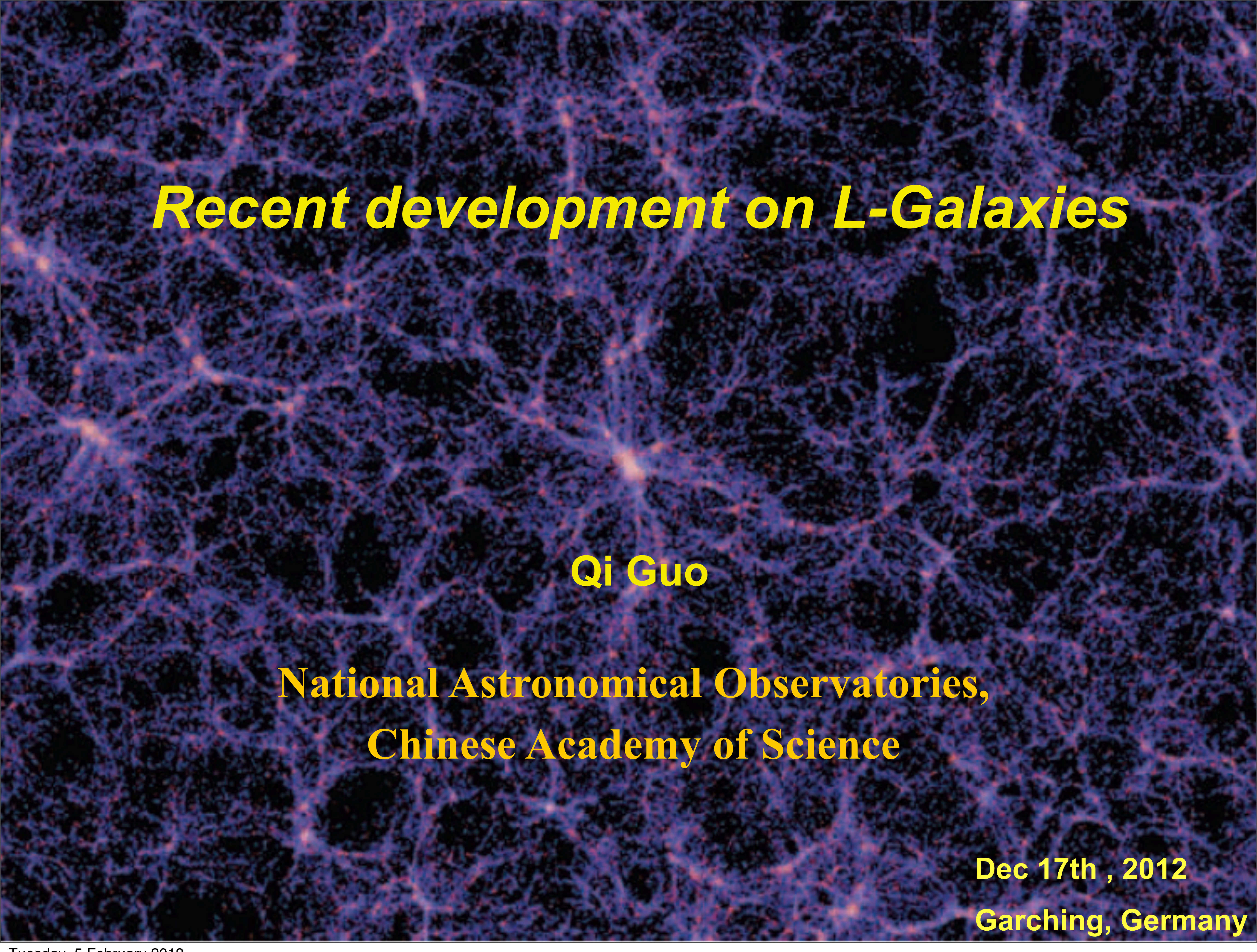


Recent development on L-Galaxies

Qi Guo

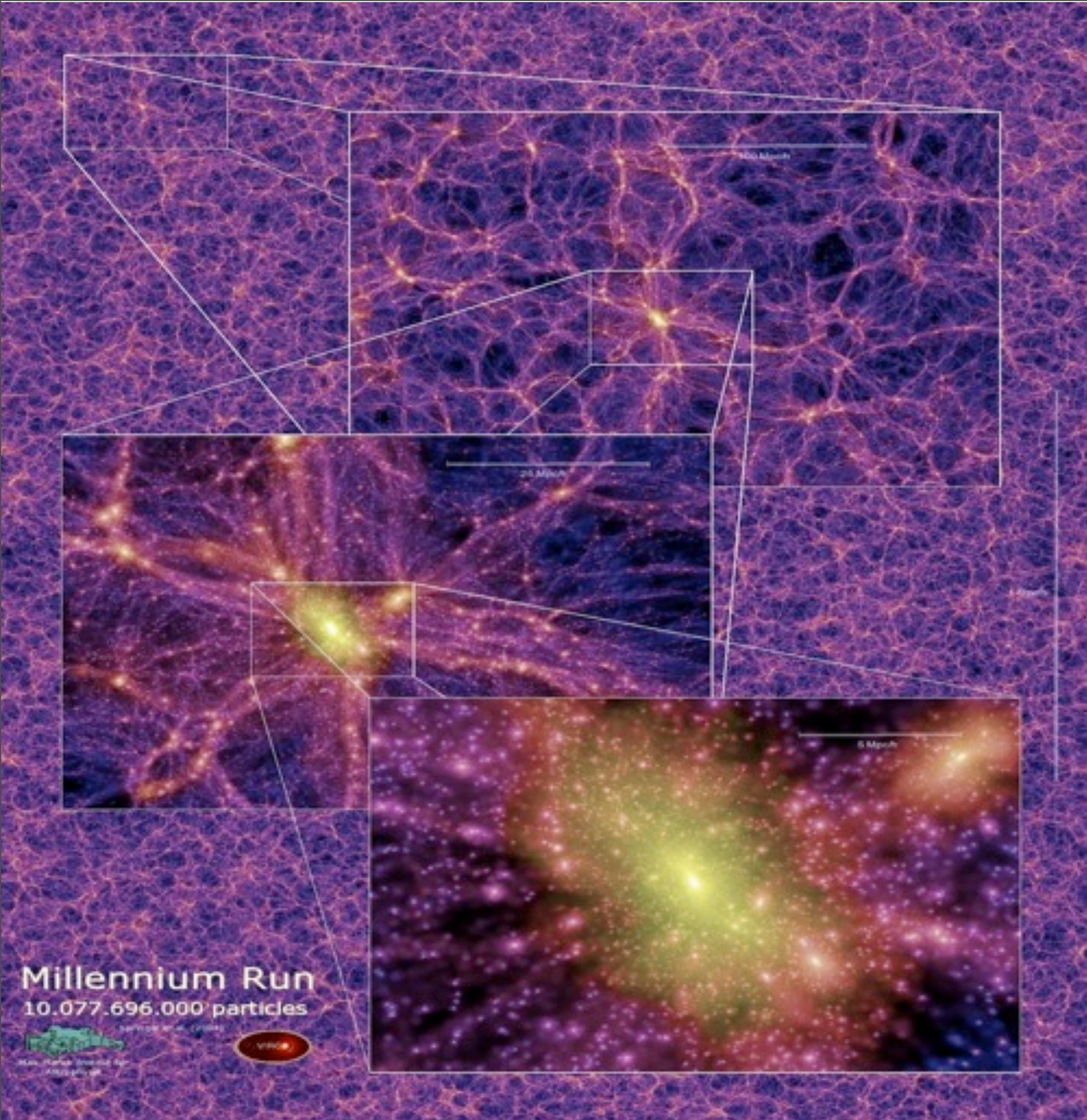
National Astronomical Observatories,
Chinese Academy of Science

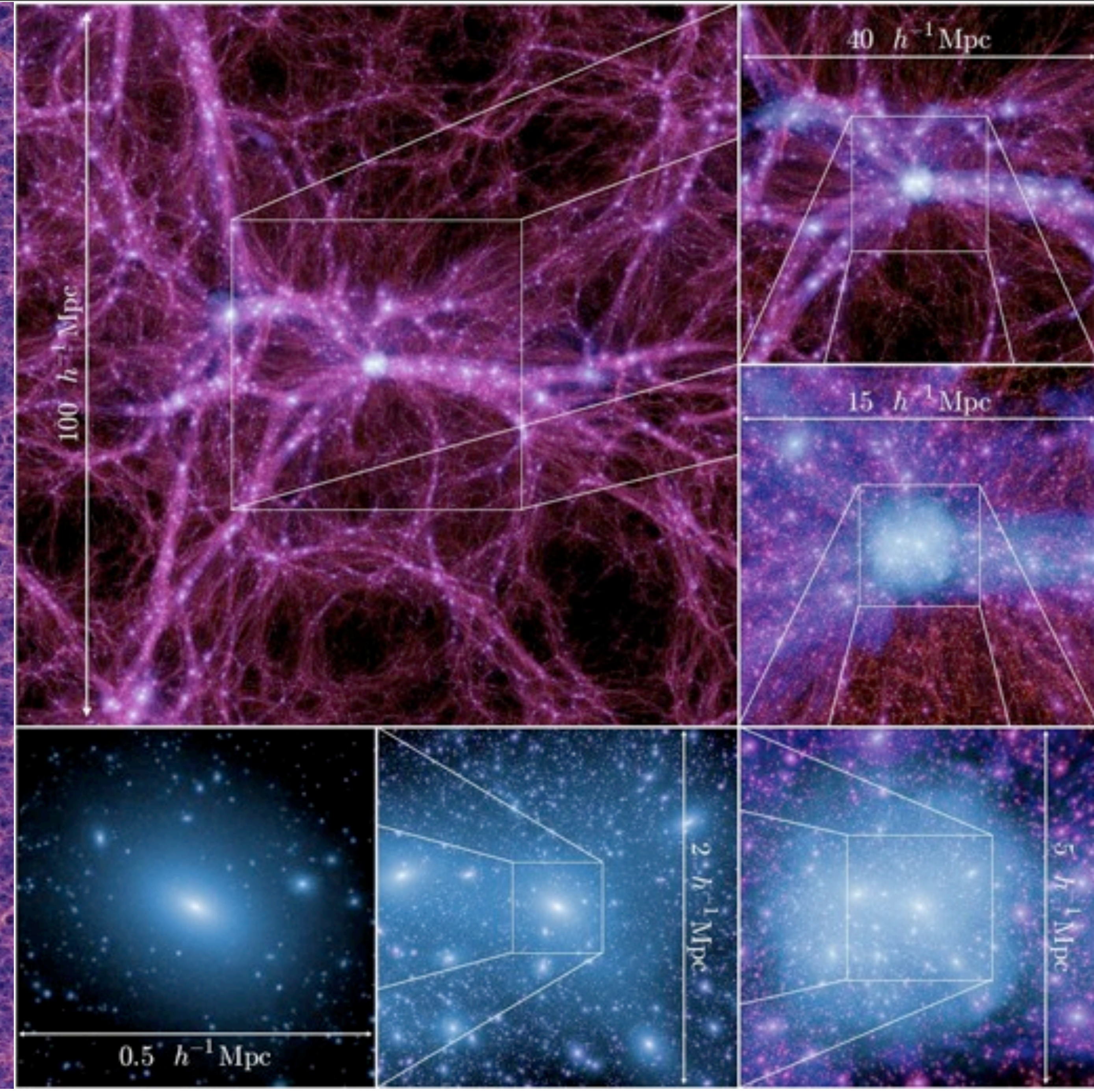
Dec 17th , 2012

Garching, Germany

Semi-analytic models

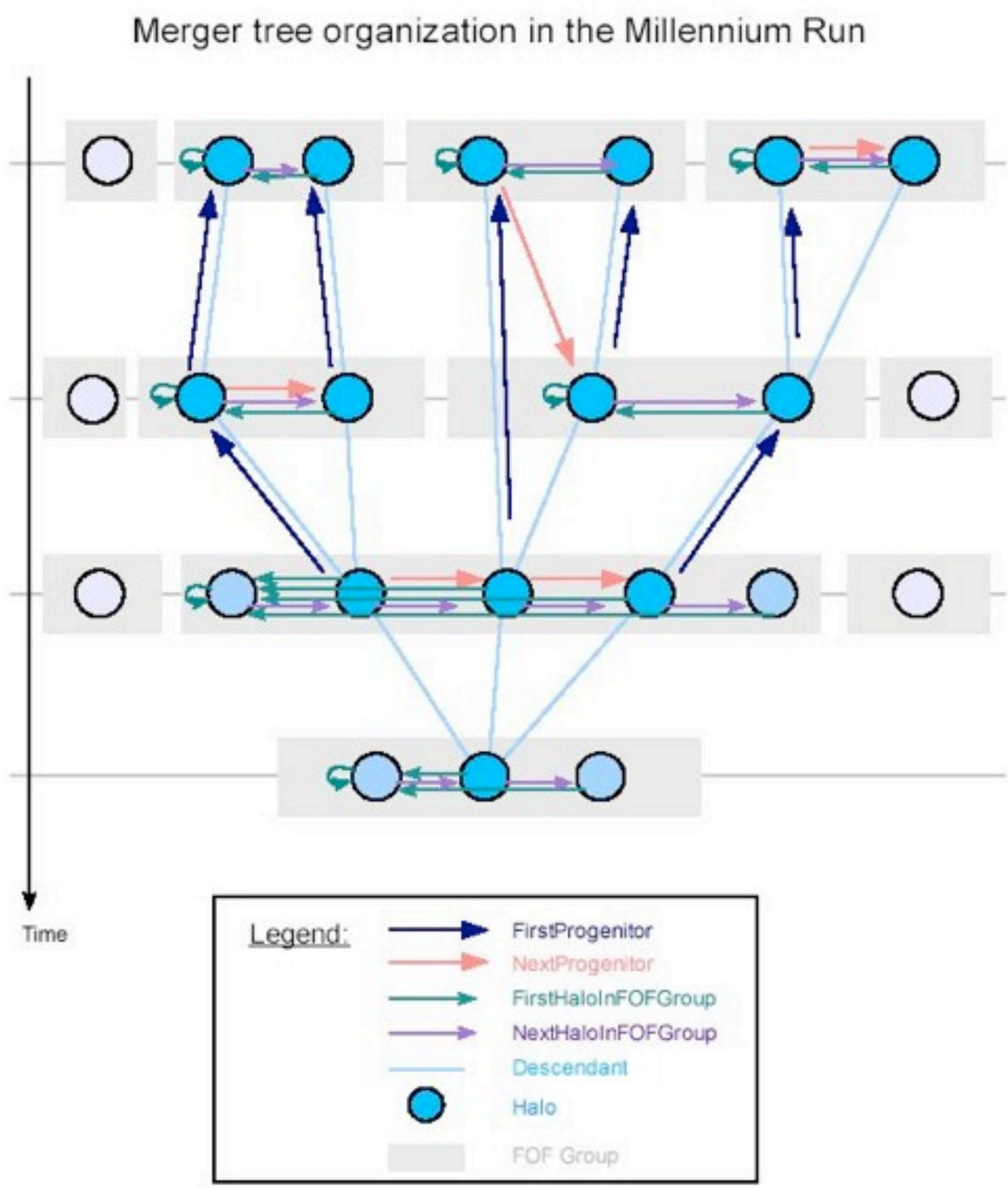
- N-body simulations and halo trees
- Prescription of baryonic processes
- Constraints from the most recent data -- the full SDSS/DR7



