Star Formation Quenching in Semi-Analytic Models

Yu Luo & Xi Kang

Purple Mountain Observatory, CAS

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luoyu@pmo.ac.cn

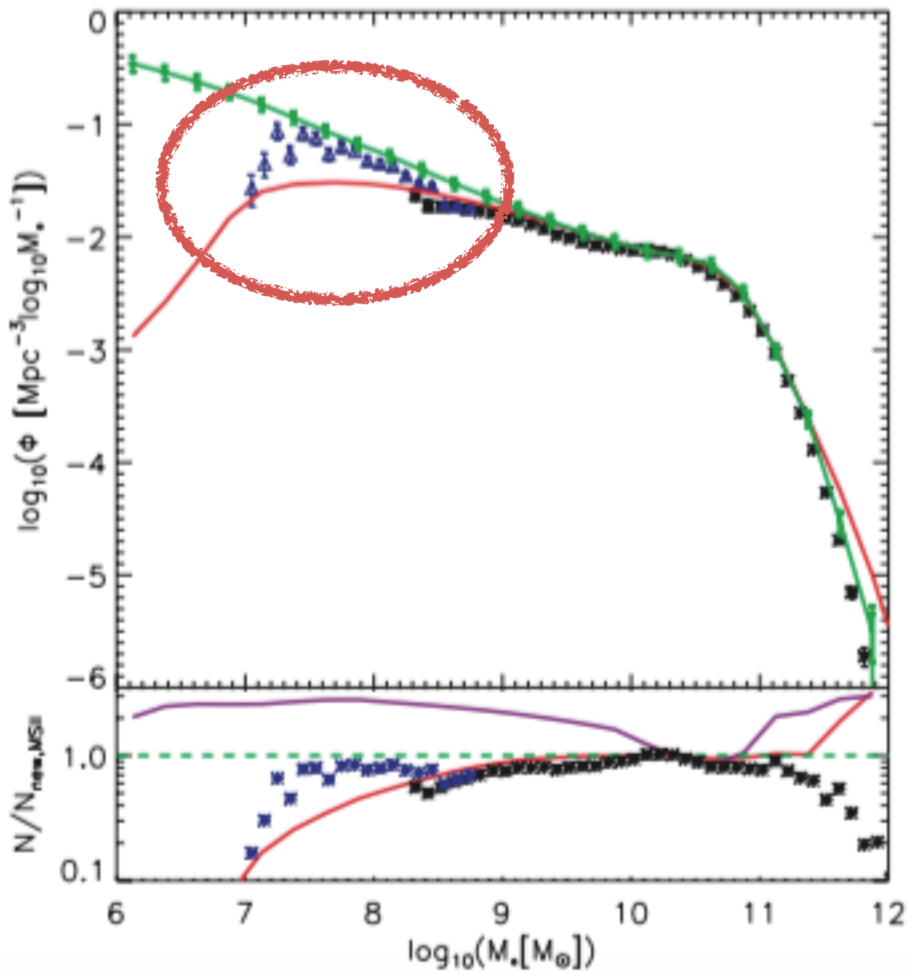
Outlines

- Introduction
- Resolution independent + environmental effects model (work at MPA: Xi Kang, Guinevere Kauffmann, Fu Jian. Luo et al. 2016)
- Satellite galaxies quenching
- Central galaxies quenching (Luo & Kang 2017)
- Future work

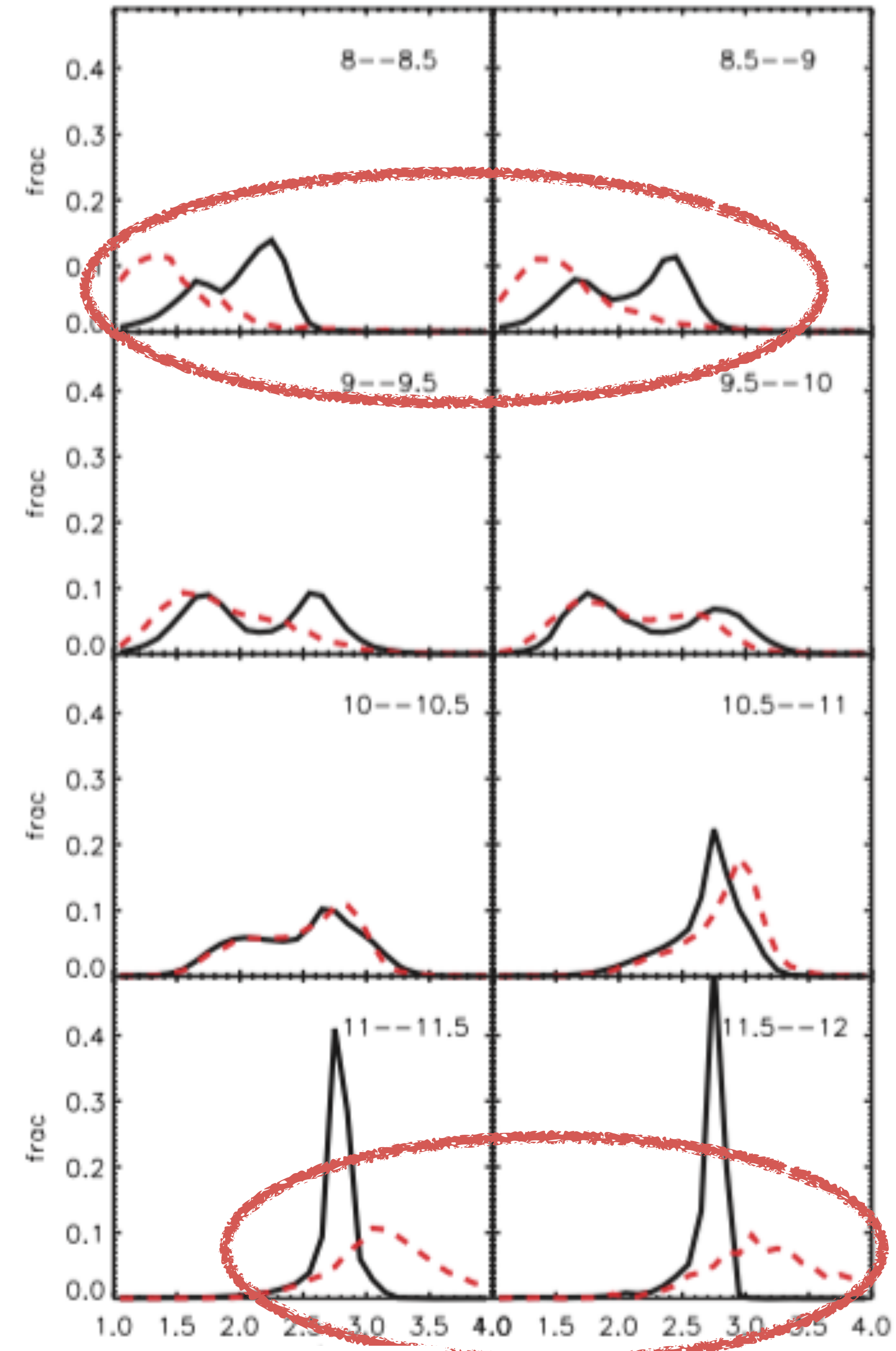
L-Galaxies

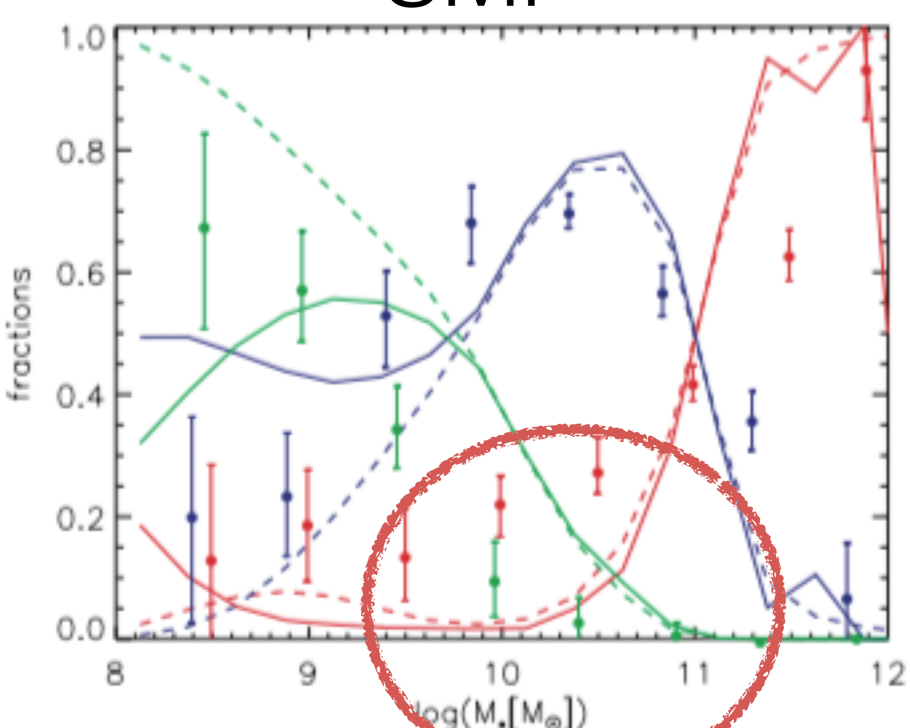
- N-body simulations + Phenomenal physical process
- Guo+2011、2013, Henriques+2015
- Reproduce: SMF, T-F relation, 2pcf, color, morphology distribution…
- Faster and easier to test the roles of various physical processes
- But …

