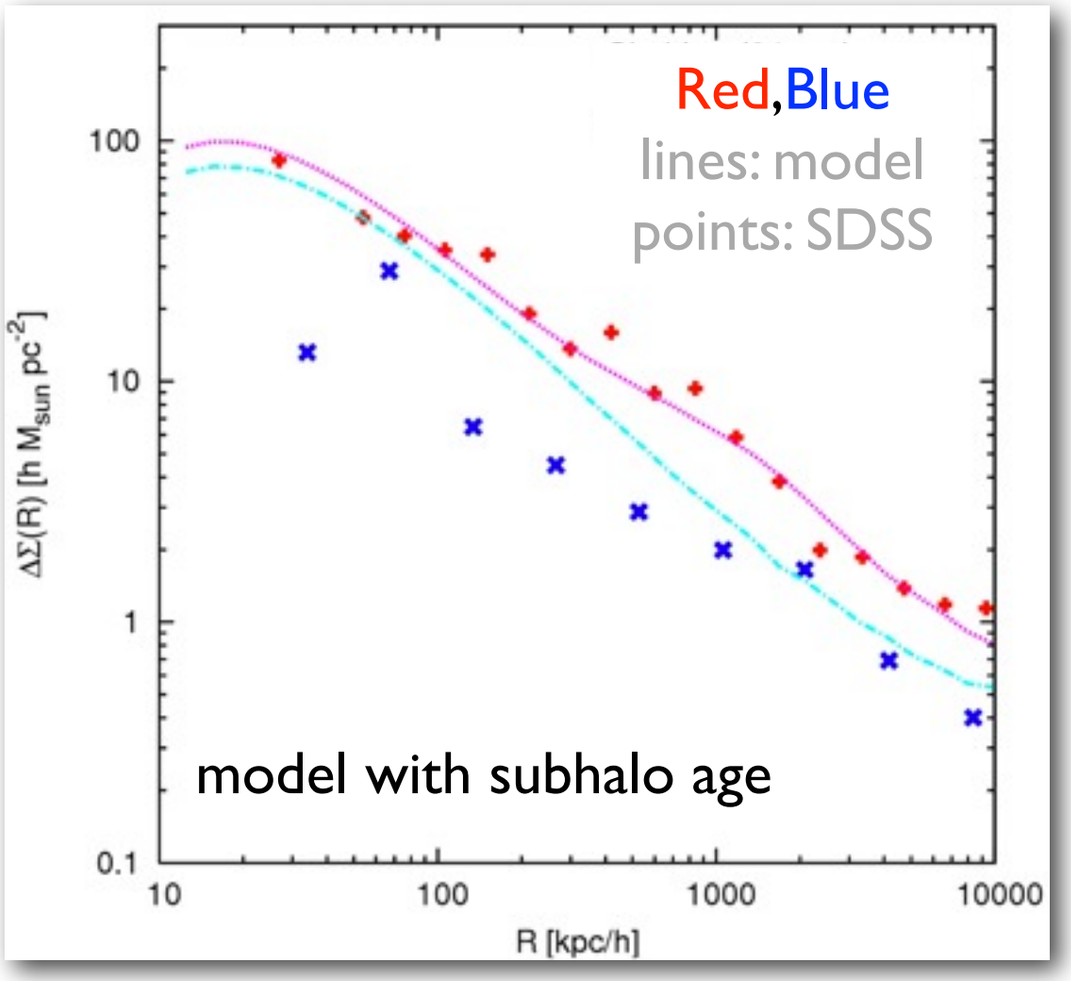
- motivation:
  halos in the high density regions are expected to form at earlier epoch
- cut the whole simulation box into cells
- count number of *N*-doby particles in each cell
- cell size L_{cell} should be tuned
- subhalos in higher density cell correspond to redder galaxies.