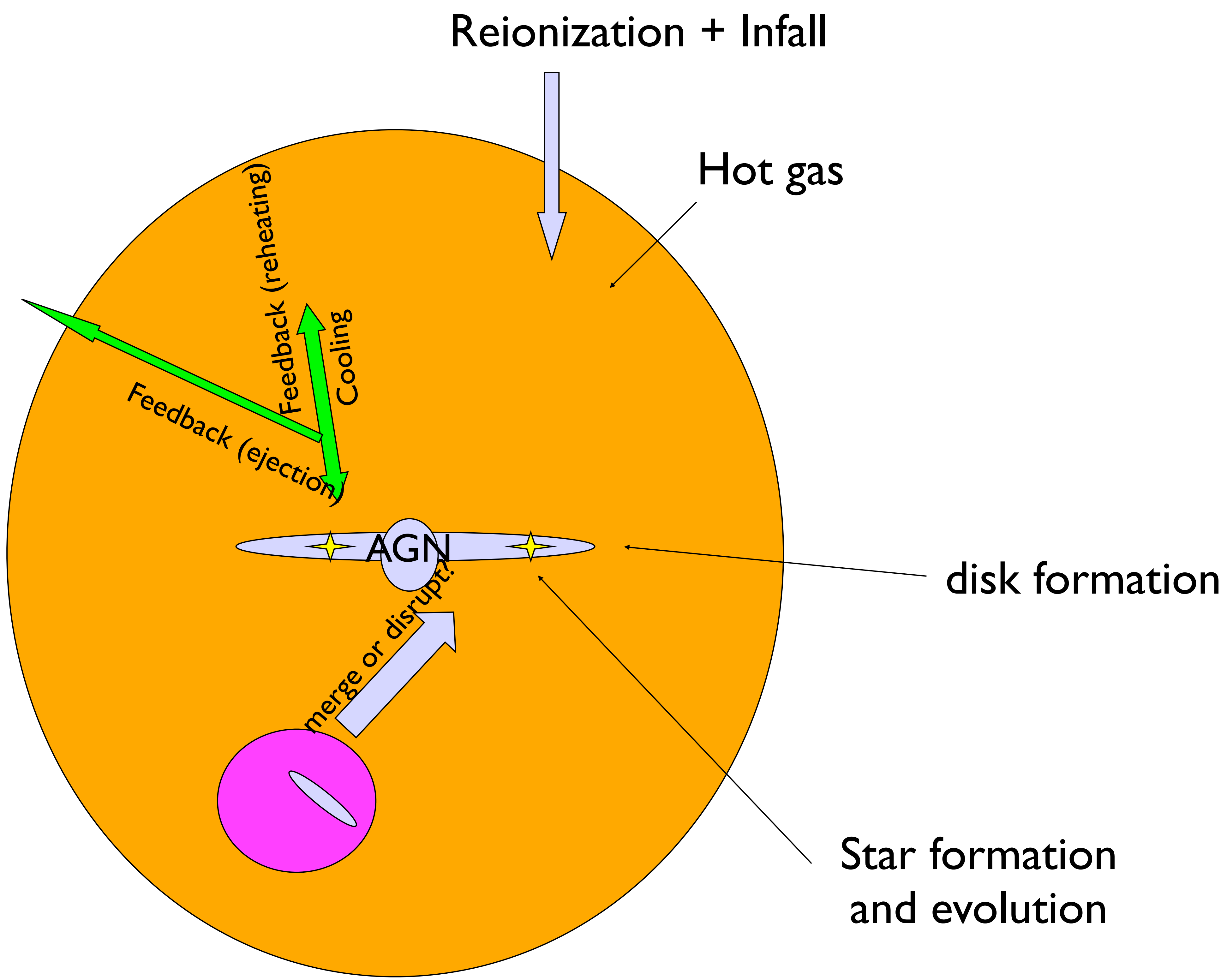


	np	Box	Mp	redshift	cosmology	f_group
MS	2160^3	500 Mpc/h	10^9Msun	0 -127	WMAP1	60%
MS-II	2160^3	100 Mpc/h	10^7Msun	0 -127	WMAP1	50%

Merge trees


Merger tree organization in the Millennium Run
Time
Legend:
FirstProgenitor
NextProgenitor
FirstHaloInFOFGroup
NextHaloInFOFGroup
Descendant
Halo
FOF Group

Model galaxy formation



Recent Development since De Lucia & Blaizot (2007)

Recipes:

* SN feedback

* Ram-pressure and tidal stripping from satellites
  (hot gas)

* Disruption of satellites (cold gas and stars)

* Include size (cold gas and stars)

* Treatment for galaxies that belongs to one FOF but with r > Rvir

* Up-to-date reionization model (Okomato et al. 2008)

* Gas reincorporation; galaxy structure; heavy elements

Cosmology:

* Apply to a cosmology with the 7-year WMAP parameters.

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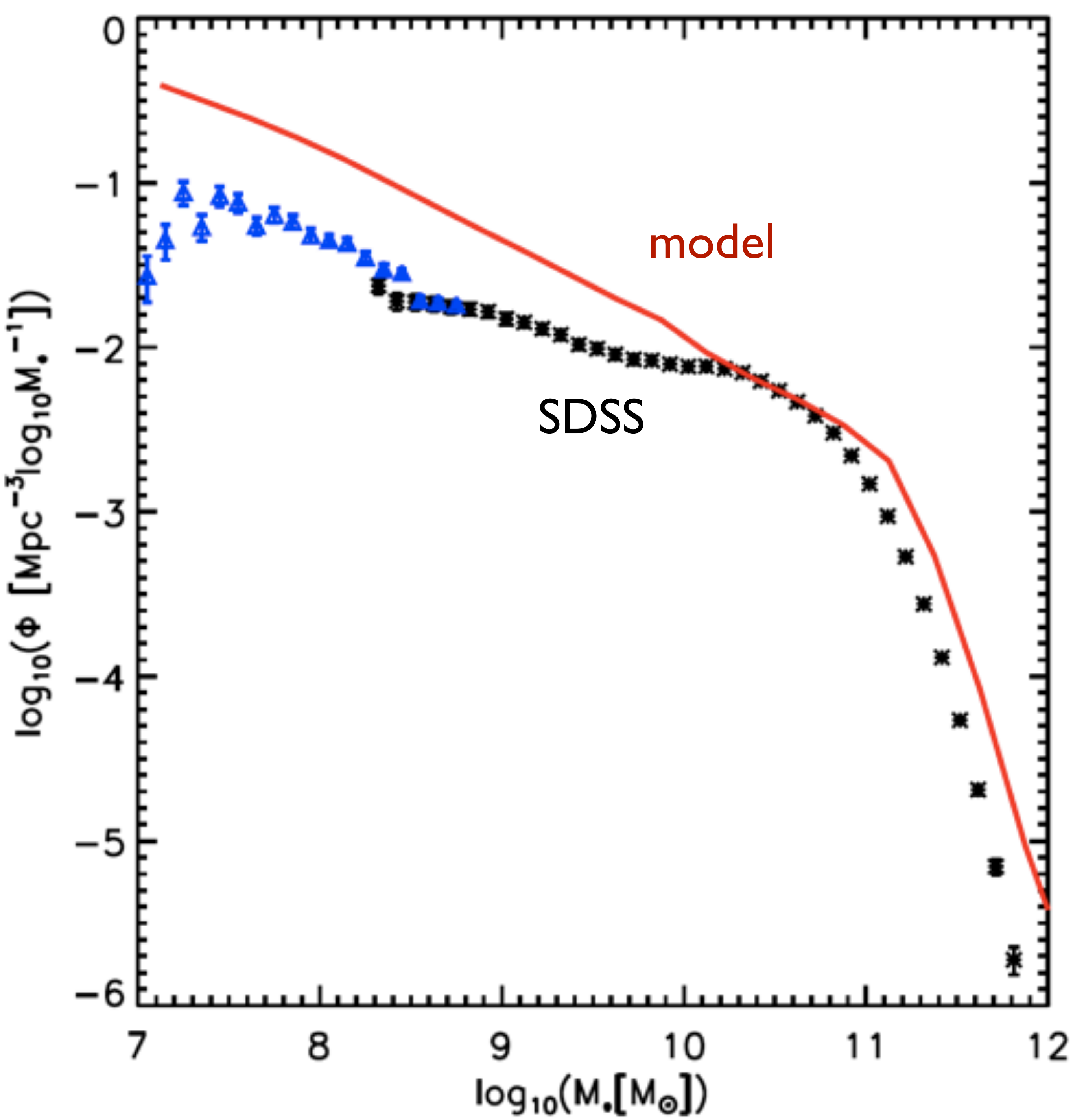
Abundance of low mass galaxies

Old model



De Lucia & Blaizot (2007)

SN feedback model

SN energy available for feedback (reheating and ejecting)

$$\delta E_{\rm SN} = \epsilon_{\rm halo} \times \frac{1}{2}\delta M_* V_{\rm SN}^2.$$

$\epsilon_{\rm halo}$ Constant Old

$$\epsilon_{\rm halo} = \eta \times \left[0.5 + \left(\frac{V_{\rm max}}{70 {\rm km/s}}\right)^{-\beta_2}\right],$$ New