Guo11

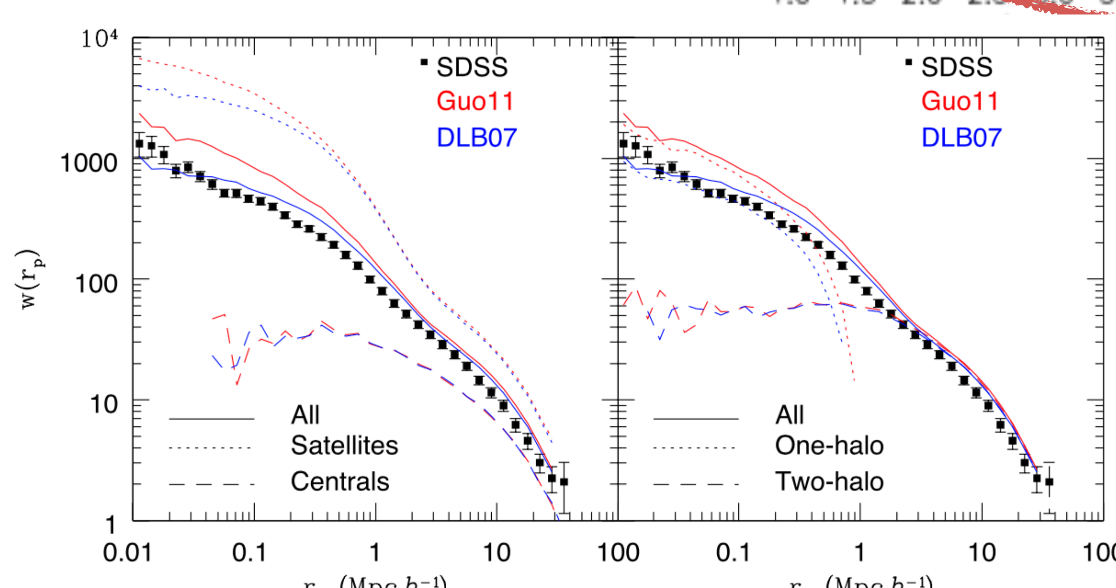


SMF



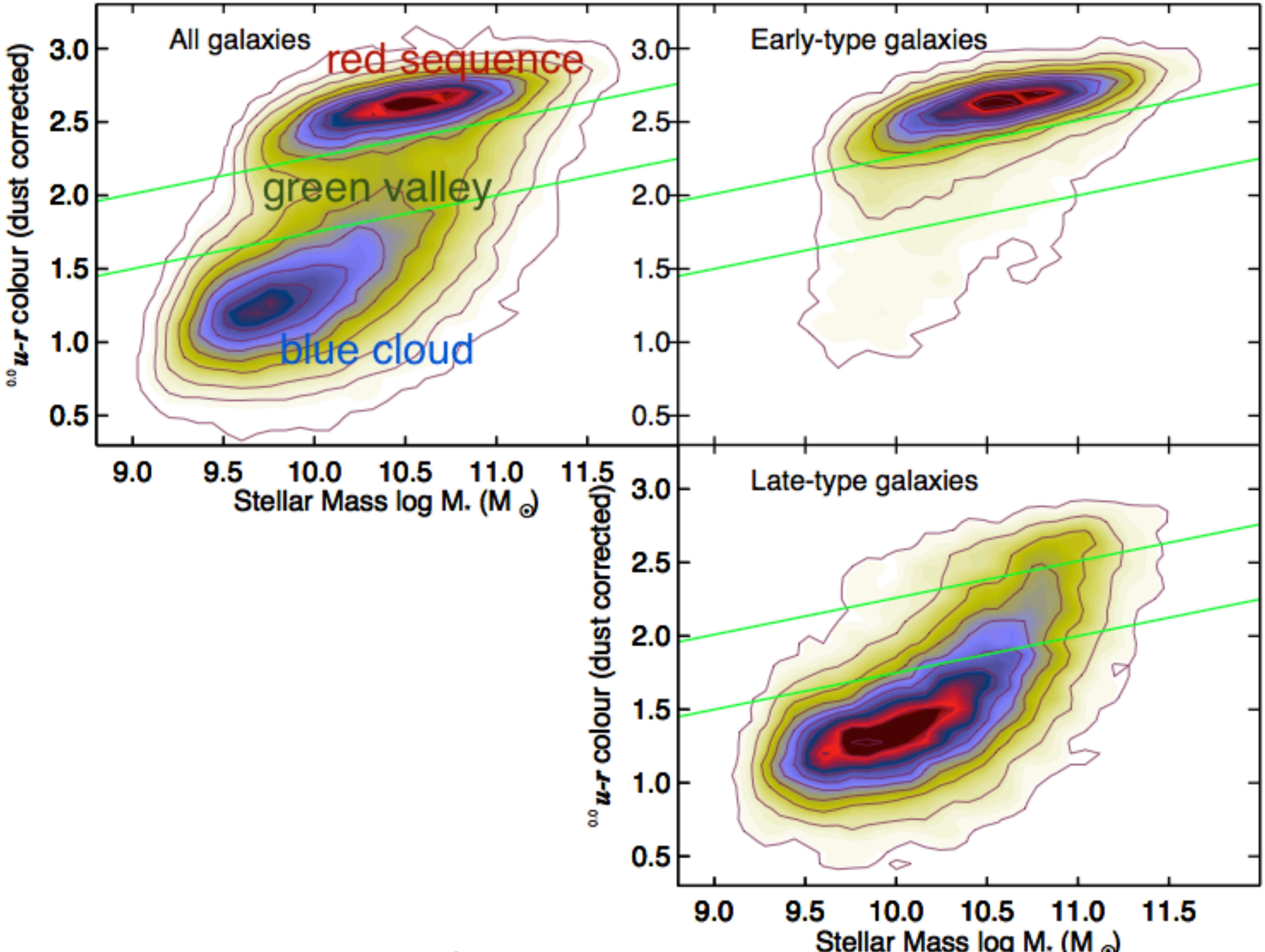


morphology

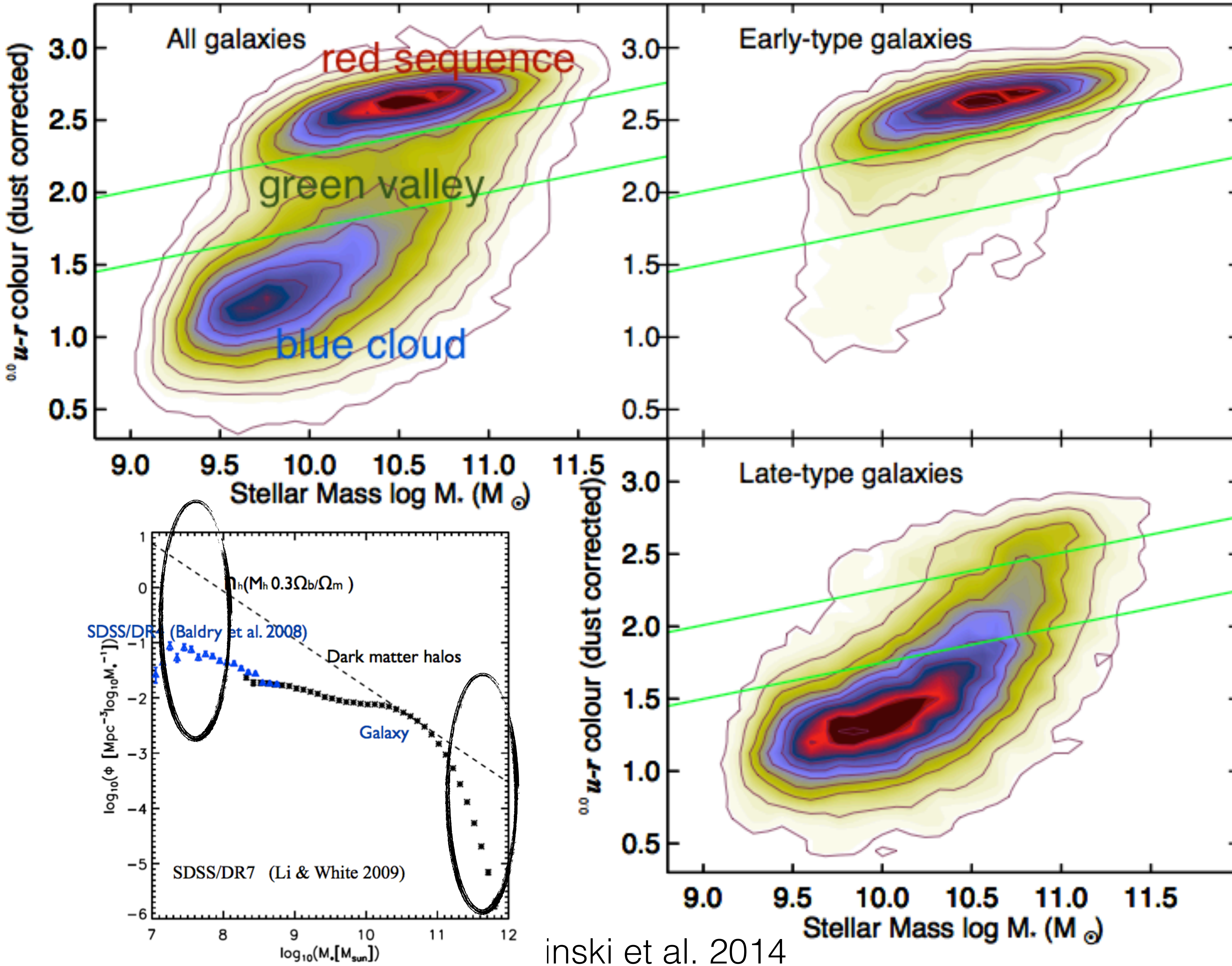


color

Kang 2014



Schawinski et al. 2014

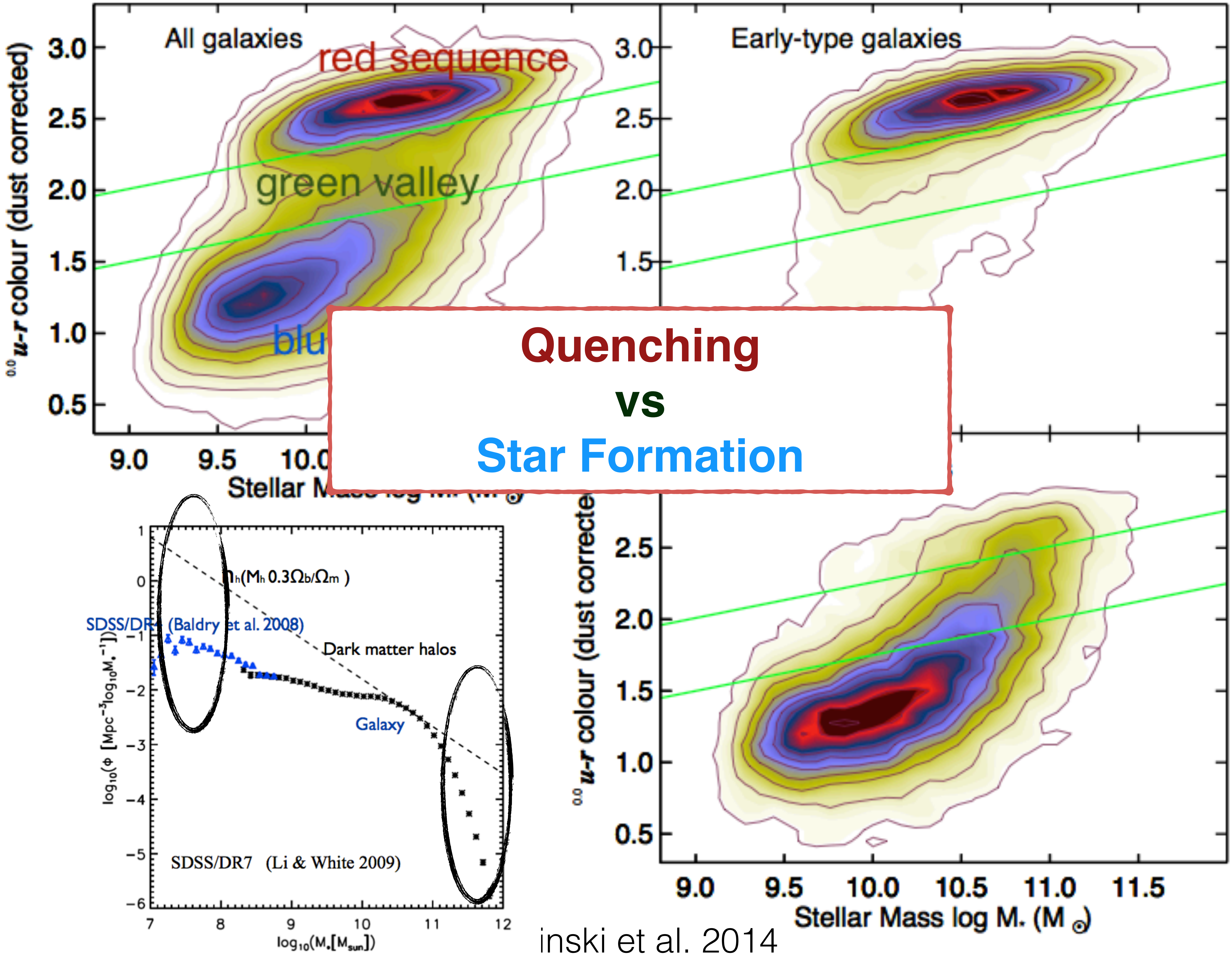


inski et al. 2014

Quenching

vs

Star Formation



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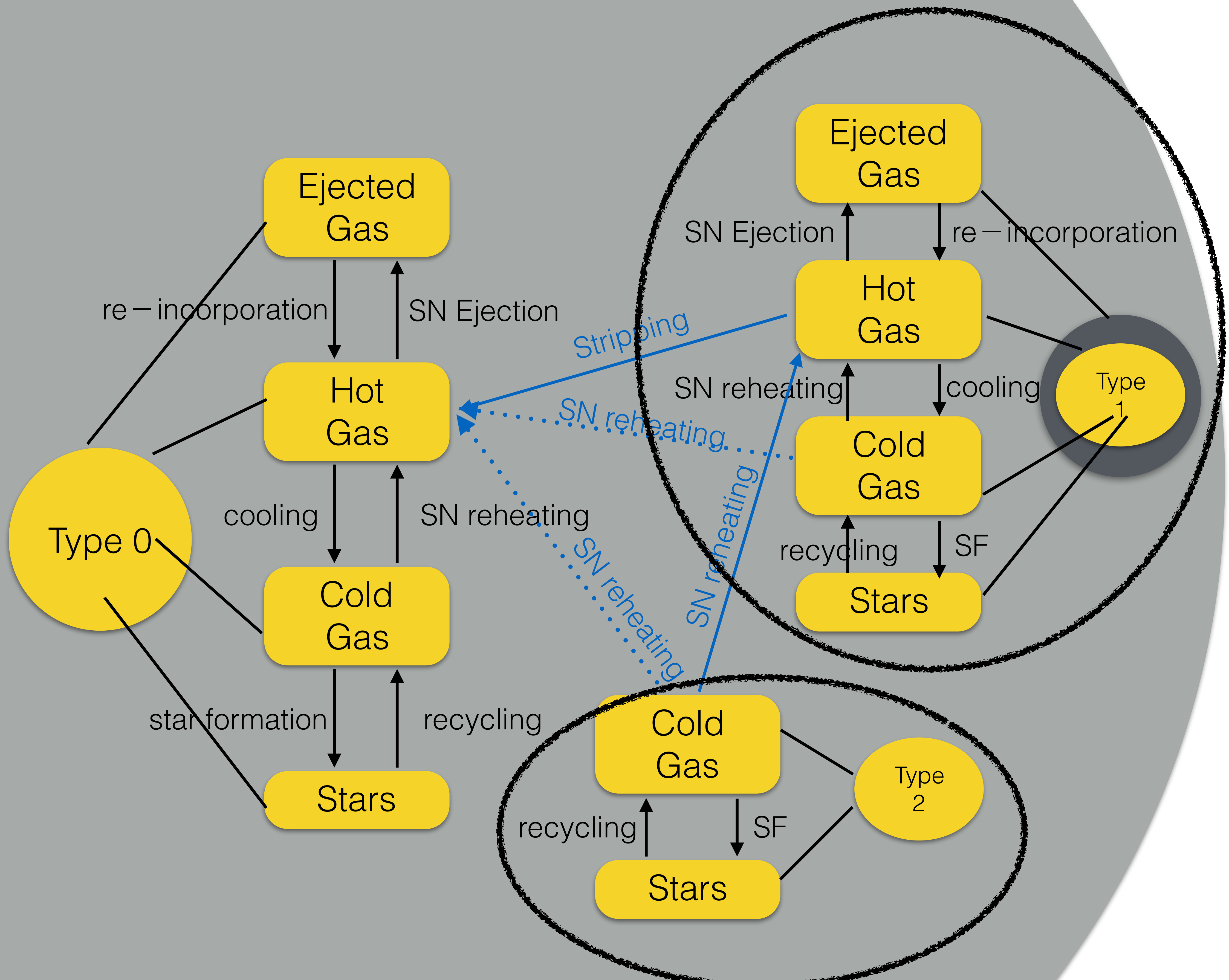
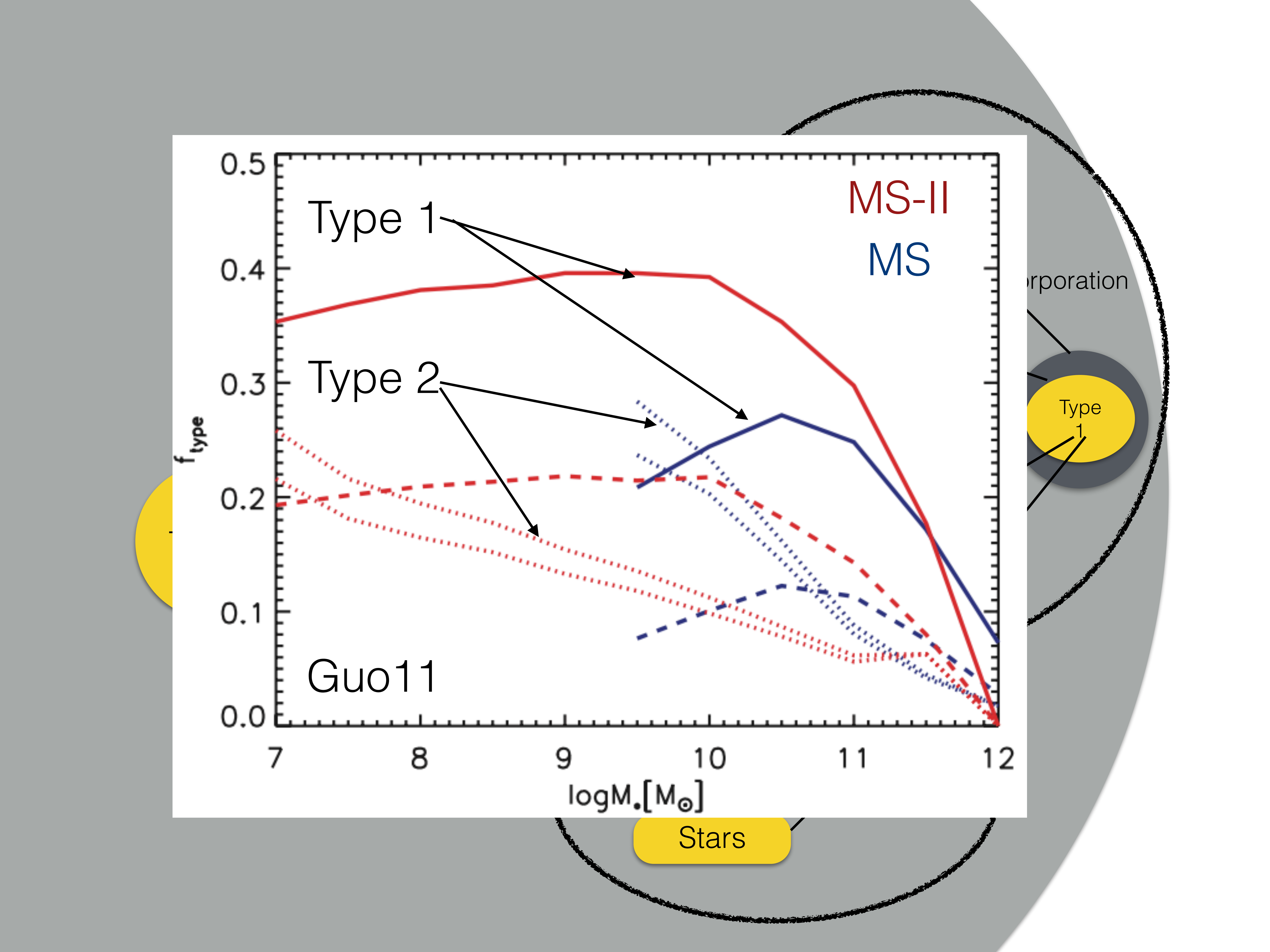
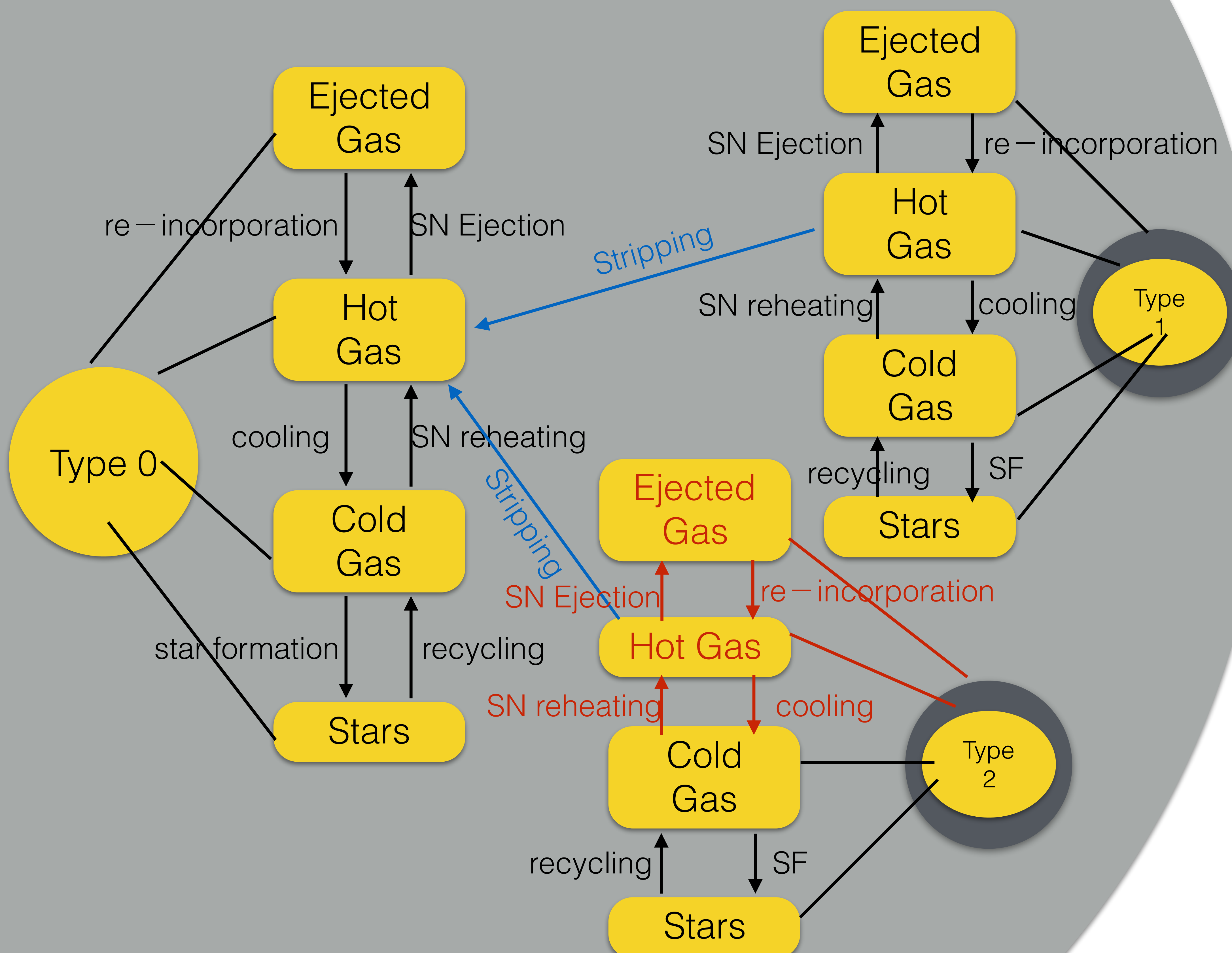


Ejected Gas
re – incorporation
SN Ejection
Hot Gas
cooling
SN reheating
Cold Gas
star formation
recycling
Stars
Type 0
Stripping
SN reheating
SN reheating
SN reheating
Ejected Gas
SN Ejection
re – incorporation
Hot Gas
SN reheating
cooling
Cold Gas
recycling
SF
Stars
Type 1
Cold Gas
recycling
SF
Stars
Type 2


MS-II
MS
Type 1
Type 2
Guo11
f_{type}
0.5
0.4
0.3
0.2
0.1
0.0
7
8
9
10
11
12
$\log M_*[M_\odot]$
Type 1
Stars

Resolution-independent model

- M_{sub} loss ratio $\dot{m} = -A \frac{m}{\tau_{dyn}} (\frac{m}{M})^{\zeta}$ (Jiang &van den Bosch 2014)
- V_{max} and R_{vir} evolve slowly, are fixed at infall time
- Apply it for unresolved subhalo (type 2s)
- Treat Type 2s in the same way as Type 1s. (their own gas circle) — increase the SN feedback in Type 2s