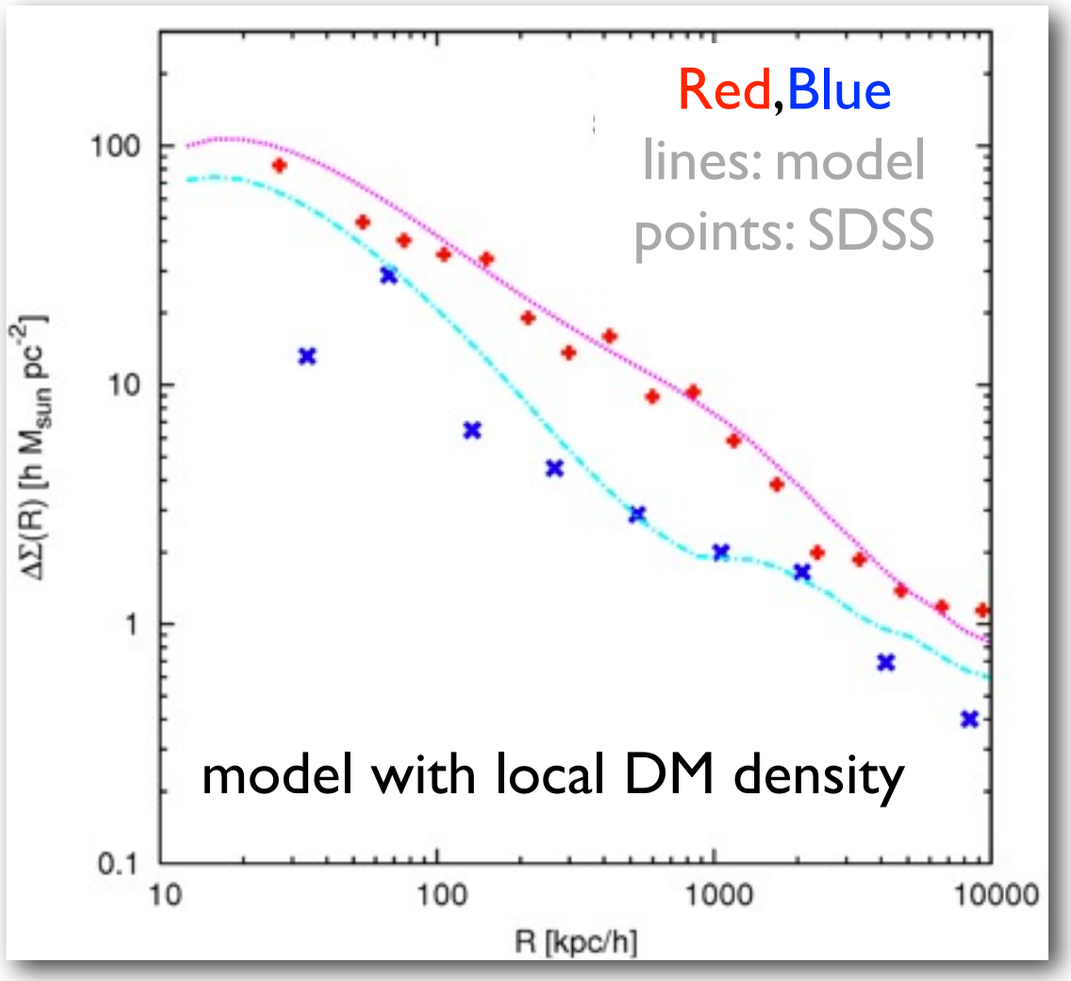


observation from *Zehavi+'12*

- As well as subhalo age model, the split depends on the density measure itself.
- Larger *Lcell* gives larger split.
- We found that counting *N*-body particle within cell of *Lcell=350kpc/h* gives good agreement.
- Also, clusterings of other mag. binned samples are reproduced very well.

Test models against color-dependent mass profile around galaxies





- To test the above models, we measure the mean mass profile around sample subhalos using simulation data.
- Comparing the lensing results by *Sheldon+'04*, we found that the model with local DM density is better one.

3. Summary

- We are now constructing a new phenomenological model to assign galaxy color to subhalos by extending SHAM.
- We found that models with "subhalo age" and local DM density give good agreement with the observed galaxy 2pt. correlation functions.
- The models are tested against color-dependent mass profiles from g-g lensing.
- The mass profiles from the model with local DM density agree with the observations better than another one.
- ***To link galaxies with dark matter halos correctly, one should consider not only clustering but also other available measurements.***