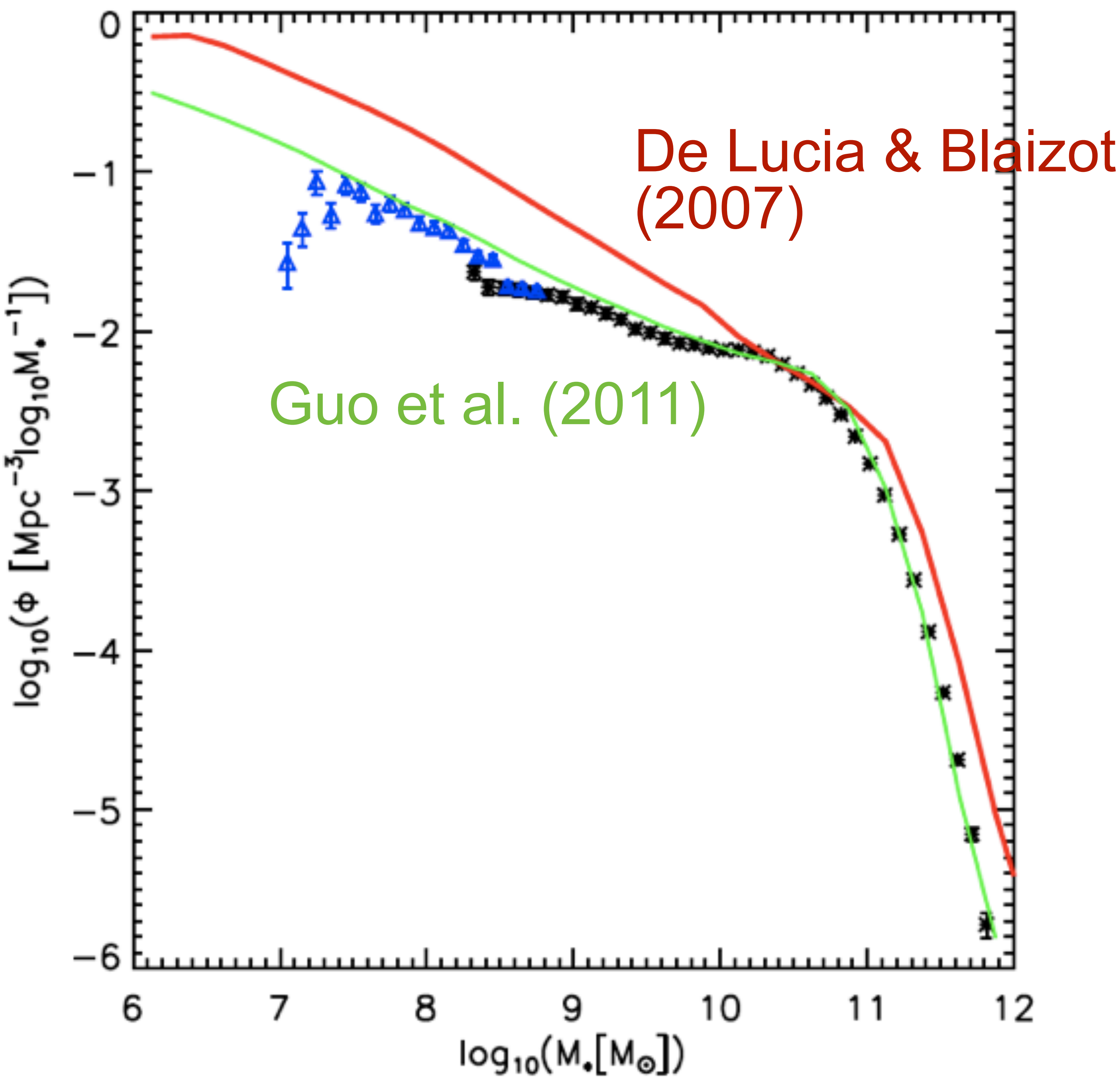
Reheated Mass

$$\delta M_{\rm reheat} = \epsilon_{\rm disk} \times \delta M_*.$$

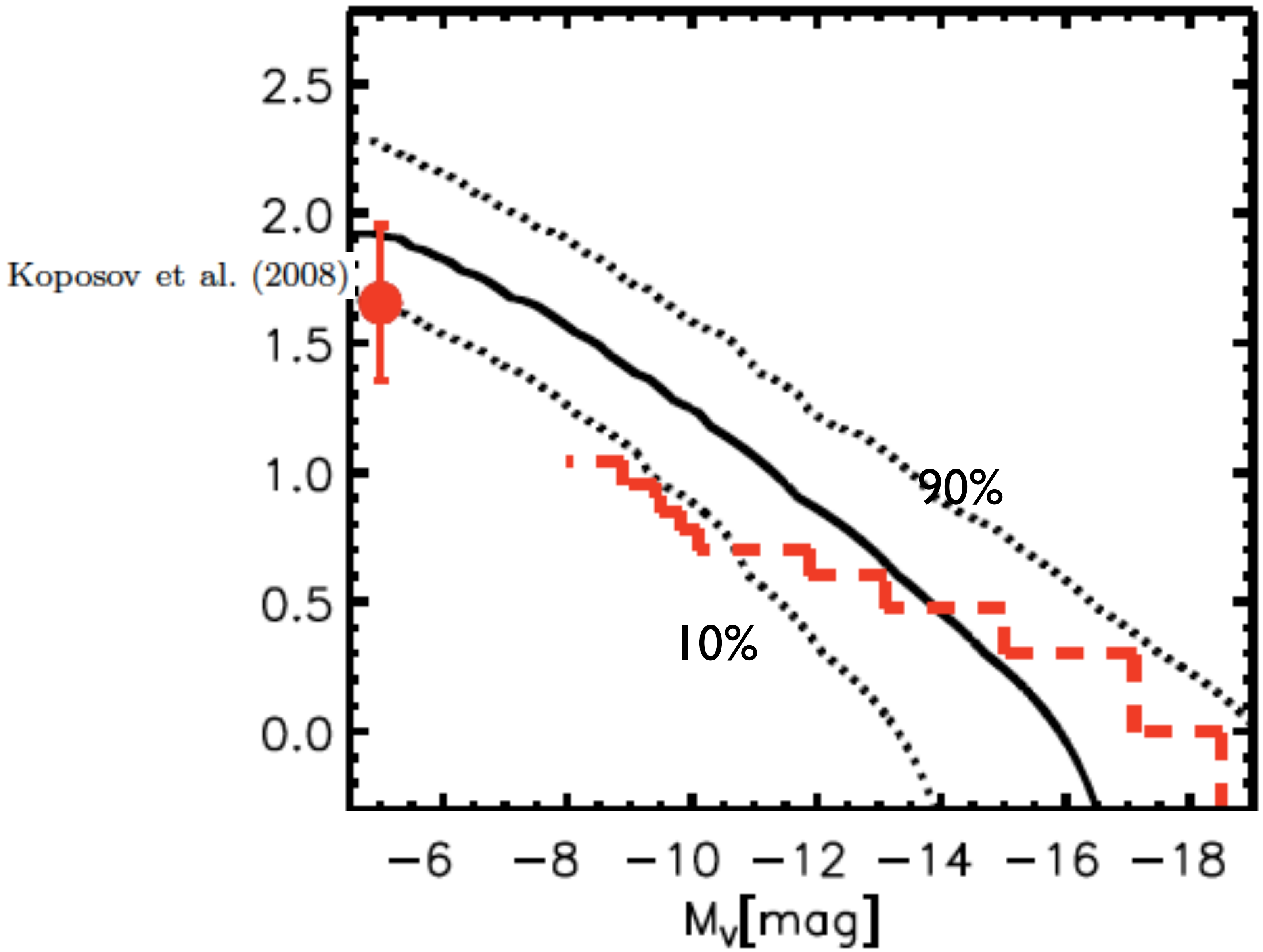
$\epsilon_{\rm disk}$: Constant Old

$$\epsilon_{\rm disk} = \epsilon \times \left[0.5 + \left(\frac{V_{\rm max}}{70 {\rm km/s}}\right)^{-\beta_1}\right],$$ New

Abundance of low mass galaxies



Satellites around the MW



Nothing has been fine-tuned to reproduce the luminosity function of the MW satellites.

Striping the hot gas from satellites

Old: Instantaneously striping after infall

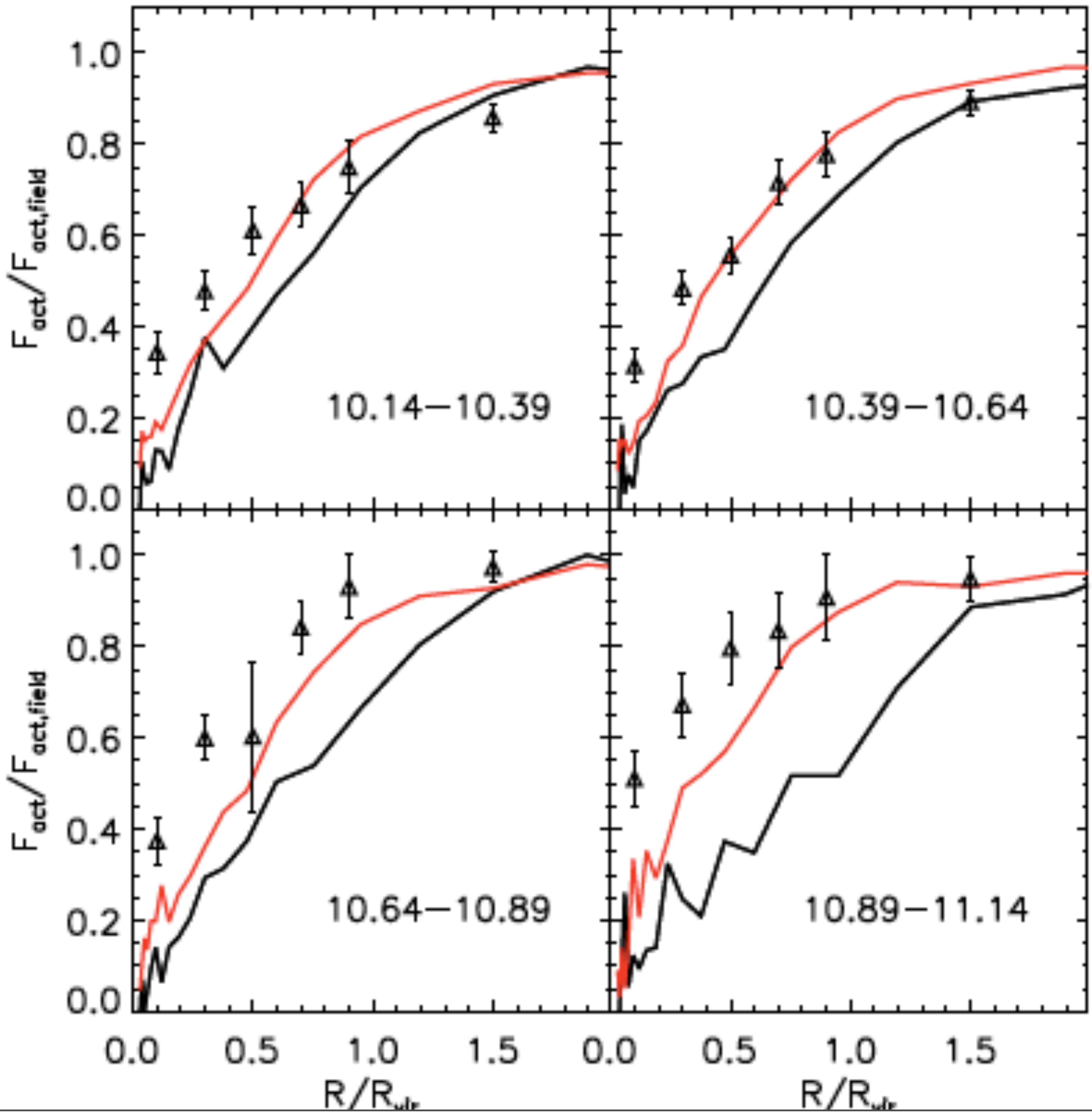
New: Ram-pressure + tidal force induced gradually stripping

ram pressure $$\rho_{\rm sat}(R_{\rm r.p.})V_{\rm sat}^2 = \rho_{\rm par}(R)V_{\rm orbit}^2,$$

tidal force $$R_{\rm tidal} = \left(\frac{M_{\rm DM}}{M_{\rm DM,infall}}\right) R_{\rm DM,infall}$$

stripping radius $$R_{\rm strip} = min(R_{\rm tidal}, R_{\rm r.p.}).$$

Fraction of actively star-forming galaxies



sSFR > 1d-11

De Lucia & Blaizot (2007)

vs.

Guo et al. (2011)

The model with gradually stripping matches the observation better.

Size of Galaxies

Late Type

Gas disk

$$\Delta \vec{J}_{\rm gas} = \delta \vec{J}_{\rm gas,cooling} + \delta \vec{J}_{\rm gas,acc} + \delta \vec{J}_{\rm gas,SF},$$

$$R_{\rm gas,d} = \frac{J_{\rm gas}/M_{\rm gas}}{2V_{\rm max}},$$

Stellar disk

$$\delta \vec{J}_{\rm gas,SF} = -\dot{M}_* \frac{\vec{J}_{\rm gas}}{M_{\rm gas}} \delta t = -\delta \vec{J}_{*,\rm SF},$$

$$R_{*,\rm d} = \frac{J_*/M_{*,\rm d}}{2V_{\rm max}},$$

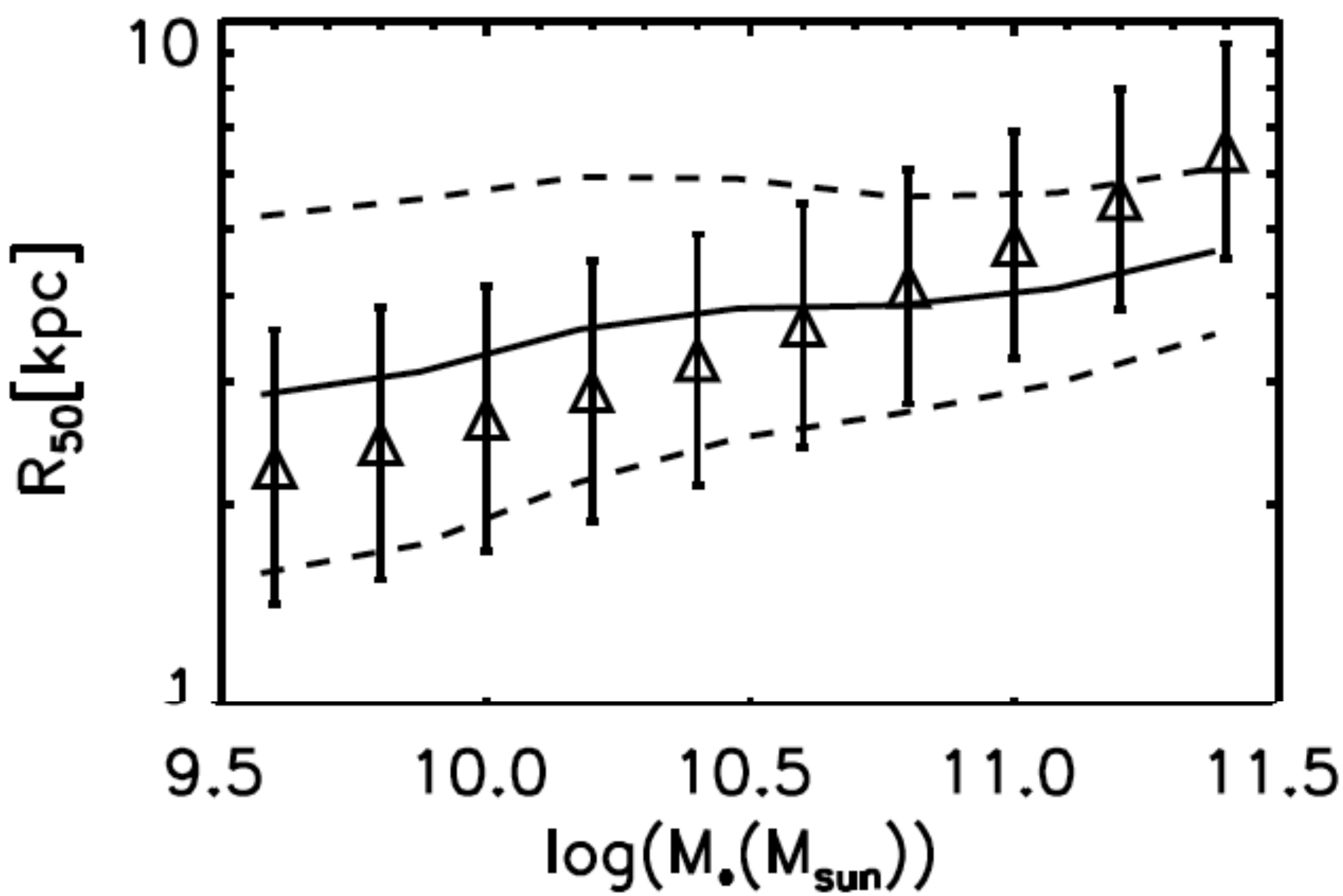
Size of Galaxies

Late Type

Gas disk

$$\Delta \vec{J}_{\rm gas} = \delta \vec{J}_{\rm gas,cooling} + \delta \vec{J}_{\rm gas,acc} + \delta \vec{J}_{\rm gas,SF},$$