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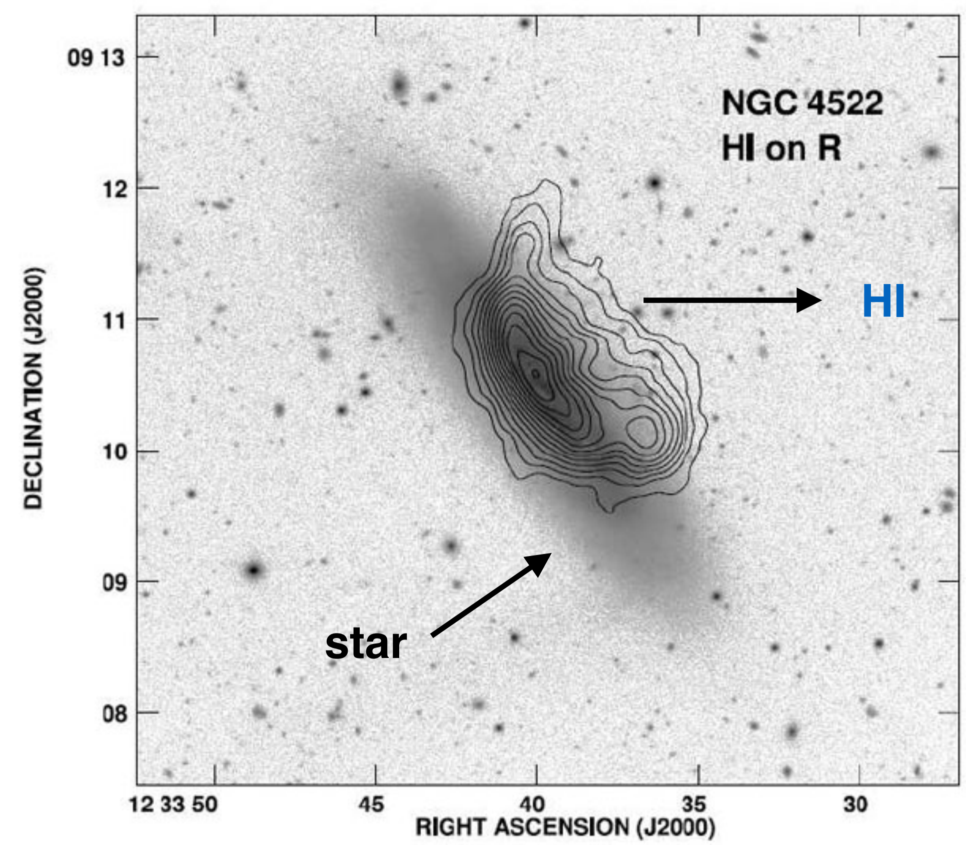
Recipe of RP Stripping of cold gas

$$P_{r.p}(R) = \rho_{ICM}(R)v^2$$ (Gunn & Gott 1972)

$$P_{ISM}(r) = 2\pi G\Sigma_{disc}(r)\Sigma_{gas}(r)$$

$$SP_{frac} = \begin{cases} 0, & P_{r.p} < P_{ISM} \\ \frac{P_{r.p} - P_{ISM}}{P_{r.p}}, & P_{r.p} \geq P_{ISM} \end{cases}$$



Kenney et al. 2004

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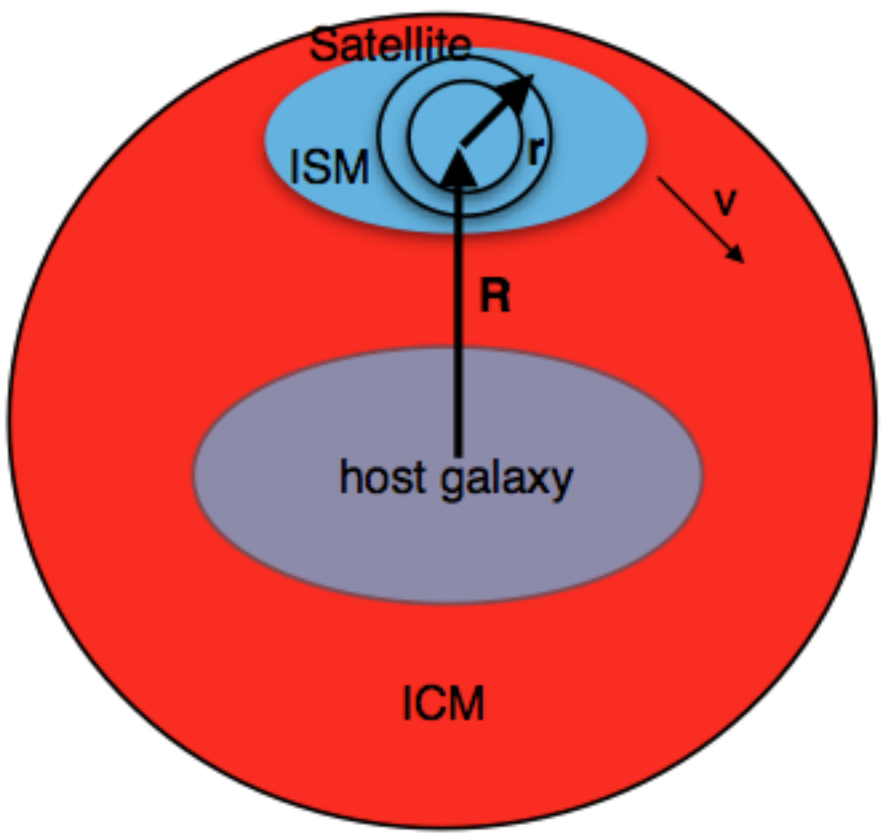

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$$\boxed{\rho_{par,hotgas}(R) = \frac{m_{hot}(R)}{4\pi R_{vir} R^2}}$$

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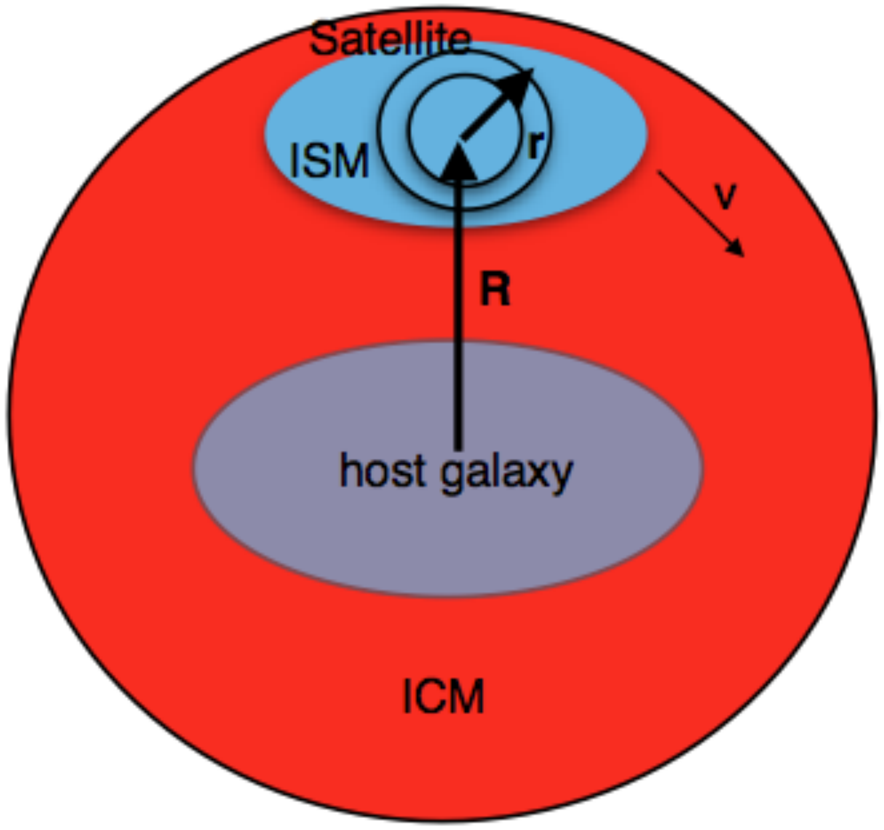

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star + cold gas

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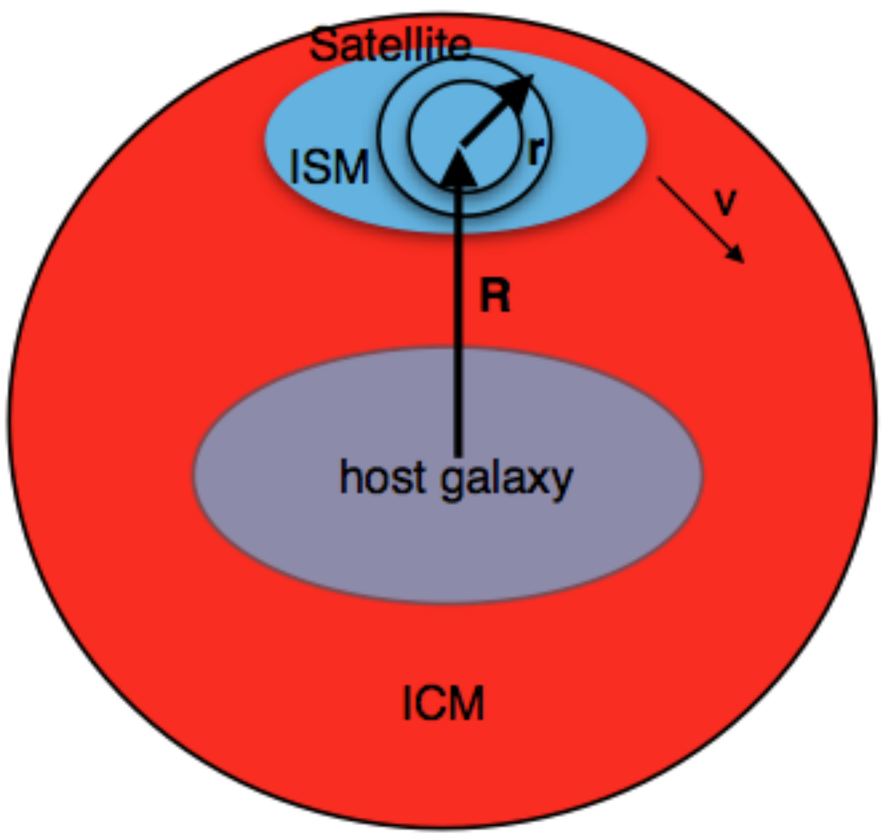

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↓ star + cold gas ↘ cold gas

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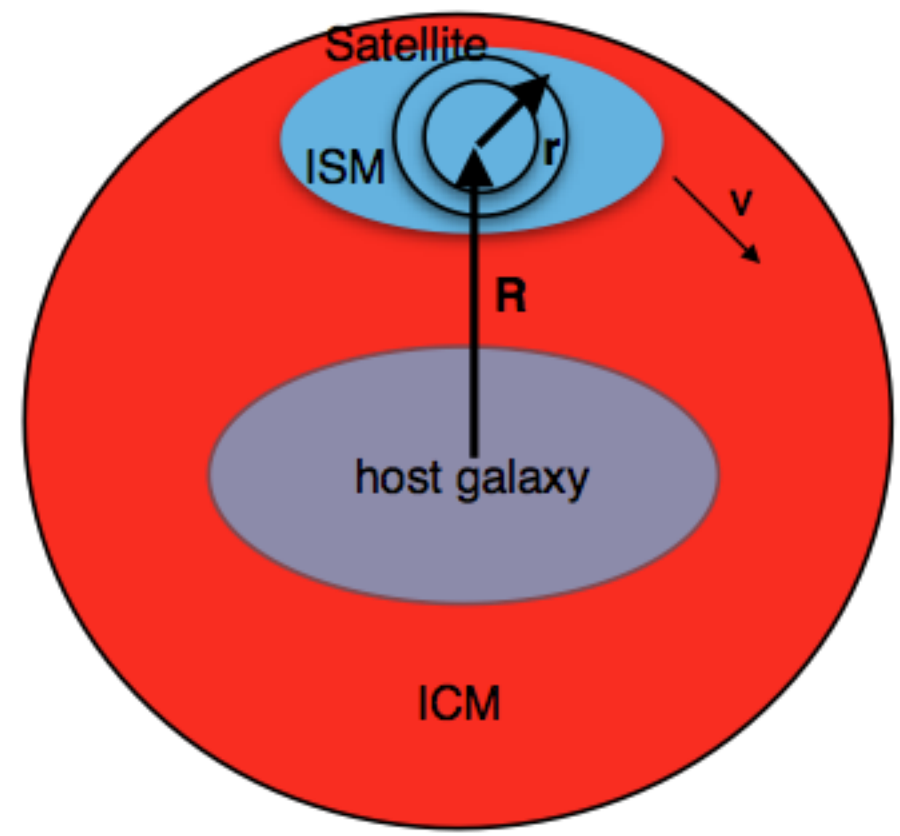
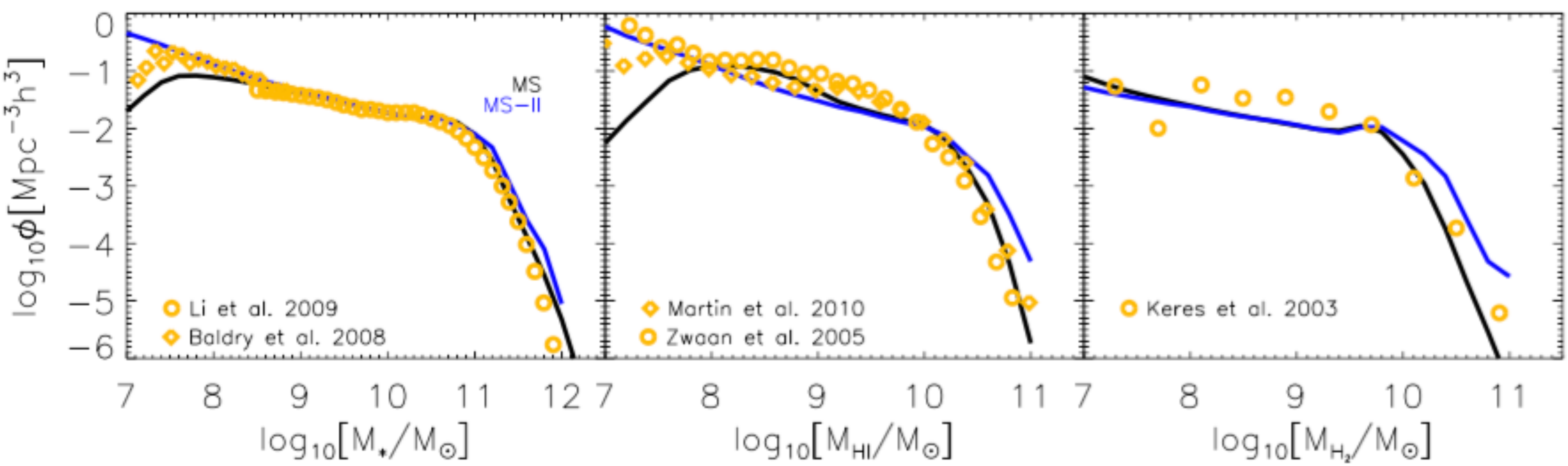


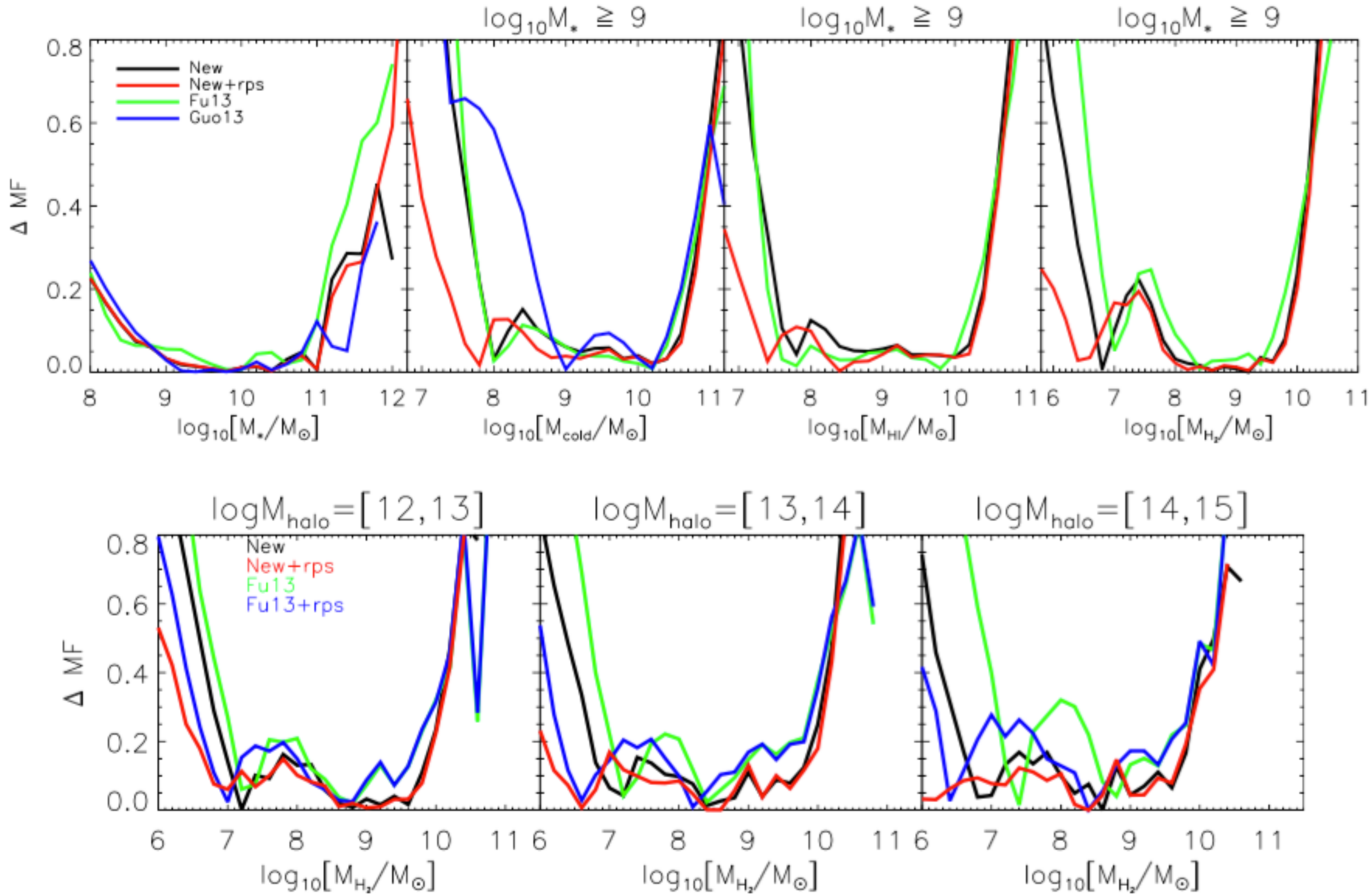
Results

- **Mass function**



⭐ Convergence check

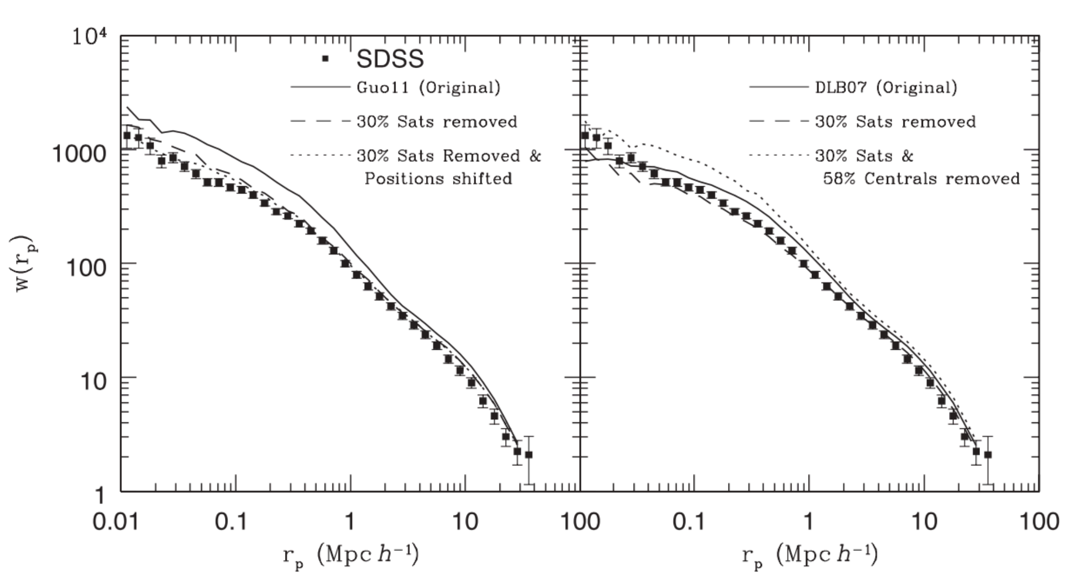
$$\Delta \mathrm{MF} = |\log_{10} \mathrm{MF_{MS}} - \log_{10} \mathrm{MF_{MS-II}}|.$$