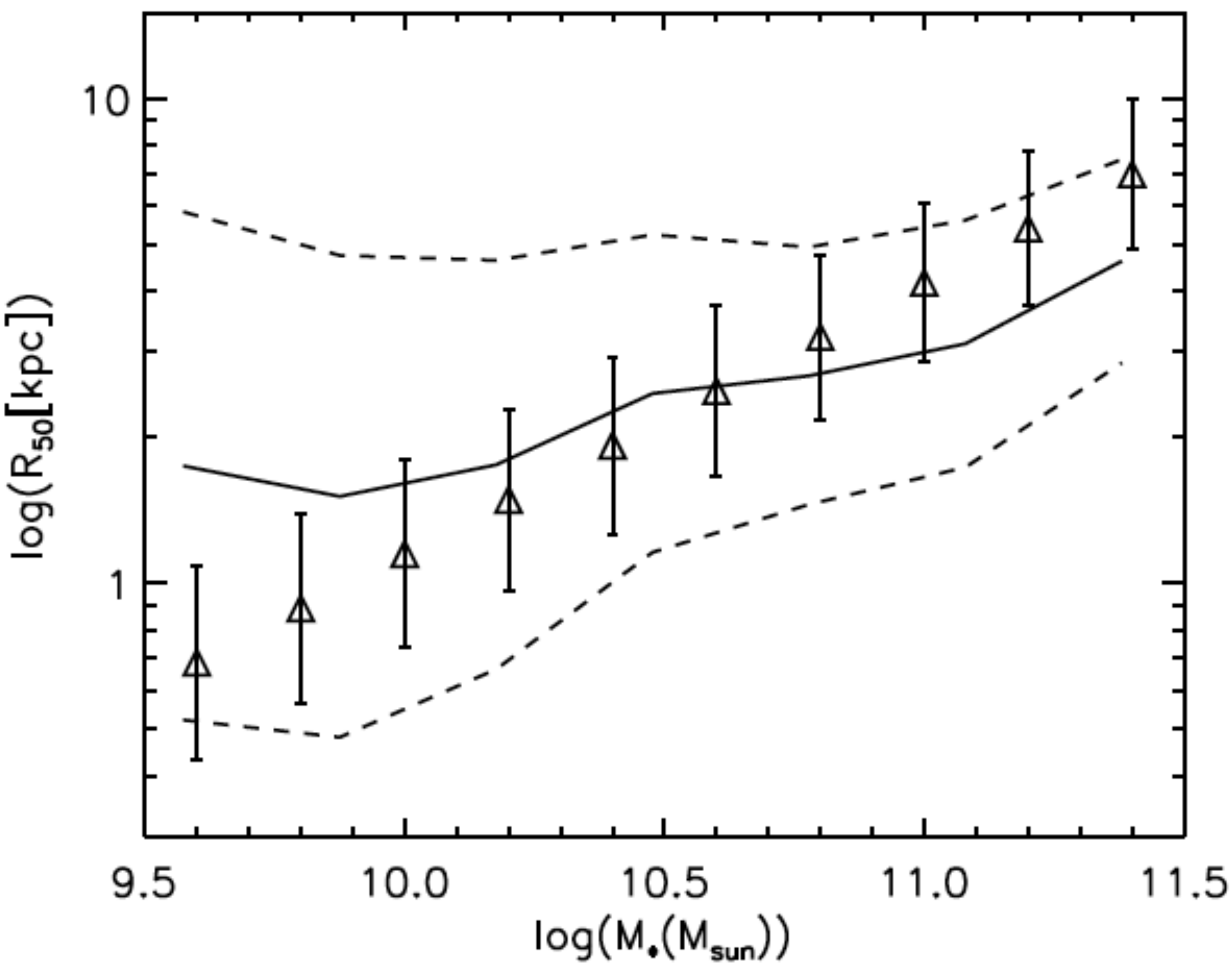
Stellar disk



Size of Galaxies

Early Type: Viral theorem + energy conservation

$$C\frac{GM_{\rm new,bulge}^2}{R_{\rm new,bulge}} = C\frac{GM_1^2}{R_1} + C\frac{GM_2^2}{R_2} + \alpha_{\rm inter}\frac{GM_1M_2}{R_1+R_2},$$



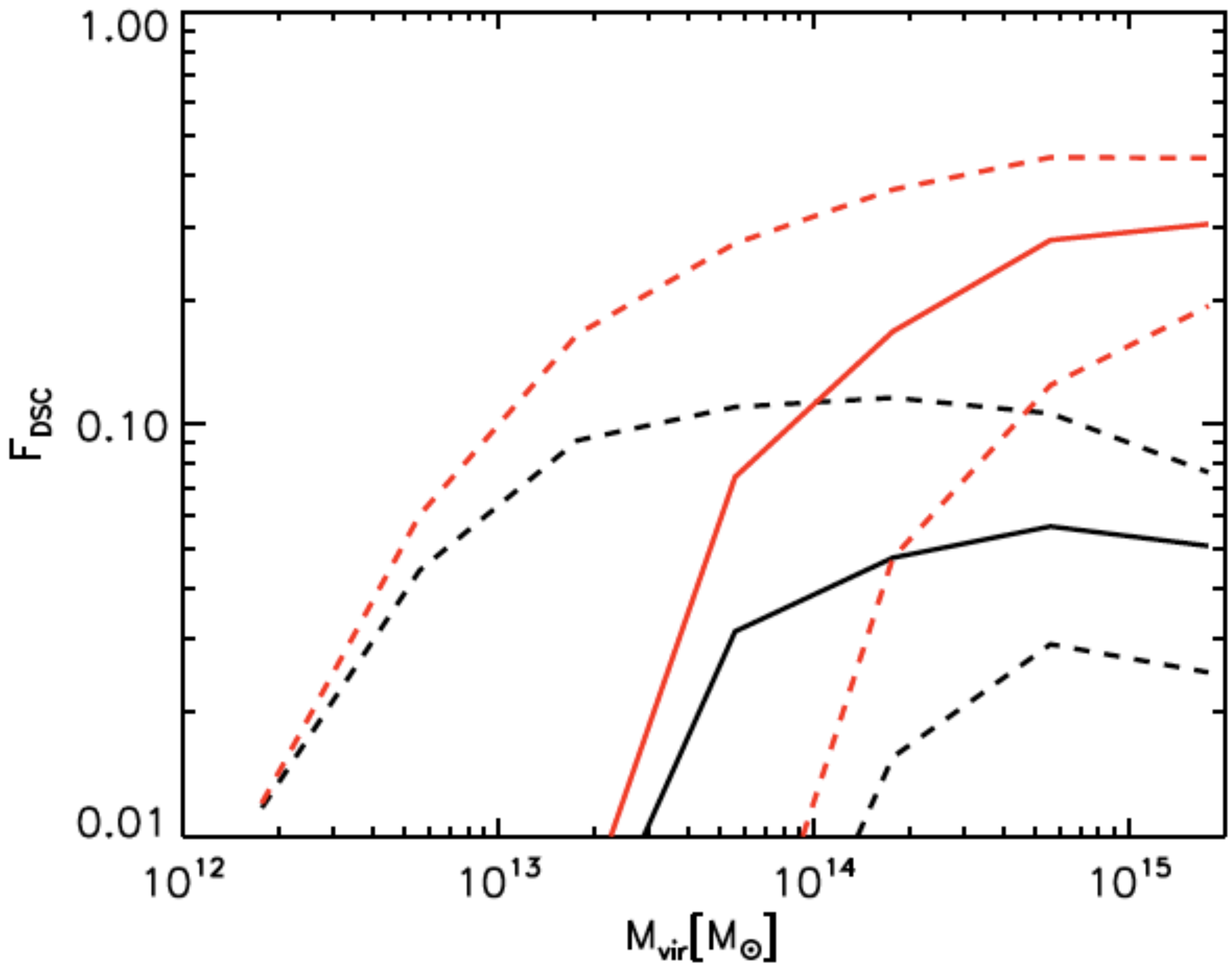
Disruption of satellites by tidal force

Tidal force:

$$\frac{M_{\rm DM,halo}(R_{\rm peri})}{R_{\rm peri}^3} \equiv \rho_{\rm DM,halo} > \rho_{\rm sat} \equiv \frac{M_{\rm sat}}{R_{\rm sat,half}^3},$$

Satellites could be disrupted and their cold gas and stars will be re-distributed as parts of the intra-cluster medium.

Intra-cluster Light

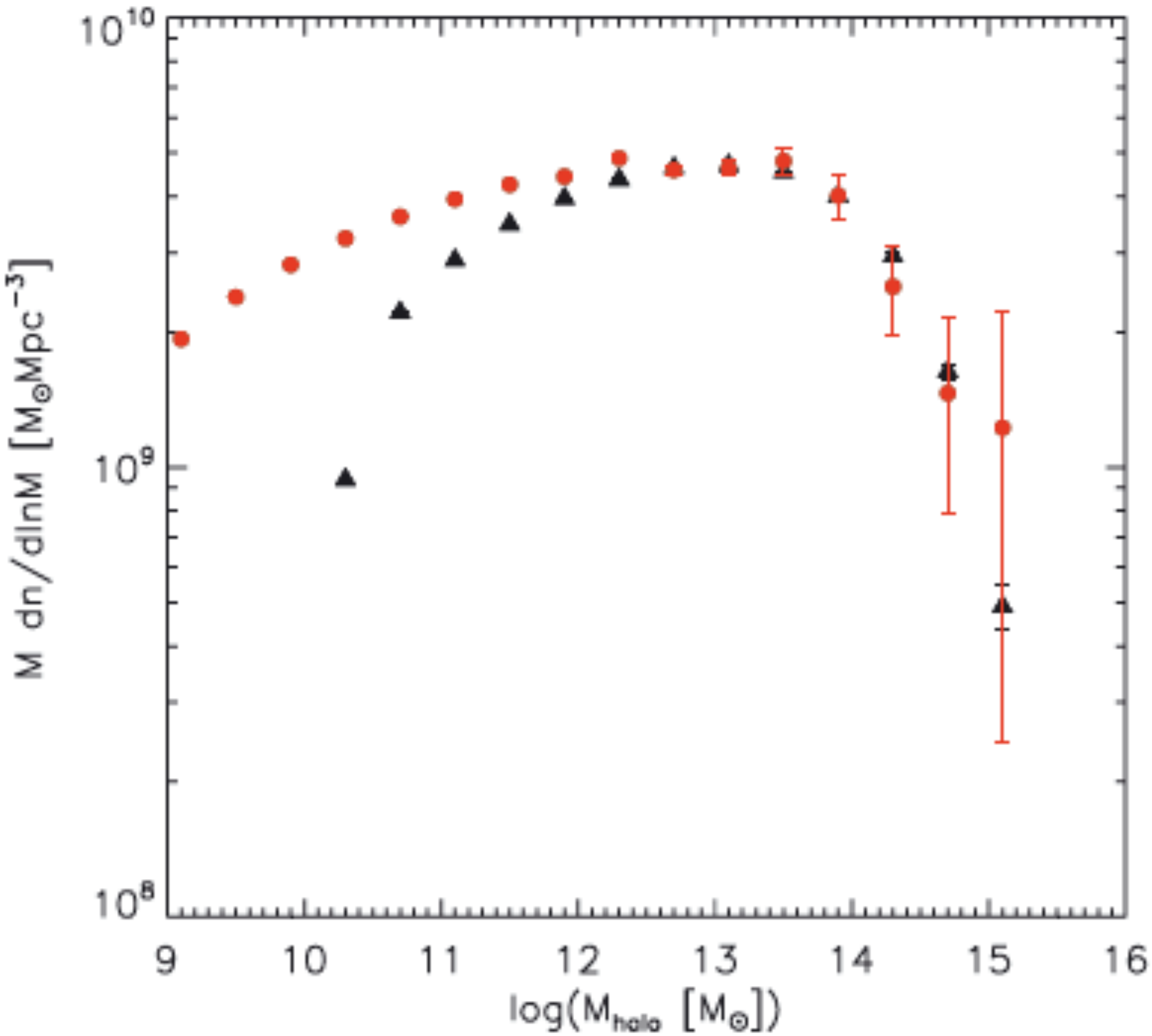


fraction of intra-cluster light associated with the central galaxies of the cluster

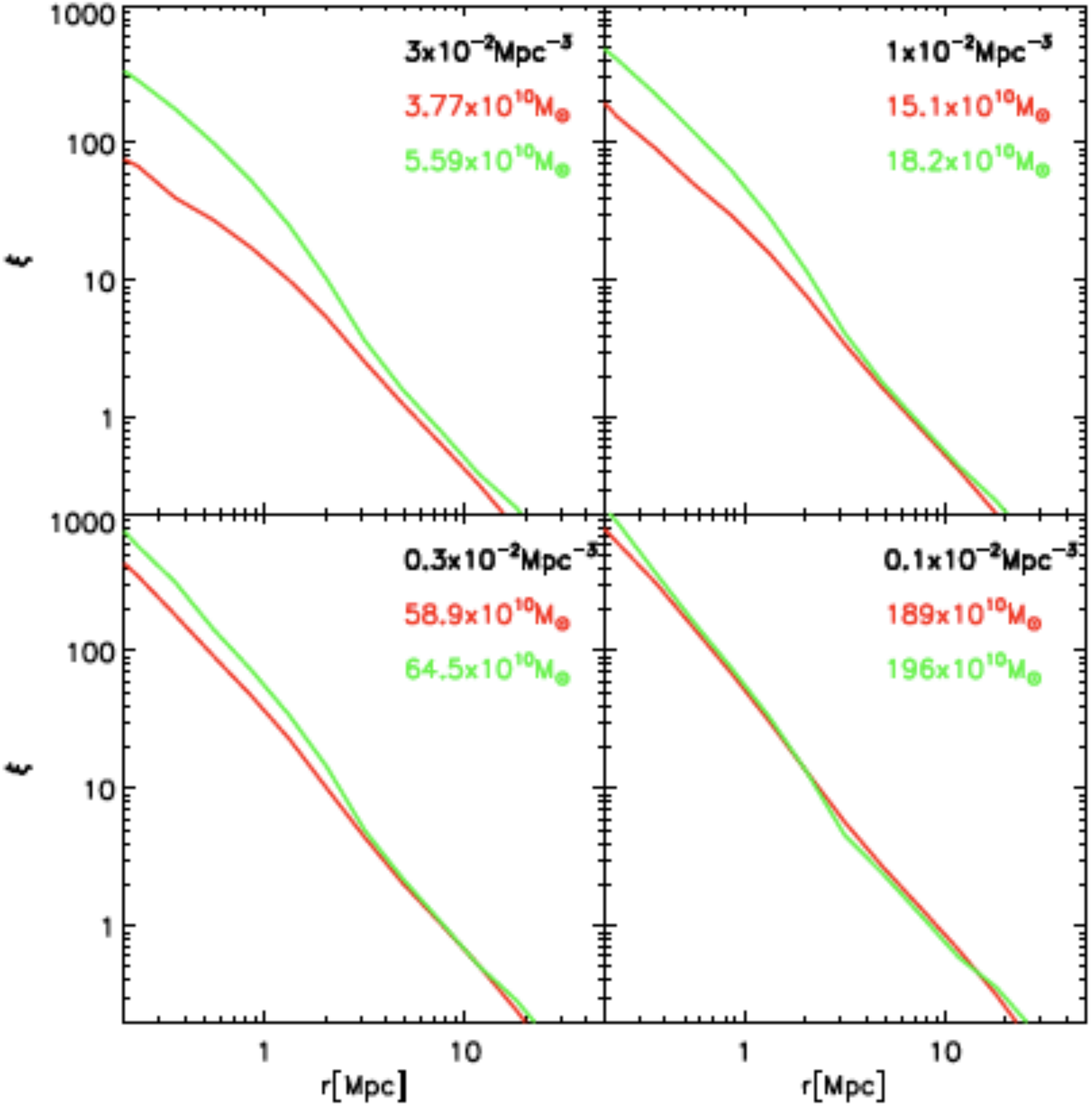
fraction of the total intra-cluster light within cluster virial radius.