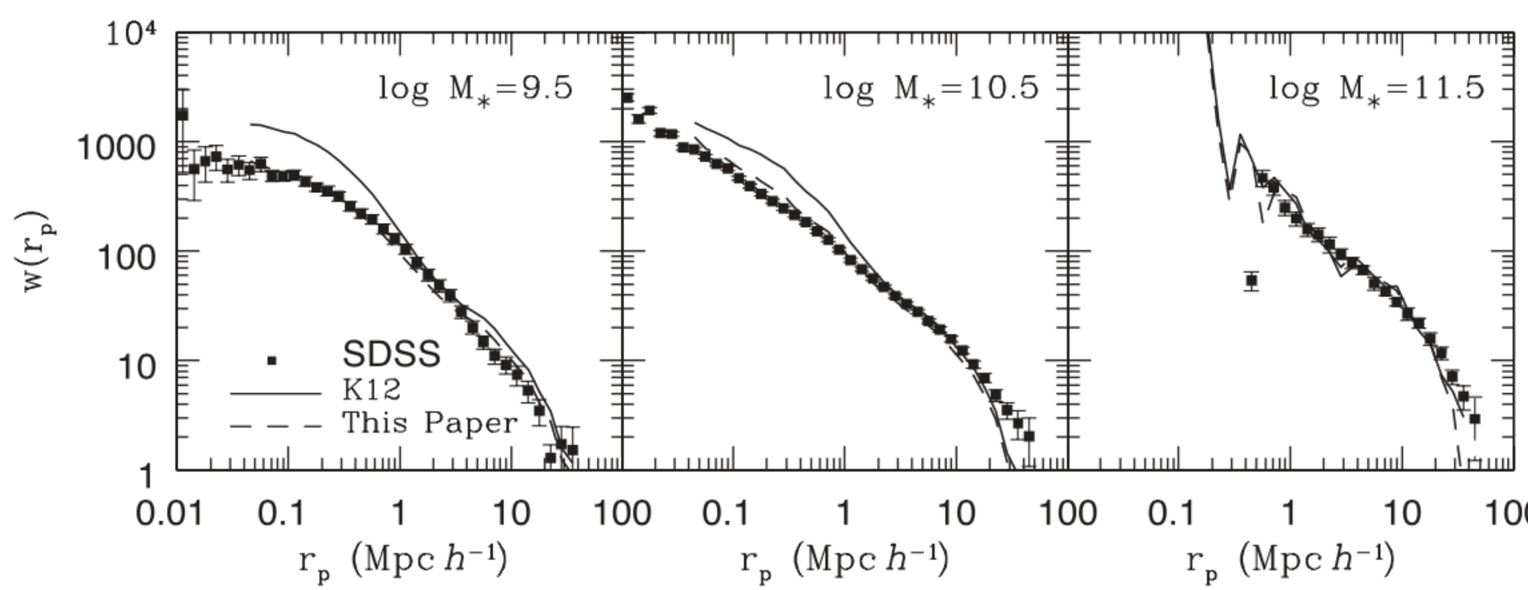


⭐ Clustering on small scales

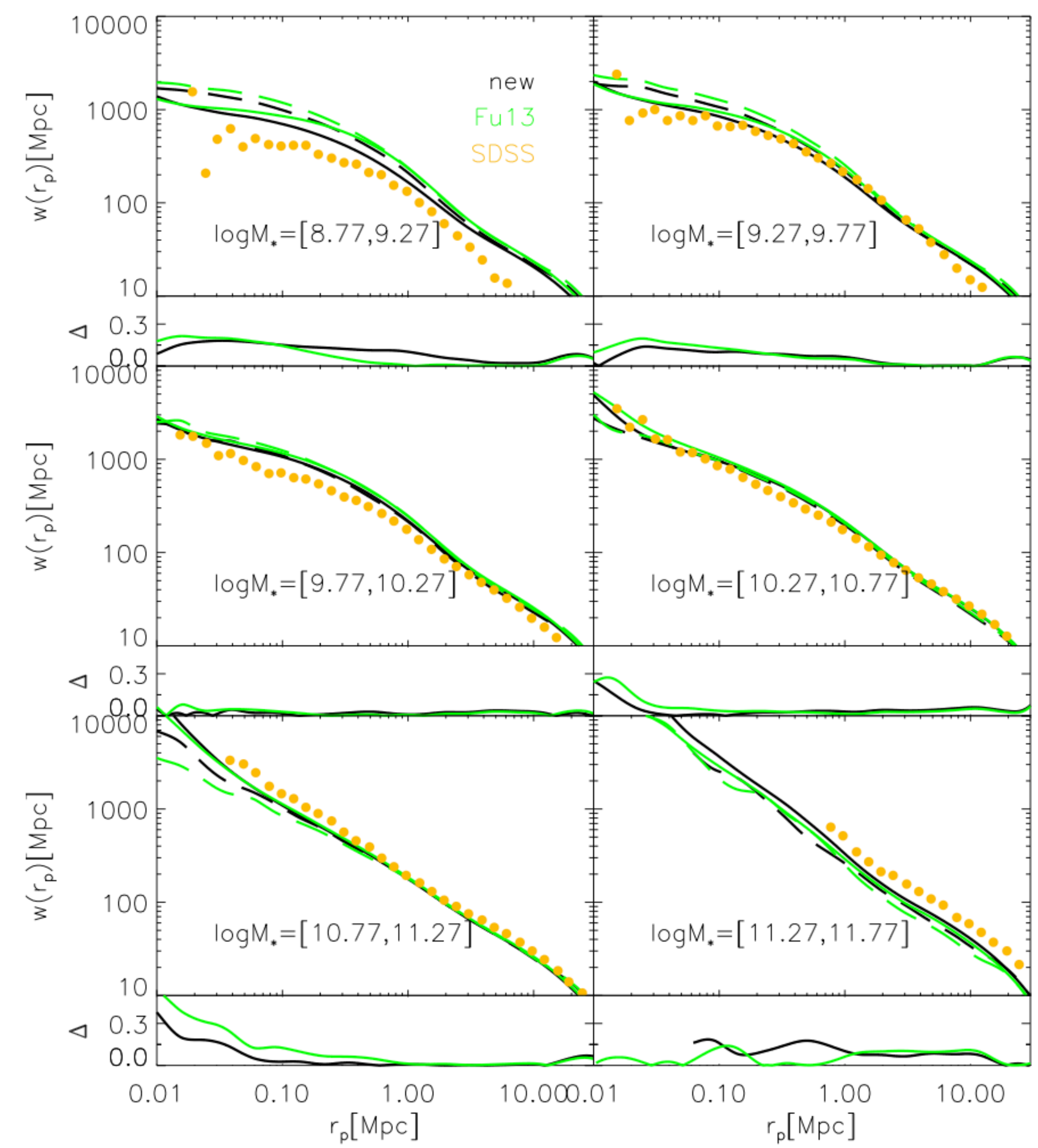
- Kang 2014: remove 30% Sats will improve the clustering on small scales in Guo11.

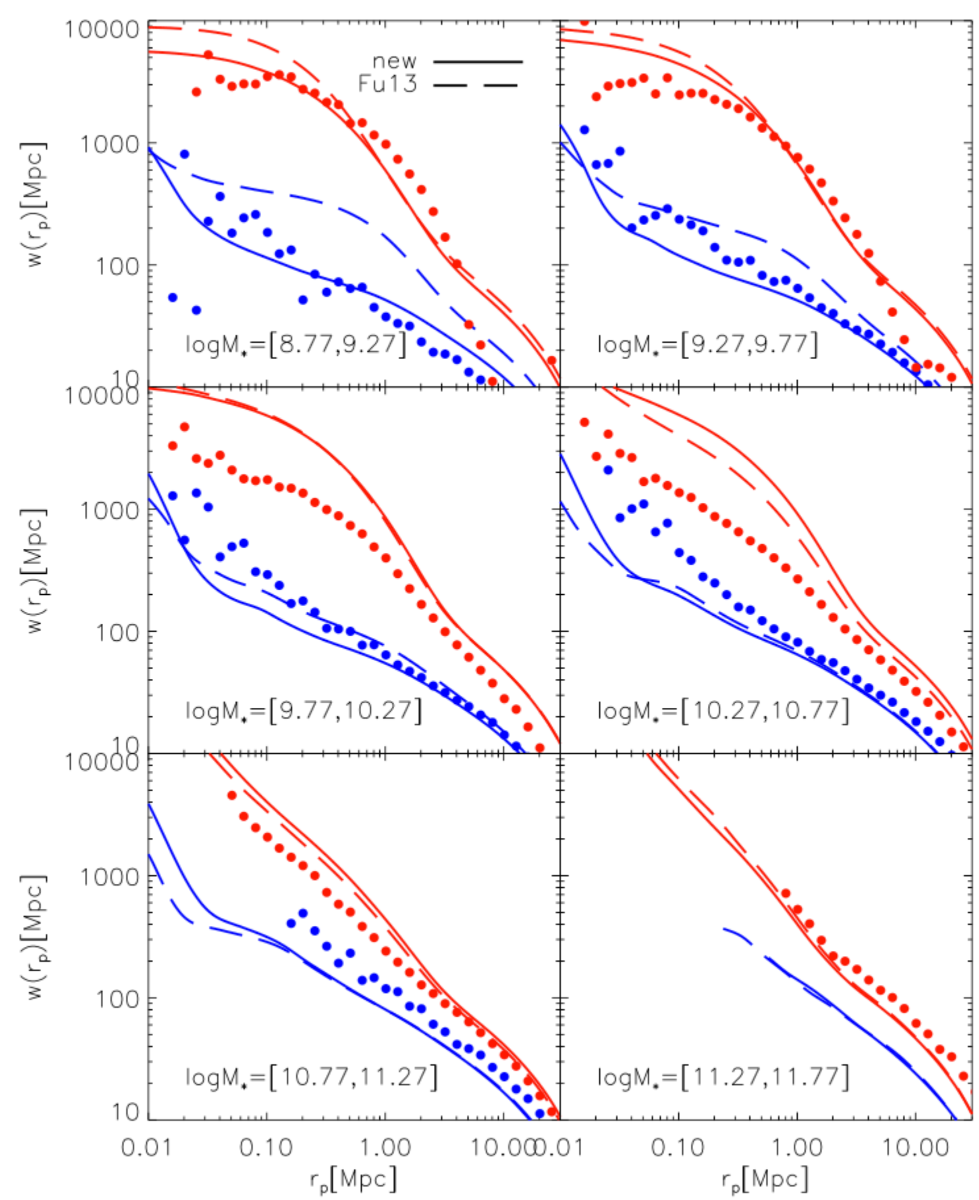
- Kang 2014: need to increase the FB in sats (also found in Henriques+13)





- better in low mass bins at small scales.

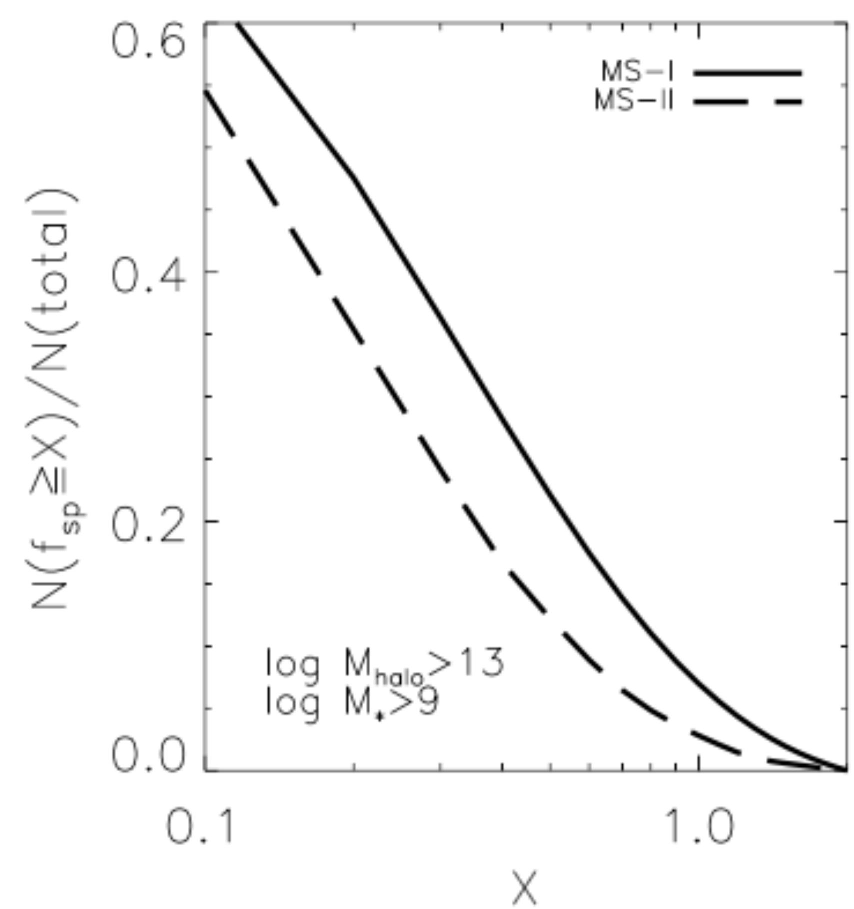




⭐ Where is rps most effective?

sample: $M_* \geq 10^9 M_\odot \quad M_{\rm halo} > 10^{13} M_\odot$

$$f_{\rm sp} = \frac{M_{\rm asp}}{M_* + M_{\rm coldgas}}$$



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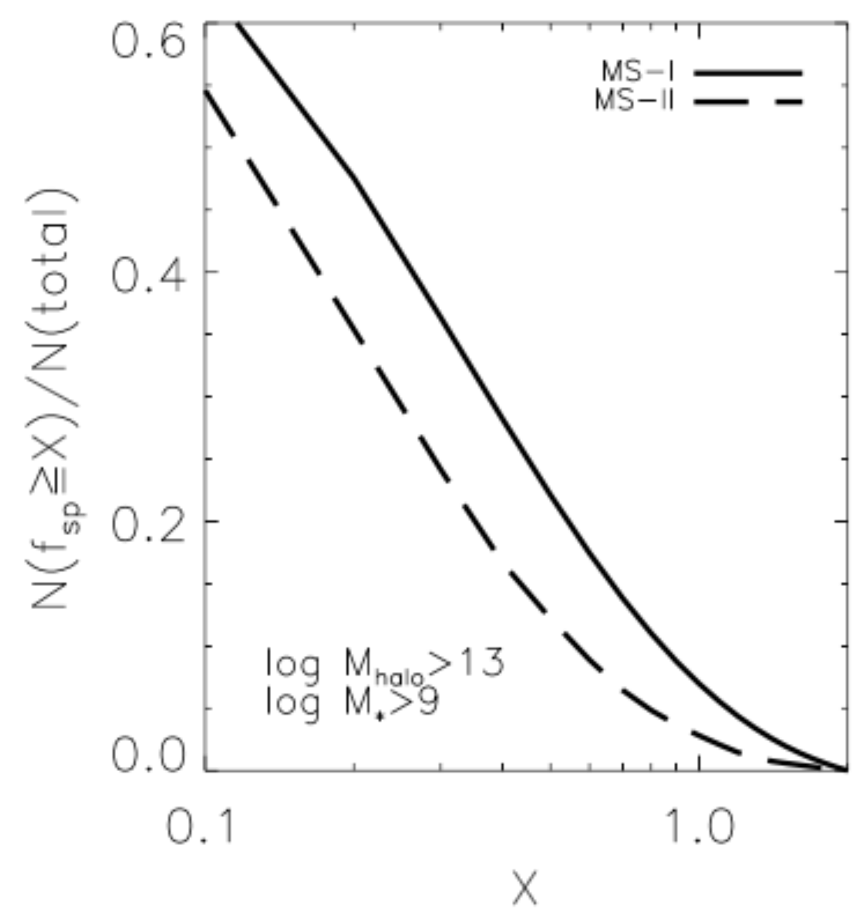
→ accumulative stripping cold gas



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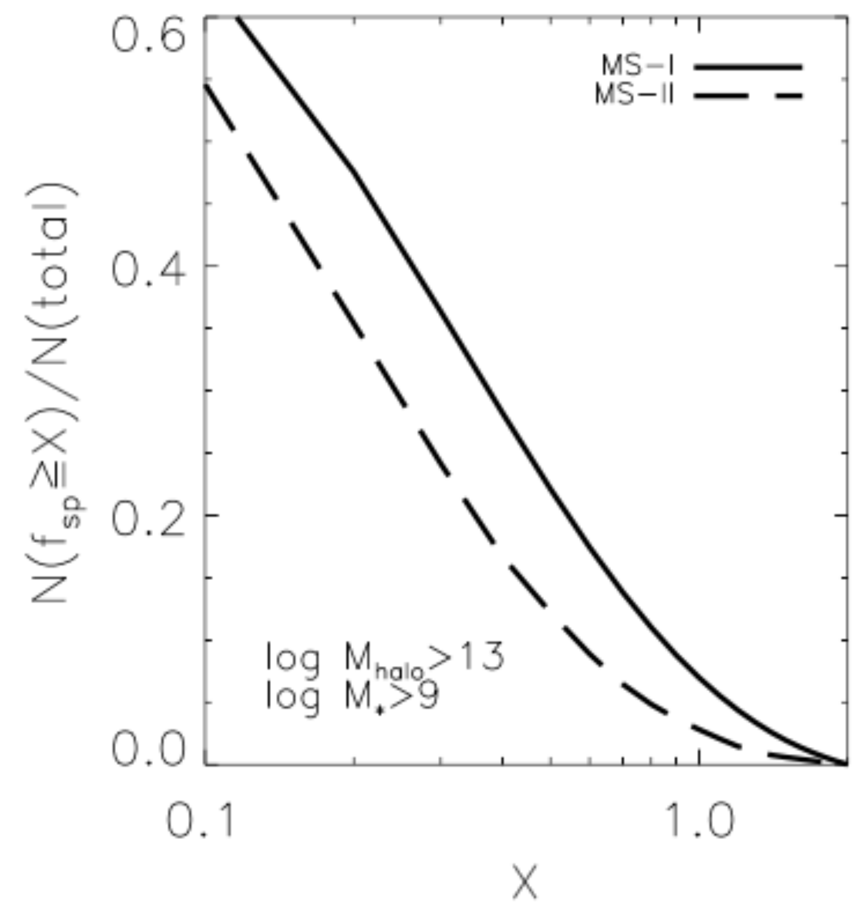
accumulative stripping cold gas

stellar mass at z=0



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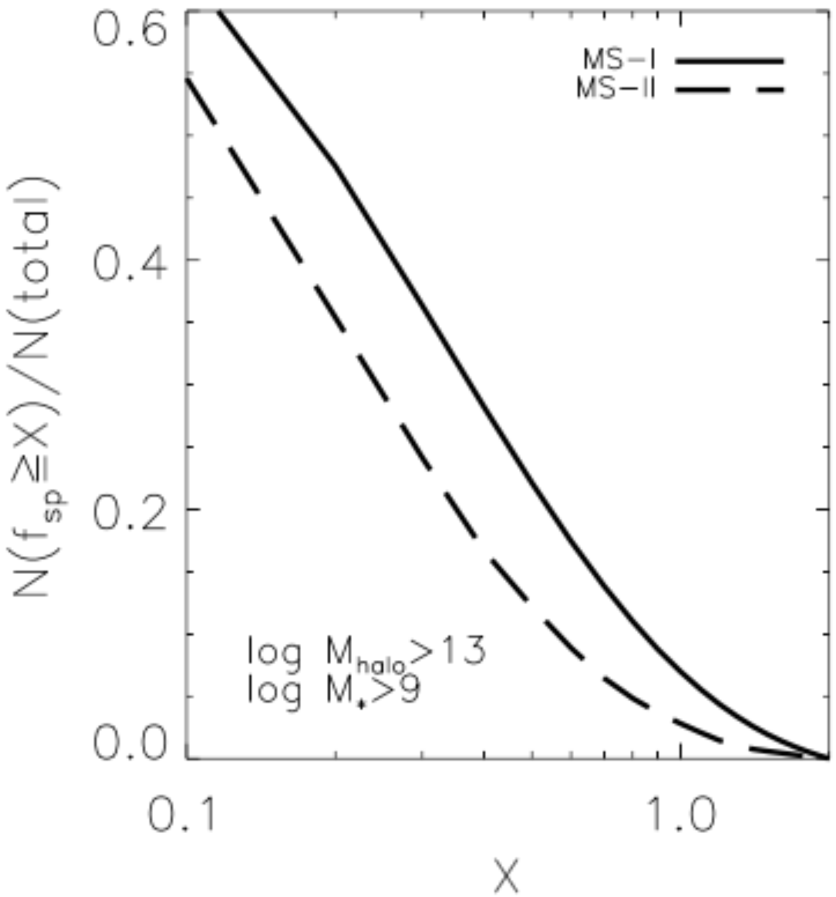
- $M_{\rm asp}$ → accumulative stripping cold gas
- M_* → stellar mass at z=0
- $M_{\rm coldgas}$ → cold gas at z=0



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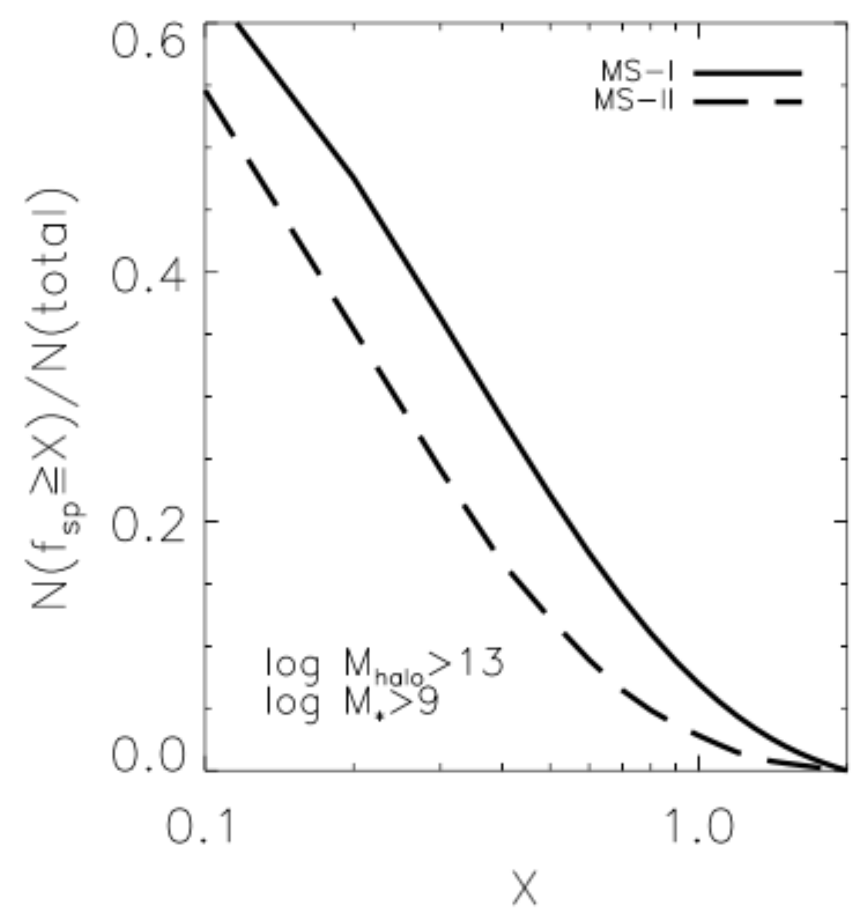

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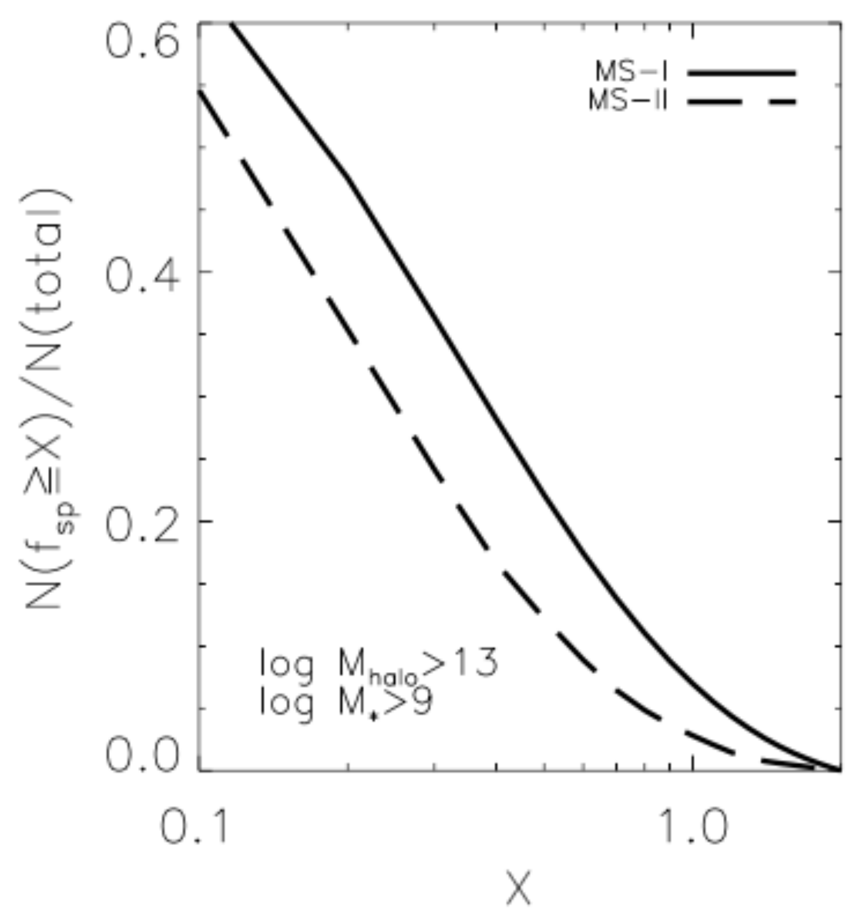
$$f_{sp} \geq 0.1 \;\sim\; 50\%$$

$$f_{sp} \geq 0.5 \;\sim\; 10\%$$



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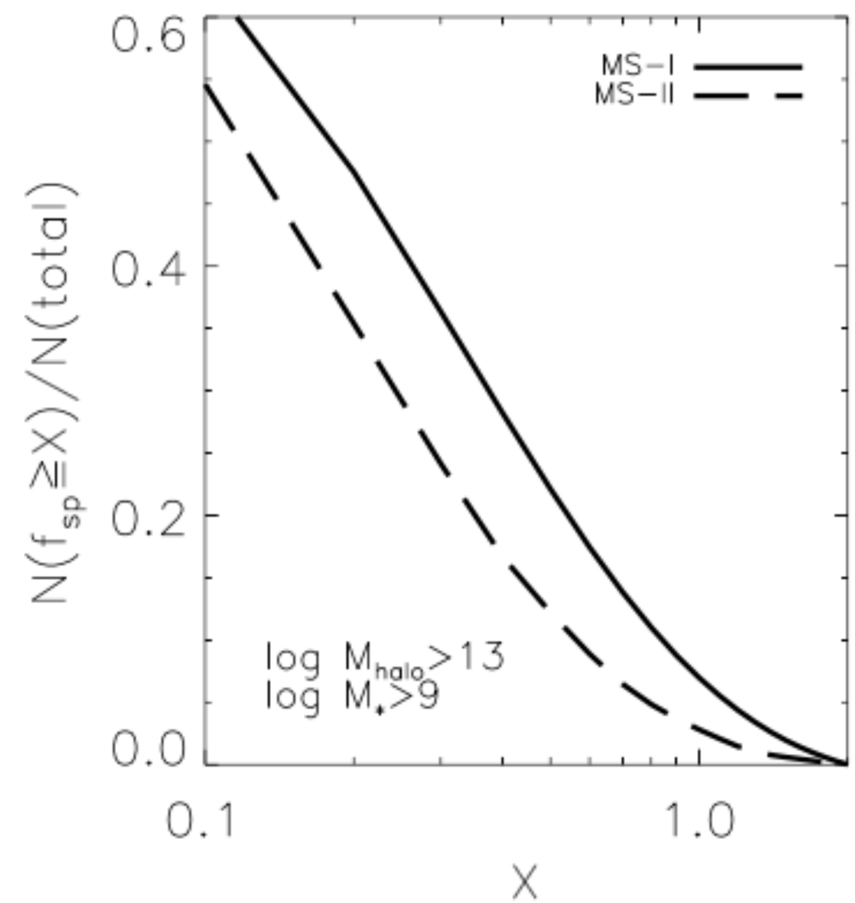