test of convergency

Halo Mass function -- Minfall



Halo Correlation Functions

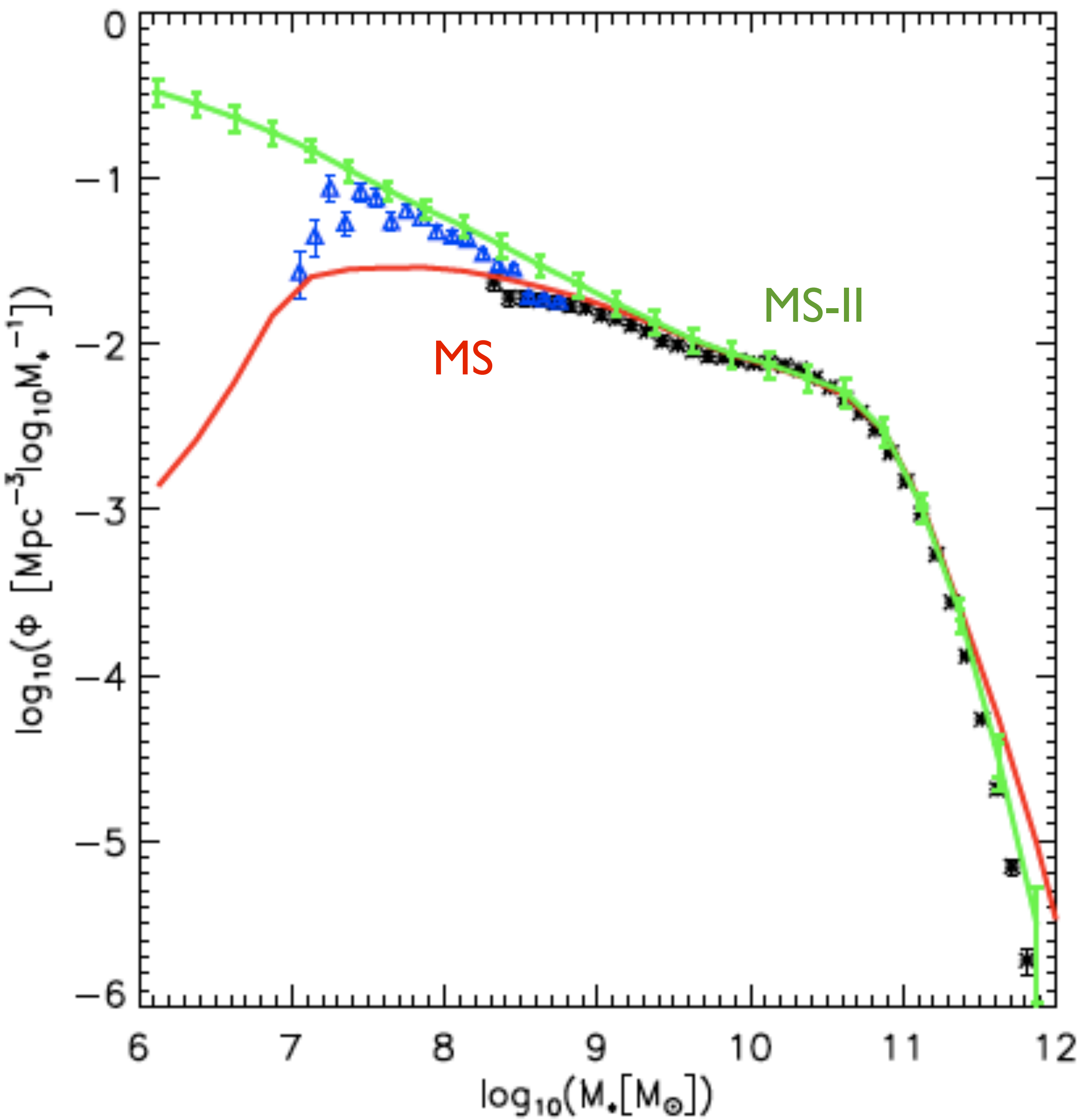


~2000 particles are required to resolve the satellites properly

Stellar Mass Functions

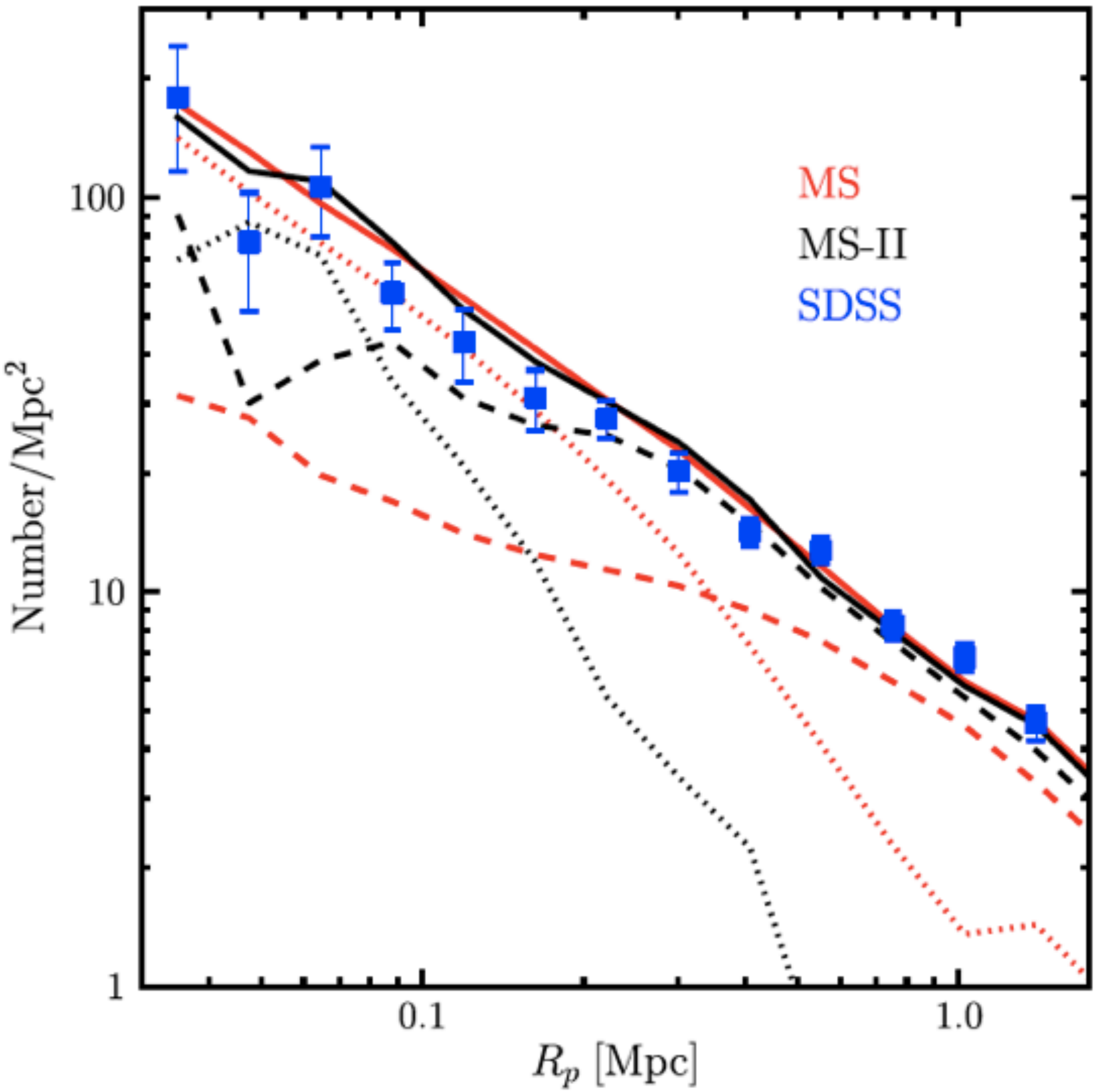
* MS and MSII give convergent results above 10**9.5 Msun

* Model predictions fit the observed galaxy abundance over 5 orders of magnitude.



(Guo et al. 2011)

Projected profile in galaxy clusters



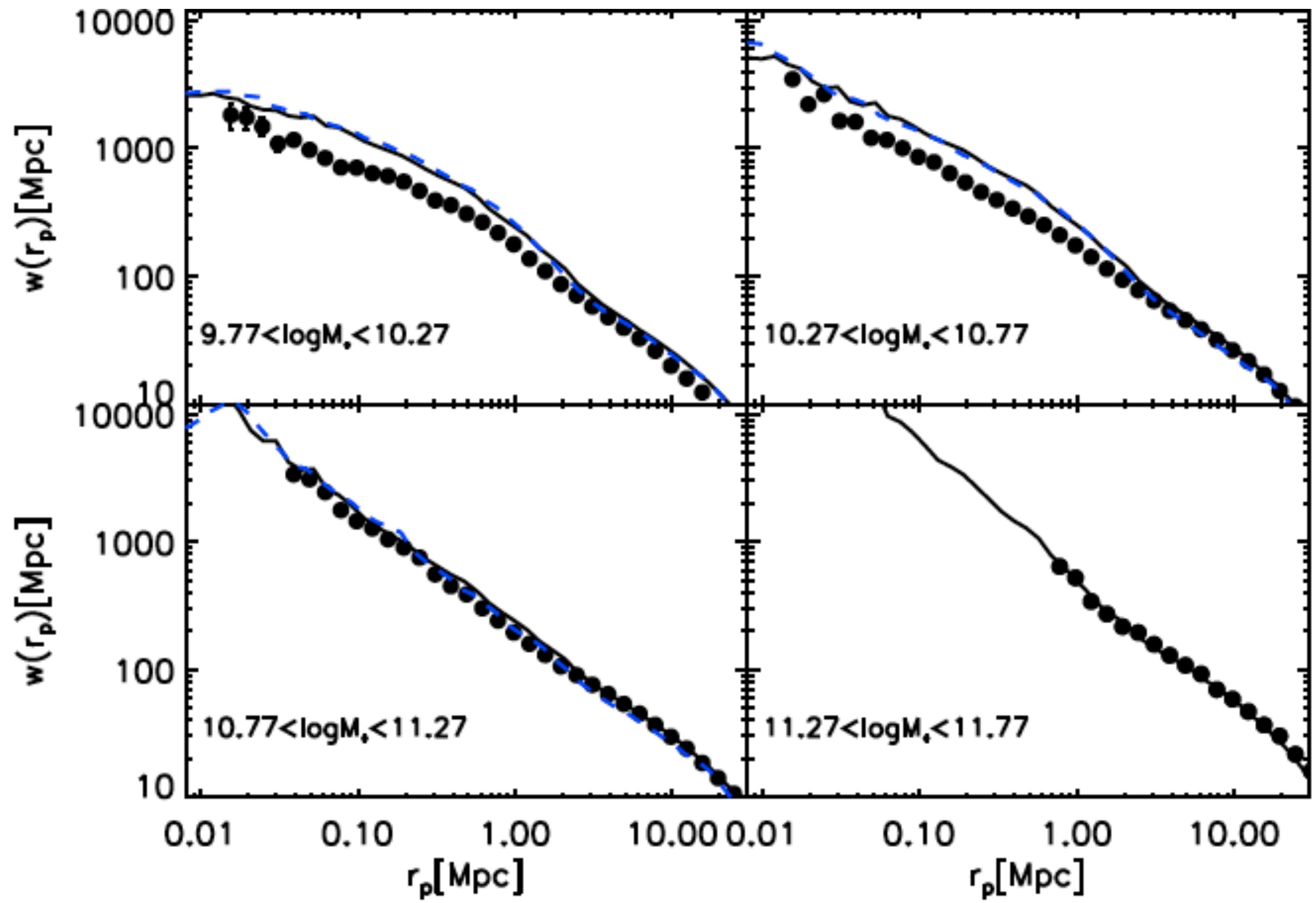
Galaxy cluster: 14<logMh<14.5

Galaxy : logM*>10

* Remarkable agreement between MS and MS-II
  -- survival times and position of type 2s are appropriate

*Model matches observations pretty well, though SDSS clusters are somewhat less concentrated.

Correlations: spatial distribution correct?

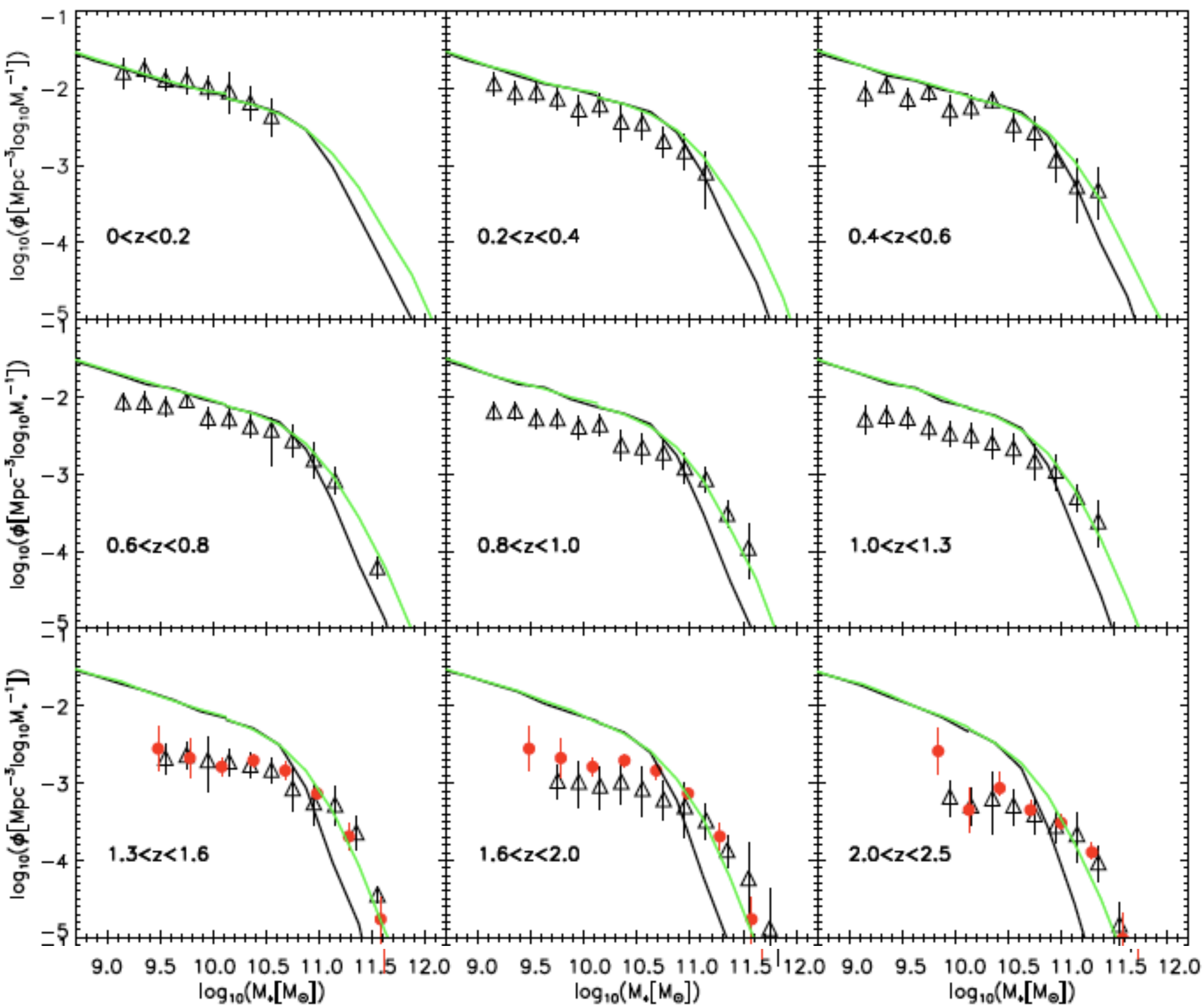


Good convergence between MS and MSII

Good fits at large scale --> central galaxies are formed in the right halos.

Excess at small scale -- > too many satellites? sigma_8 (0.9) too big?

High redshift mass function



Massive galaxy abundance is predicted correctly at high redshift.

Dwarf galaxies form too early in the model.

Pérez-González et al. (2008) Marchesini et al. (2009)

Do we need lower σ_8?

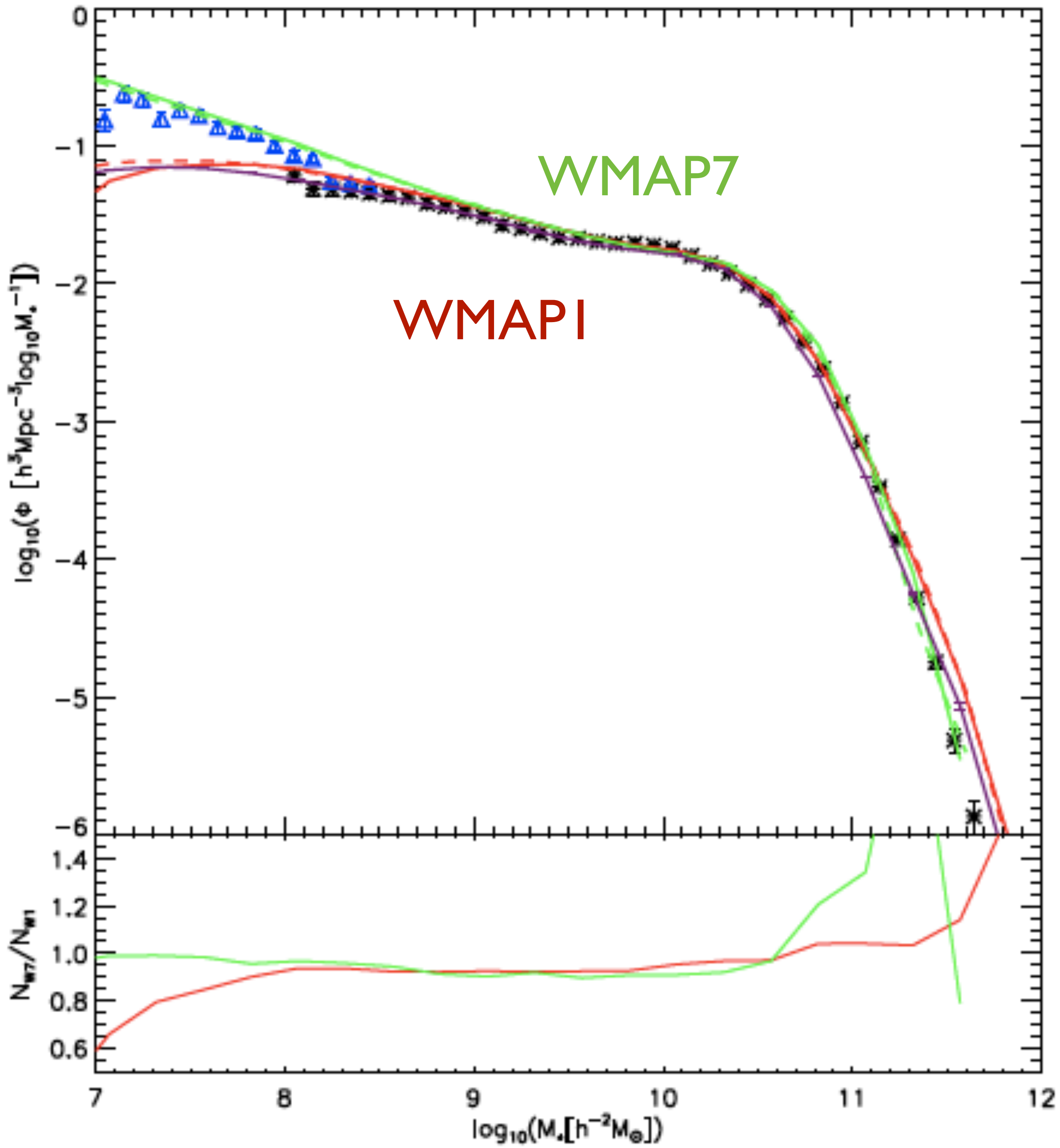
Do we need lower σ_8?

Try WMAP7

WMAP 1 vs. WMAP 7

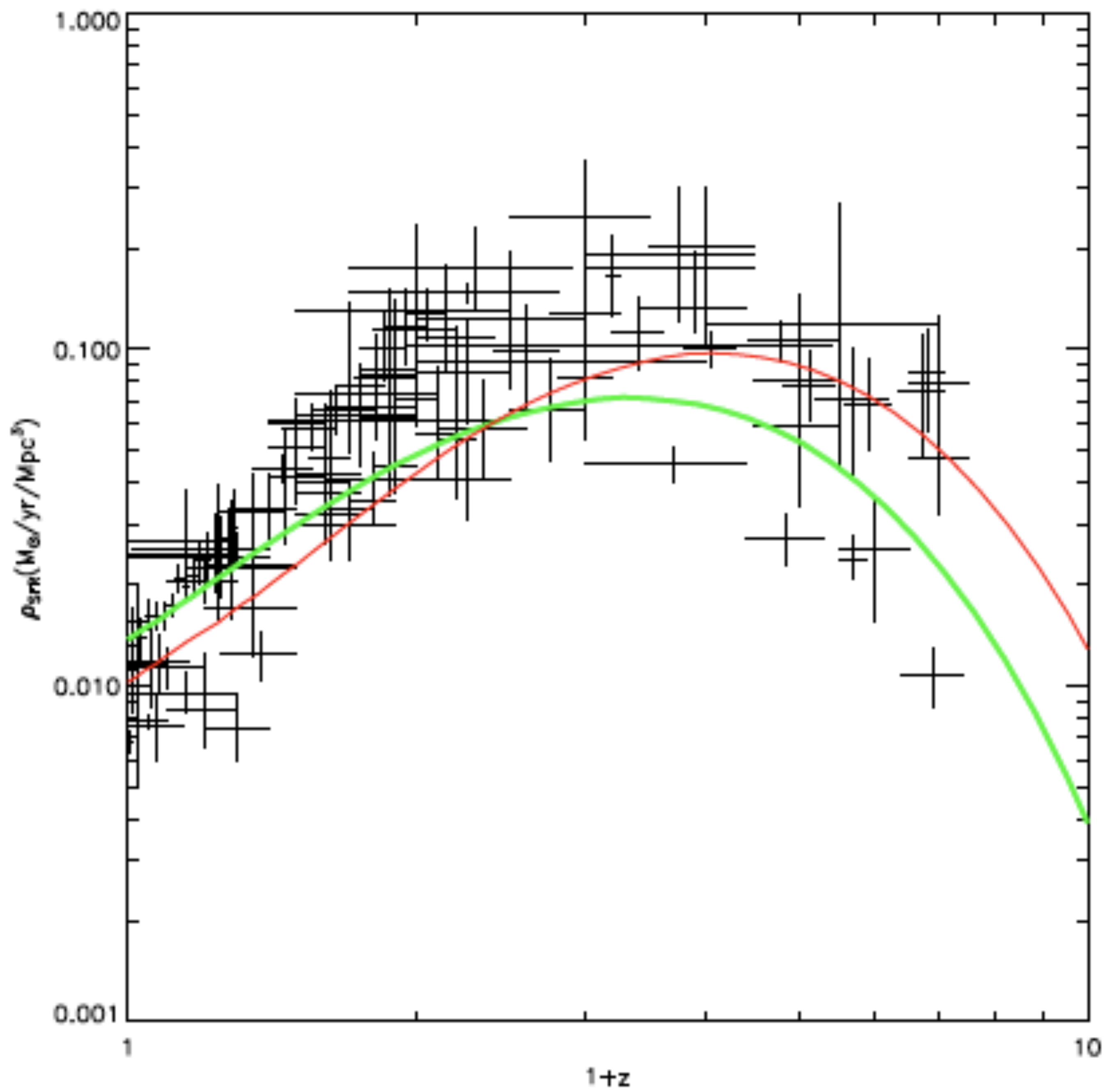
	Ω_m	Ω_Λ	baryon fraction	h	σ_8
WMAP1	0.25	0.75	17%	0.73	0.9
WMAP7	0.272	0.728	16.7%	0.704	0.81

Galaxy stellar mass function



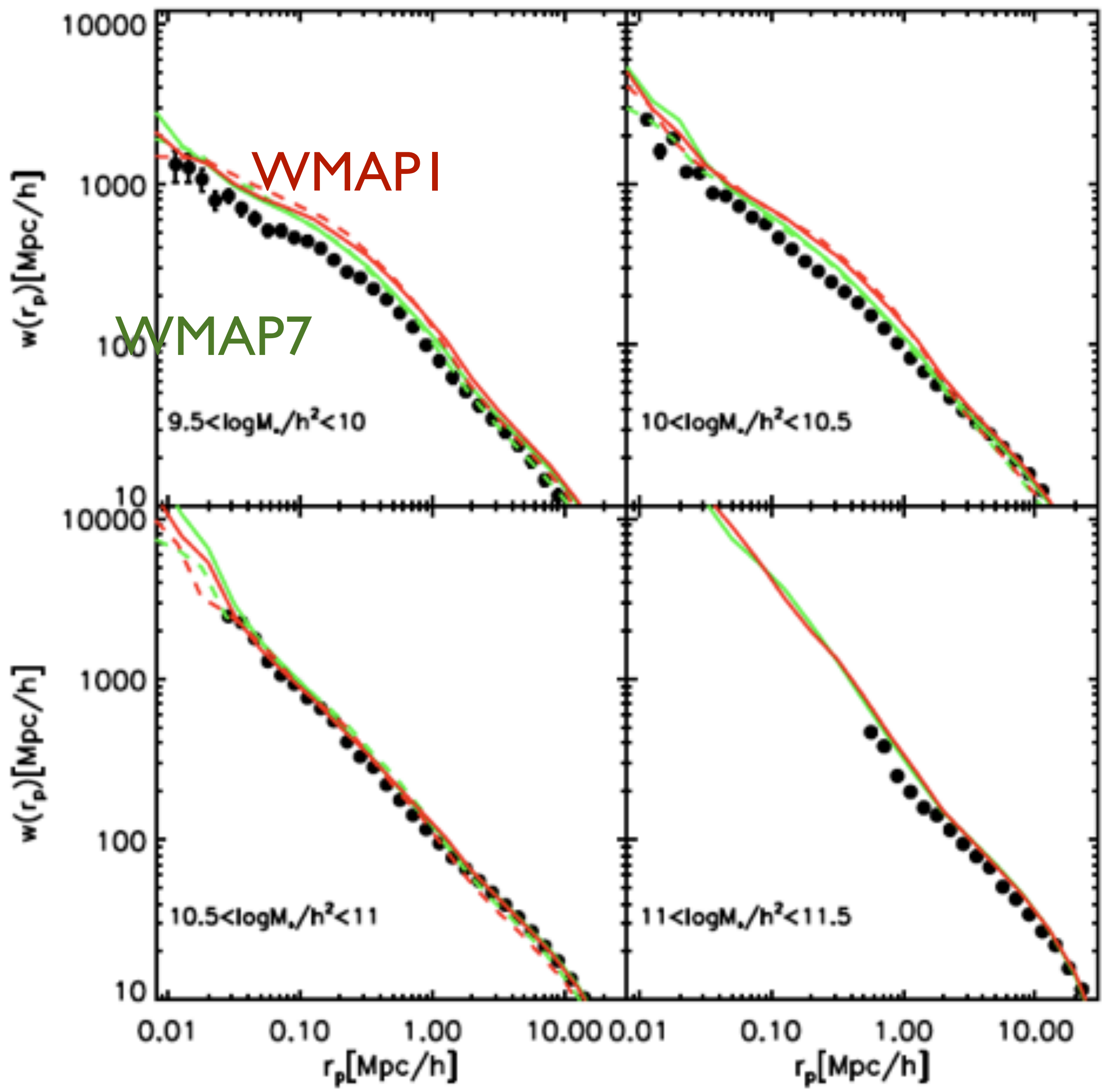
Guo et al. 2012

star formation density vs. redshift



Stars form later in WMAP7 than in WMAP1

Correlations functions

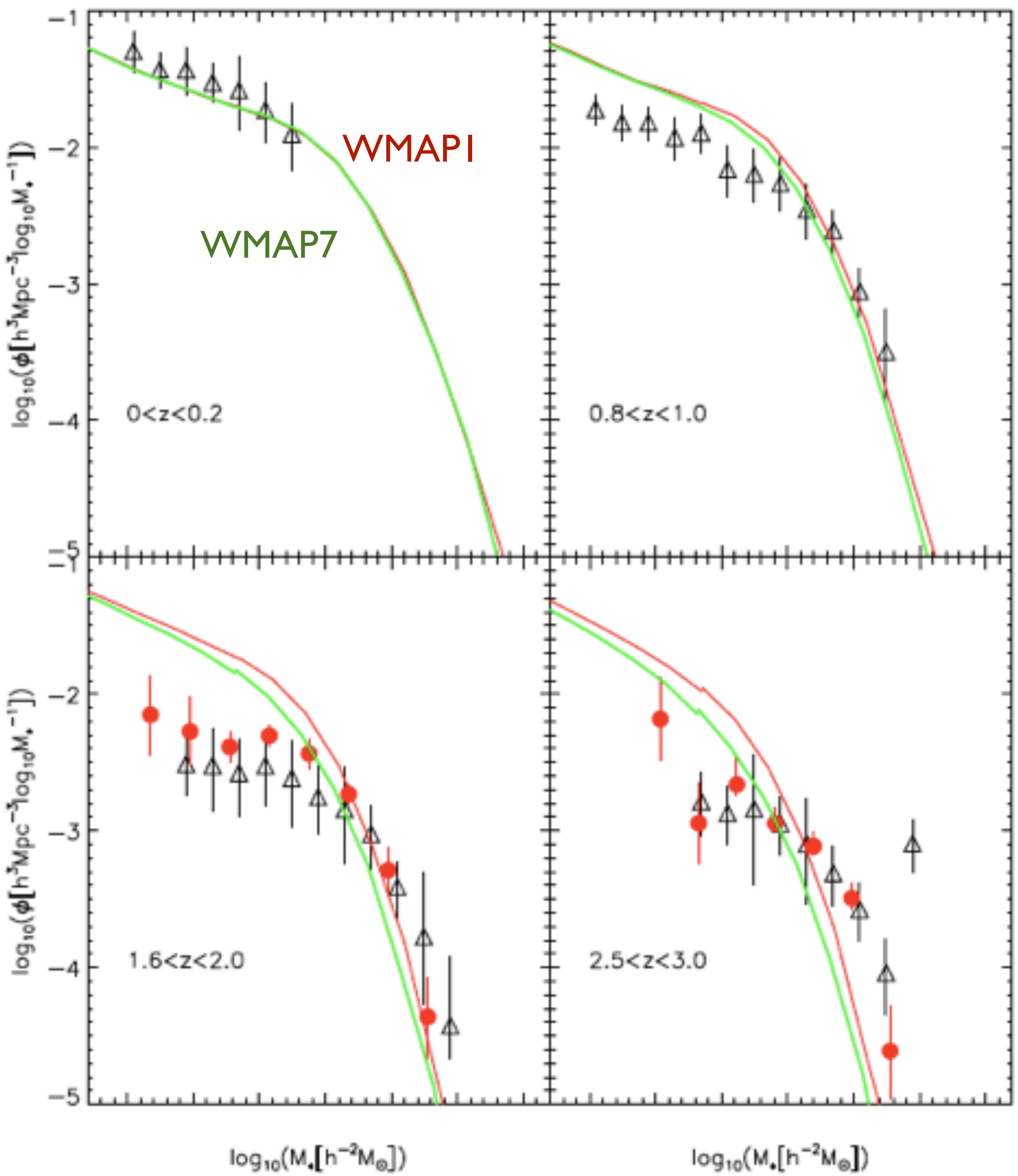


Clustering is lower at small scales and for low mass galaxies in WMAP7 than in WMAP1.

At large scales the clustering is even closer to observations.

But there is still a small scale excess.

High redshift mass function

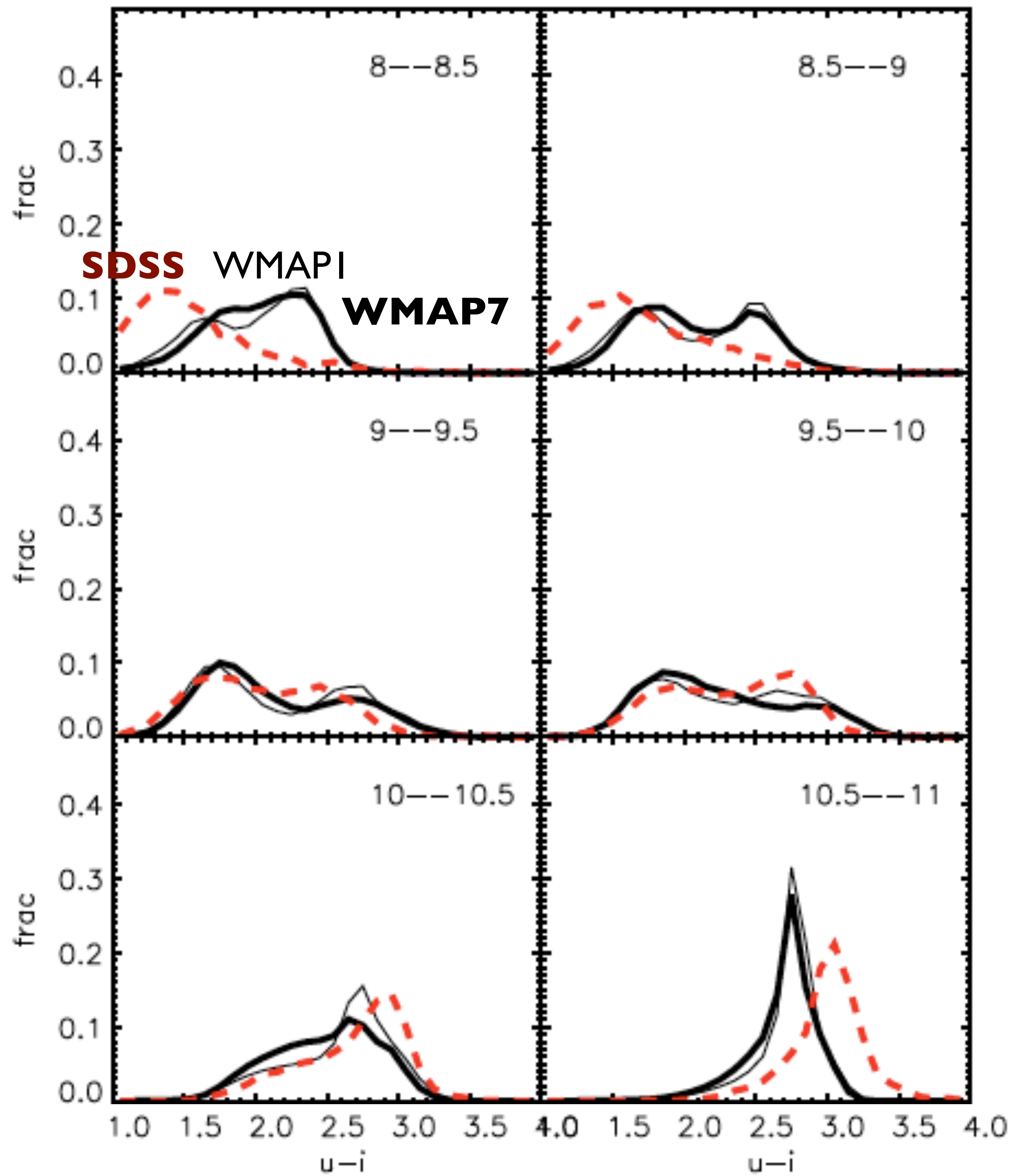


Fewer dwarfs form at high redshift

Too few massive galaxies have been assembled at z~2

Still too many dwarfs at z>0.8

Colour distribution



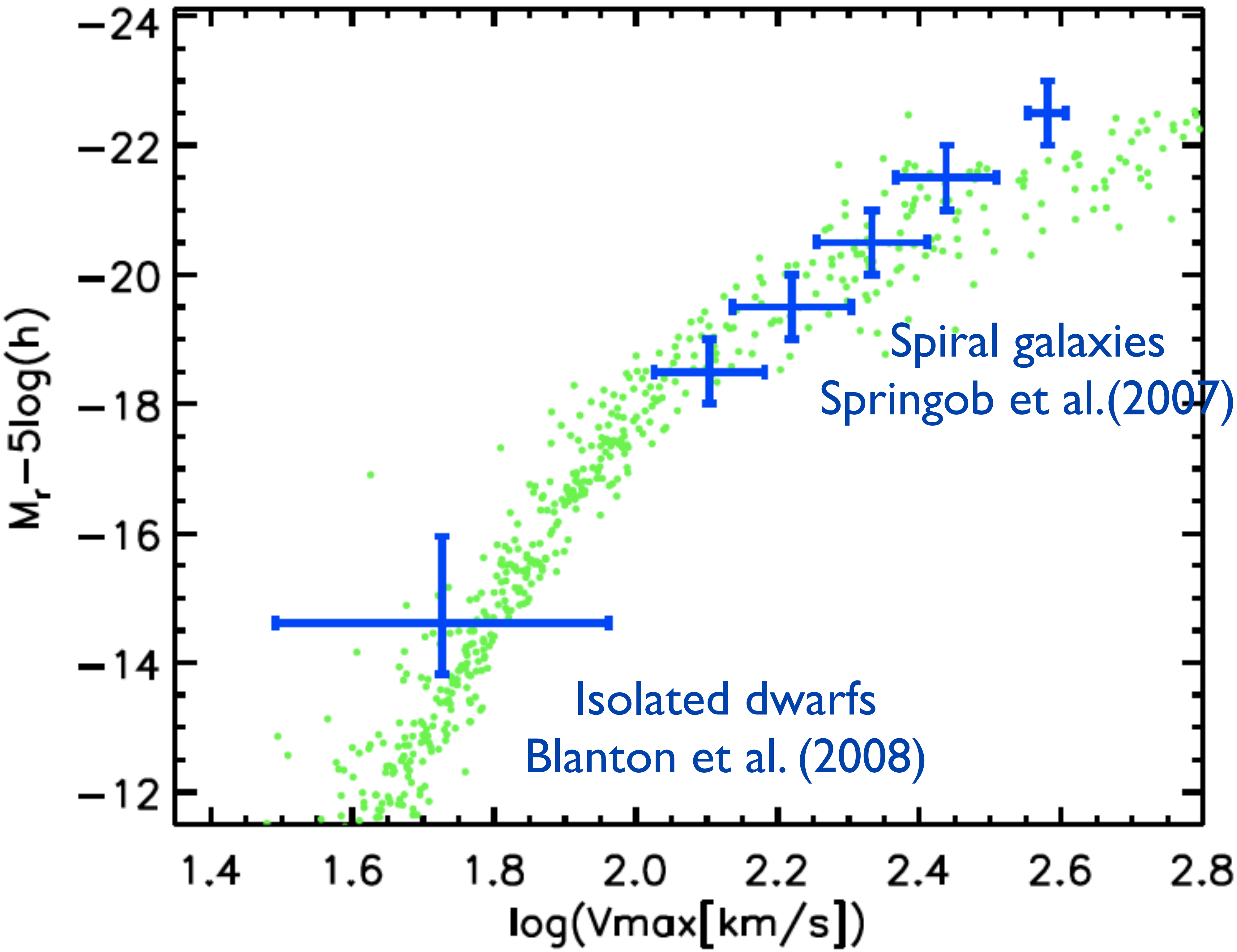
Colours are better with WMAP7 than with WMAP1.

But there are still too many red dwarfs to reproduce the observed colour distribution.

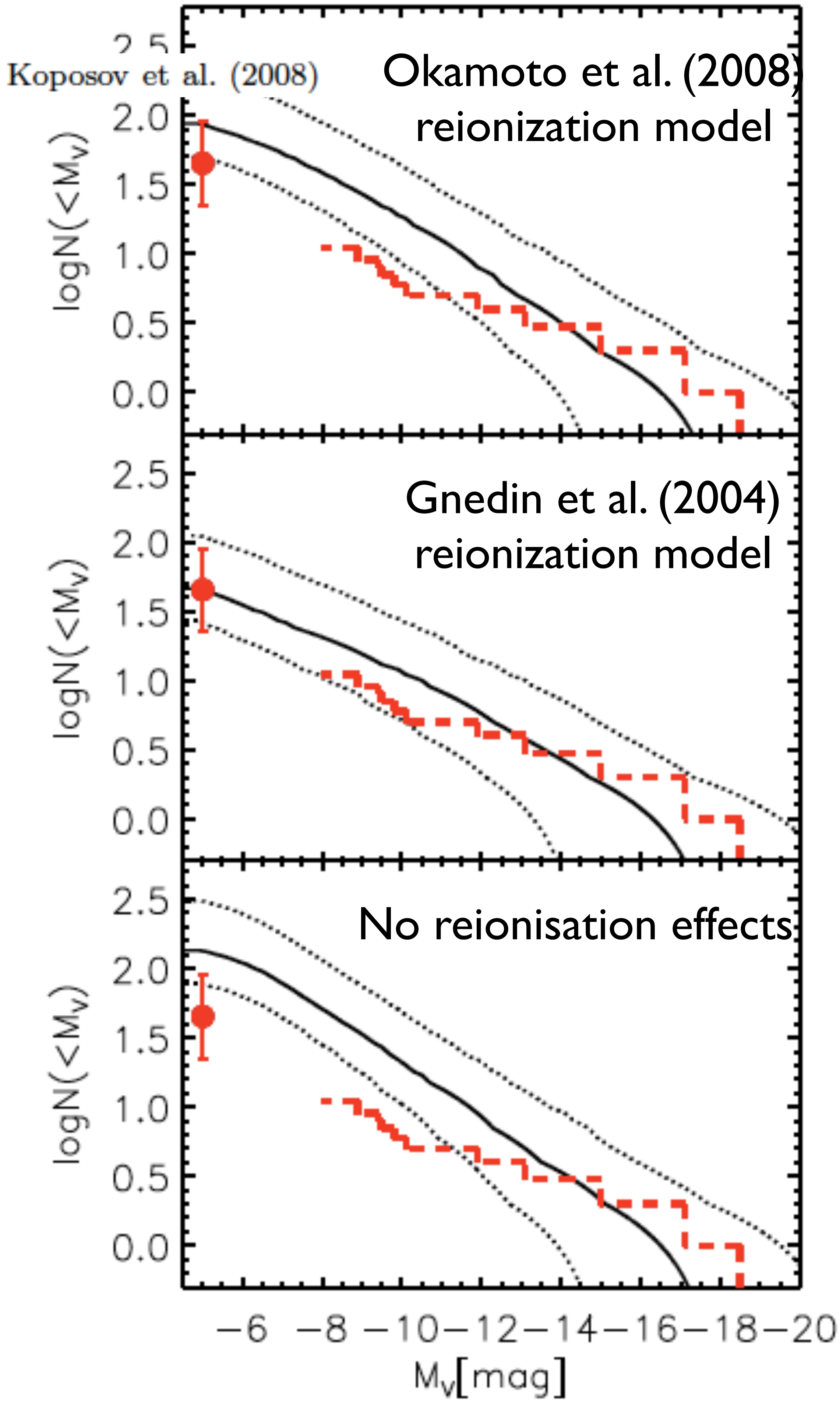
Conclusions

- Recent main developments include
  - SN feedback
  - Gradually stripping of hot gas from satellites instead of instantaneously stripping.
  - Model galaxy disk size and bulge size
  - Include the disruption of the satellites and intra-cluster light.
  - Dwarf galaxies form too early compared to observations, i.e. , too red in colour and too many at high redshift.
- Most galaxy properties both in the local universe and at high redshift are reproduced. Results are consistent between the MS and the MS-II.
- Apply the model to WMAP7 cosmology. Same problem include the color distribution of low mass galaxies, clustering at small scales and the too early formation of the low mass galaxies at high redshift (see. Bruno's talk)

Tully Fisher Relation



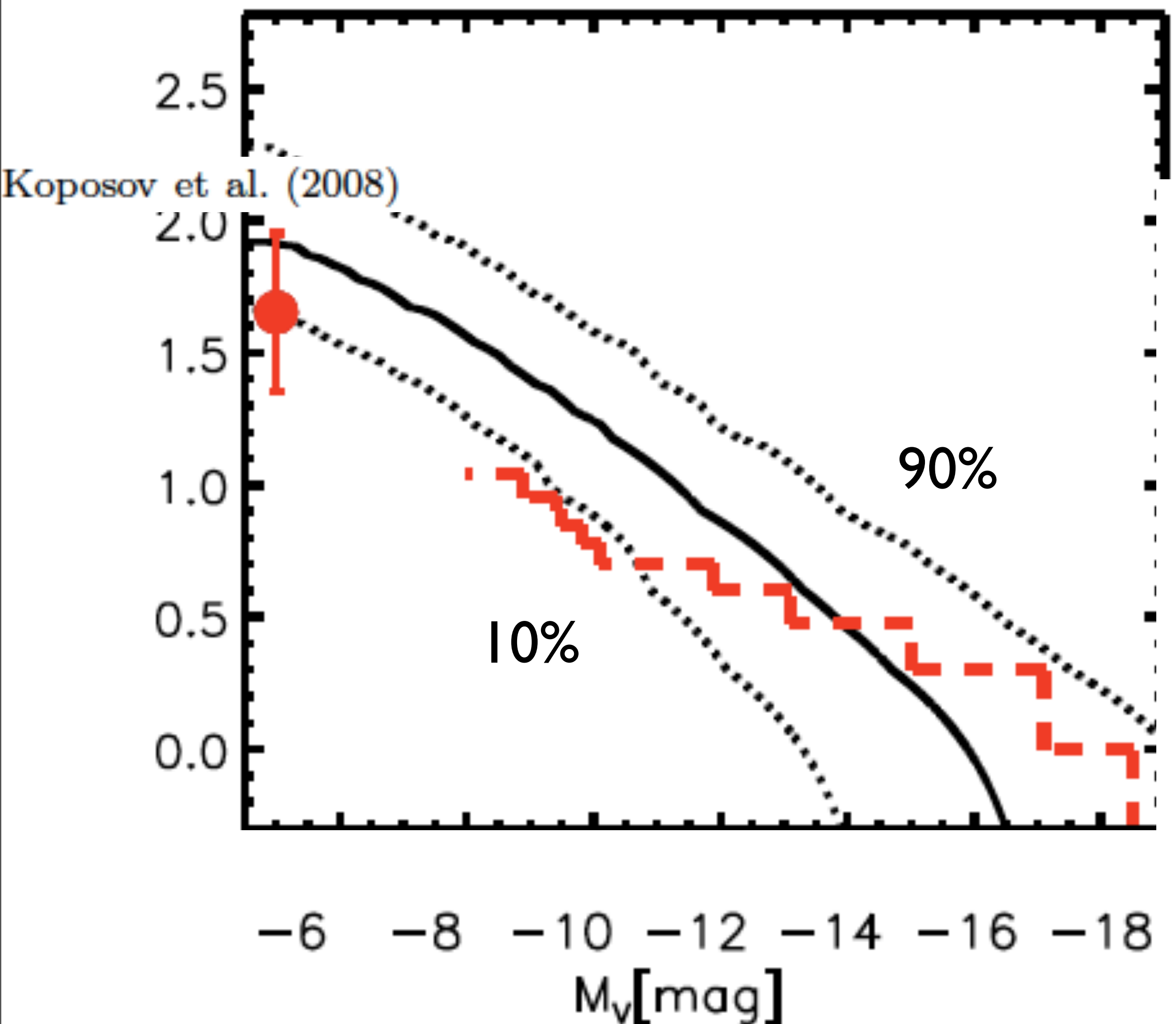
Even isolated dwarfs are in appropriate halos

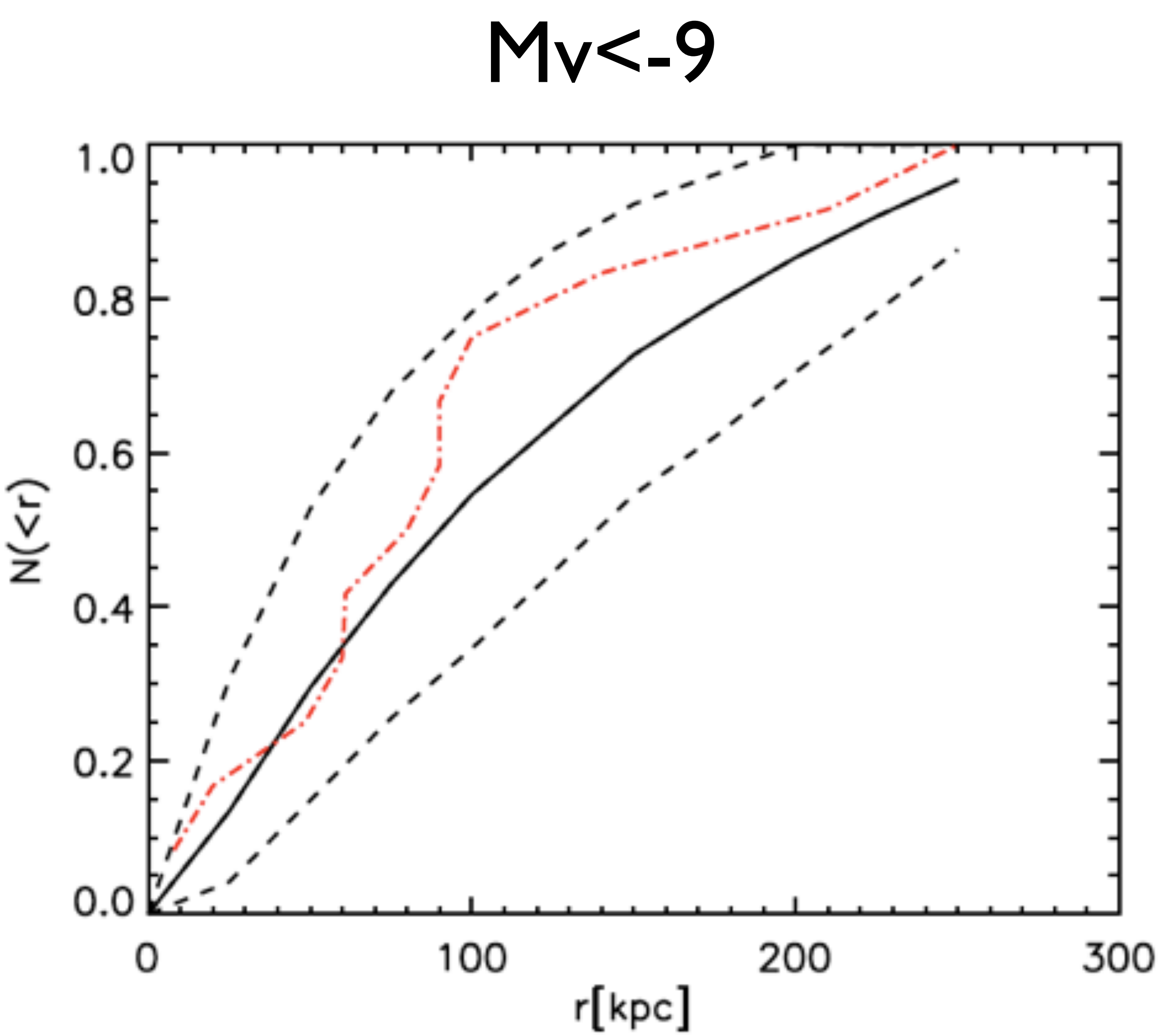


Satellites around the MW

Reionization only affects abundance for Mv > -11

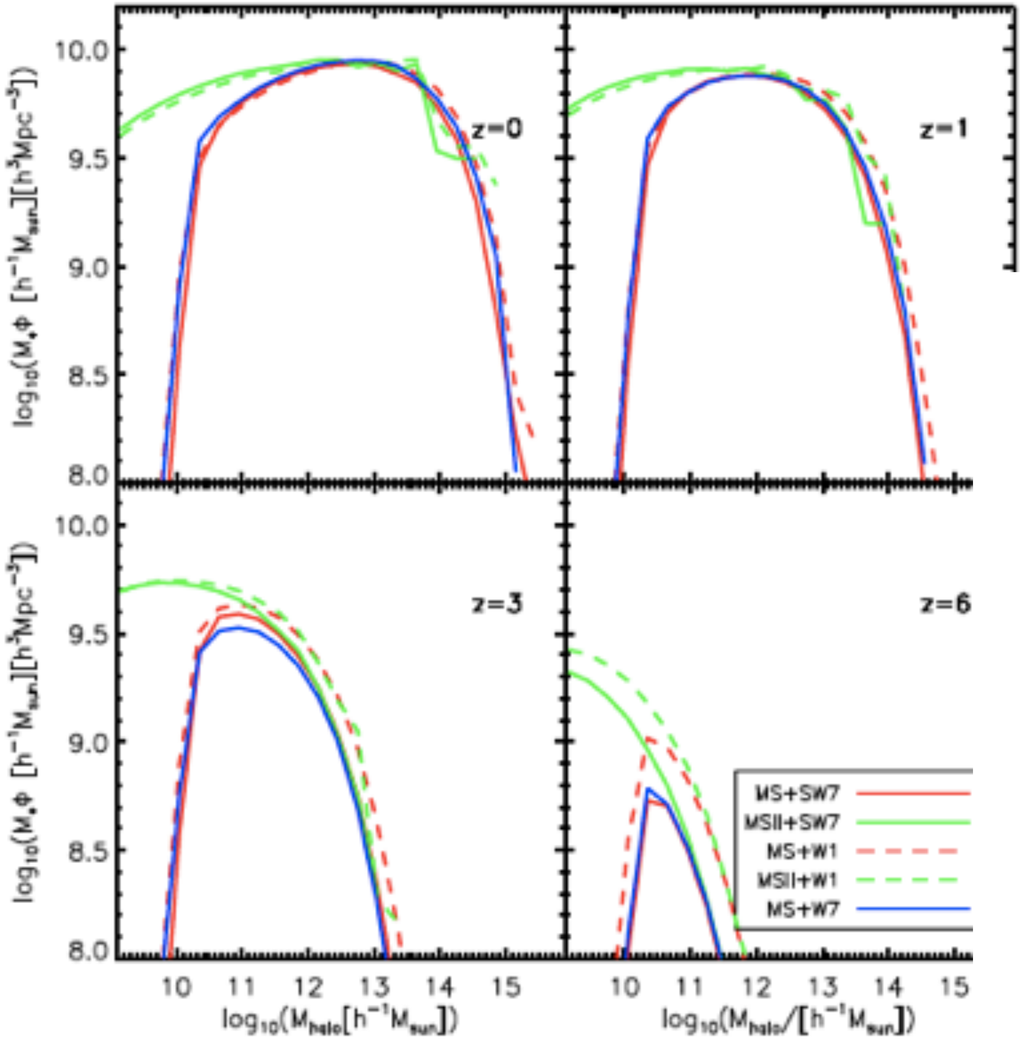
Satellites around the MW

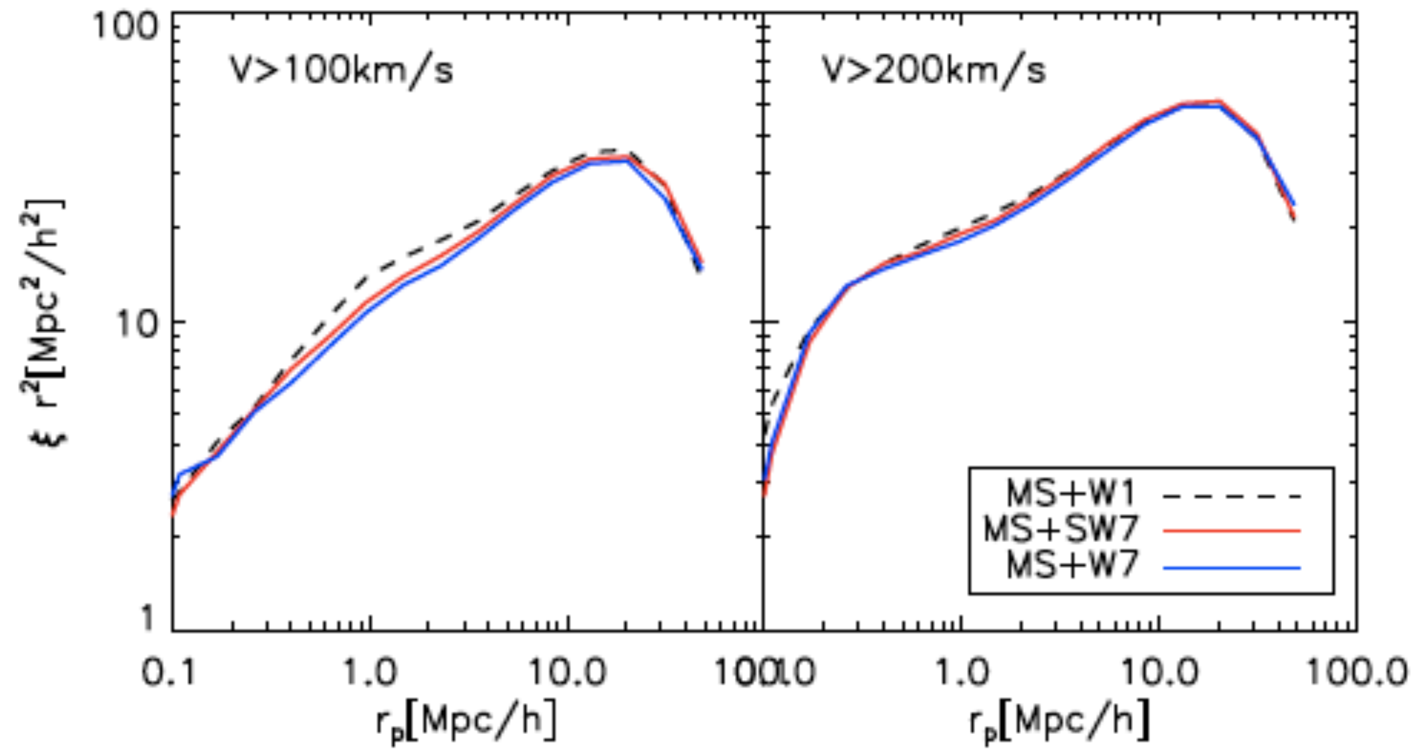




reproduce galaxy luminosity function in local groups,
as well as their positions

Evolution of dark halo





Not much difference is found between these two cosmologies