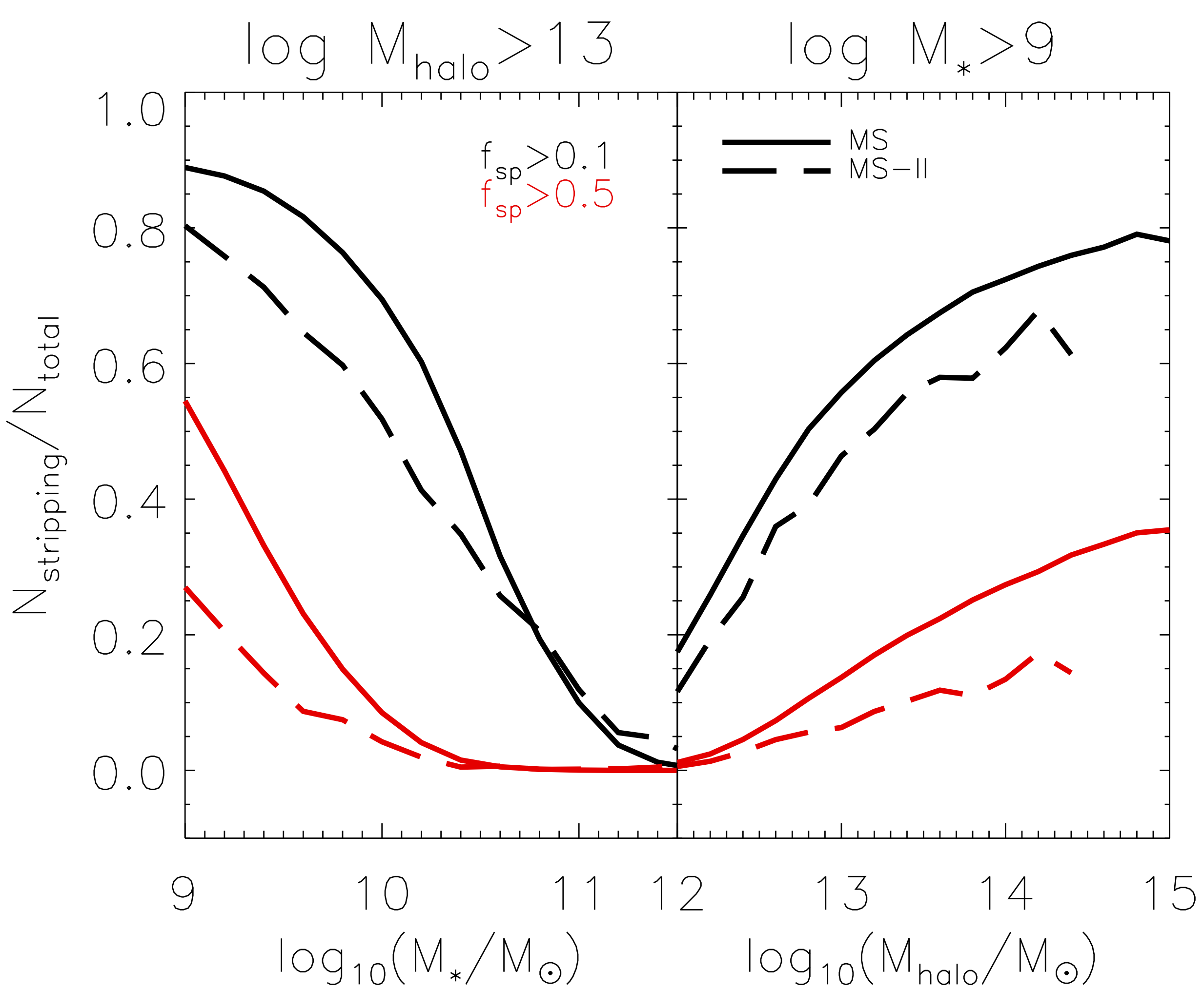
- ~ 50% galaxies in massive

clusters have experienced RPS of cold gas

- ~ 10% galaxies in massive

clusters have experienced *strong* RPS of cold gas

- $N_{Stripping}/N_{total}$ increased with halo mass
- $N_{Stripping}/N_{total}$ decreased with stellar mass



☆ Effect of RP stripping on the quenched fraction of satellite galaxies

obs data
MPA-JHU SDSS DR7
+
Yang et al.2007

$M_* > 10^{9.5} M_\odot,\ z < 0.04$
$M_* > 10^{10} M_\odot,\ z = 0.04 \sim 0.06$

SAM sample

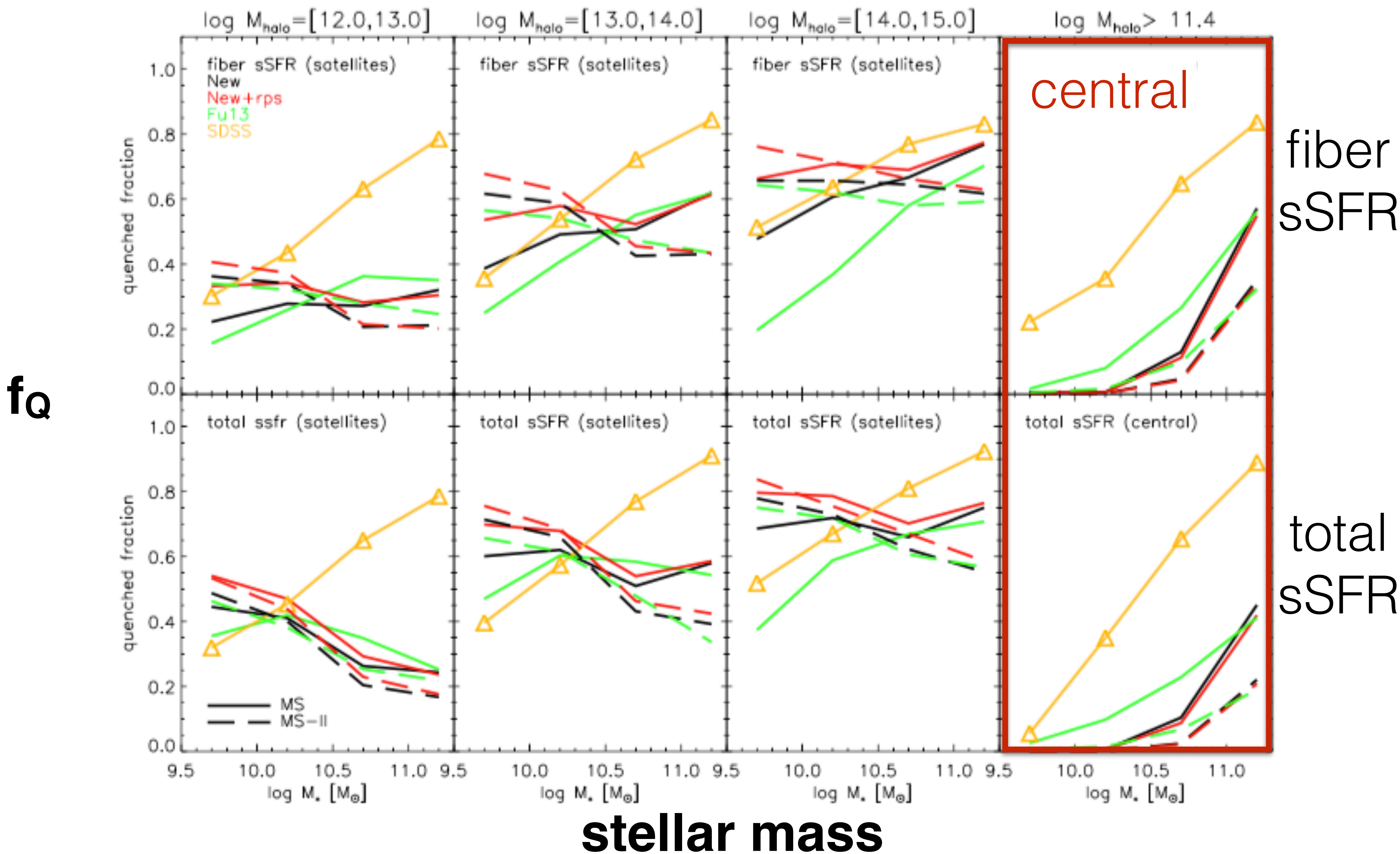
$M_* > 10^{9.5} M_\odot,\ z \sim 0$

Quenched galaxies: $sSFR = \frac{SFR}{M_*} < 10^{-11} yr^{-1}$

f_Q is the fraction of quenched galaxies in a cluster.

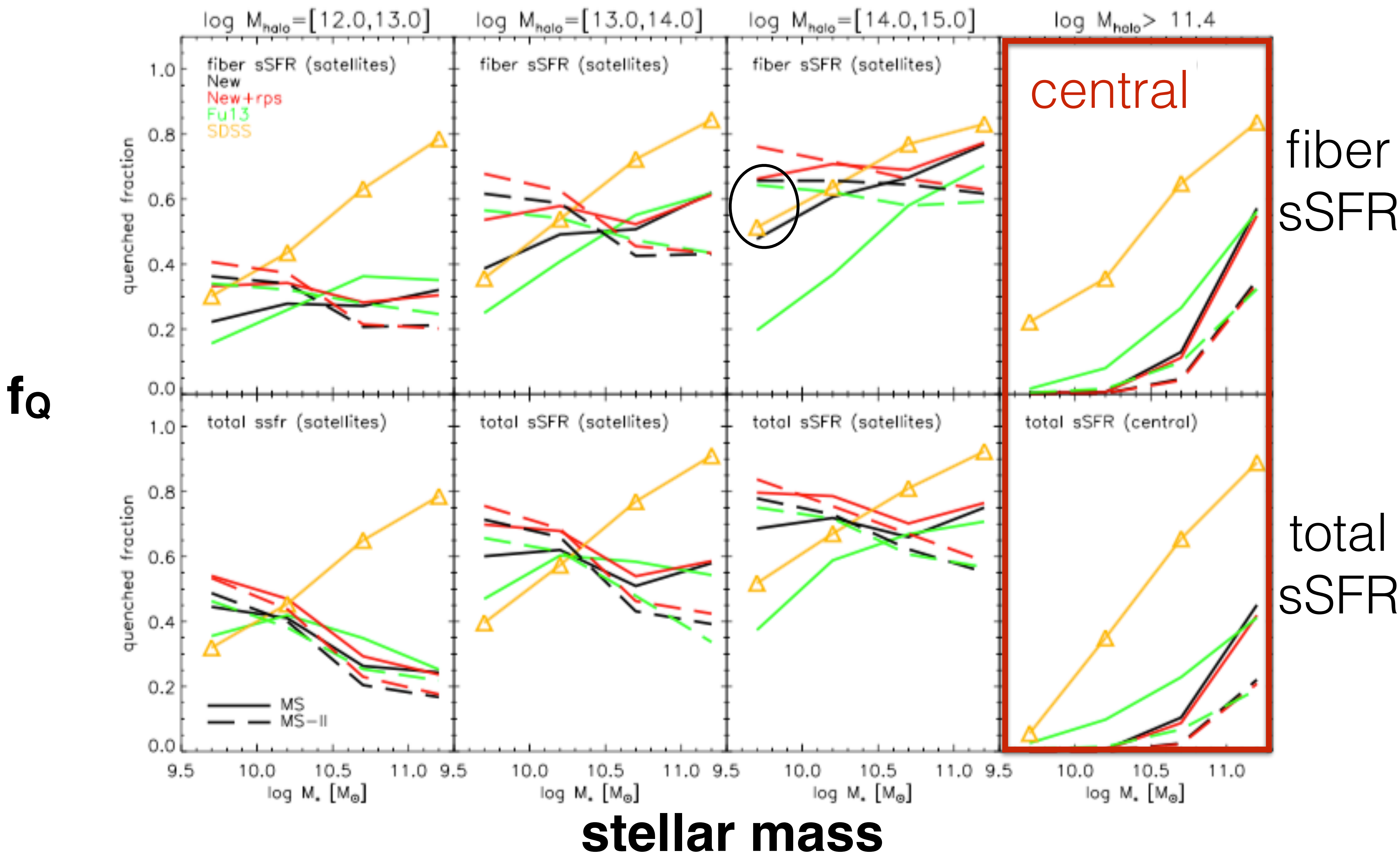
fQ VS stellar mass

data: a strong dependence of fQ on stellar mass



f_Q VS stellar mass

data: a strong dependence of f_Q on stellar mass



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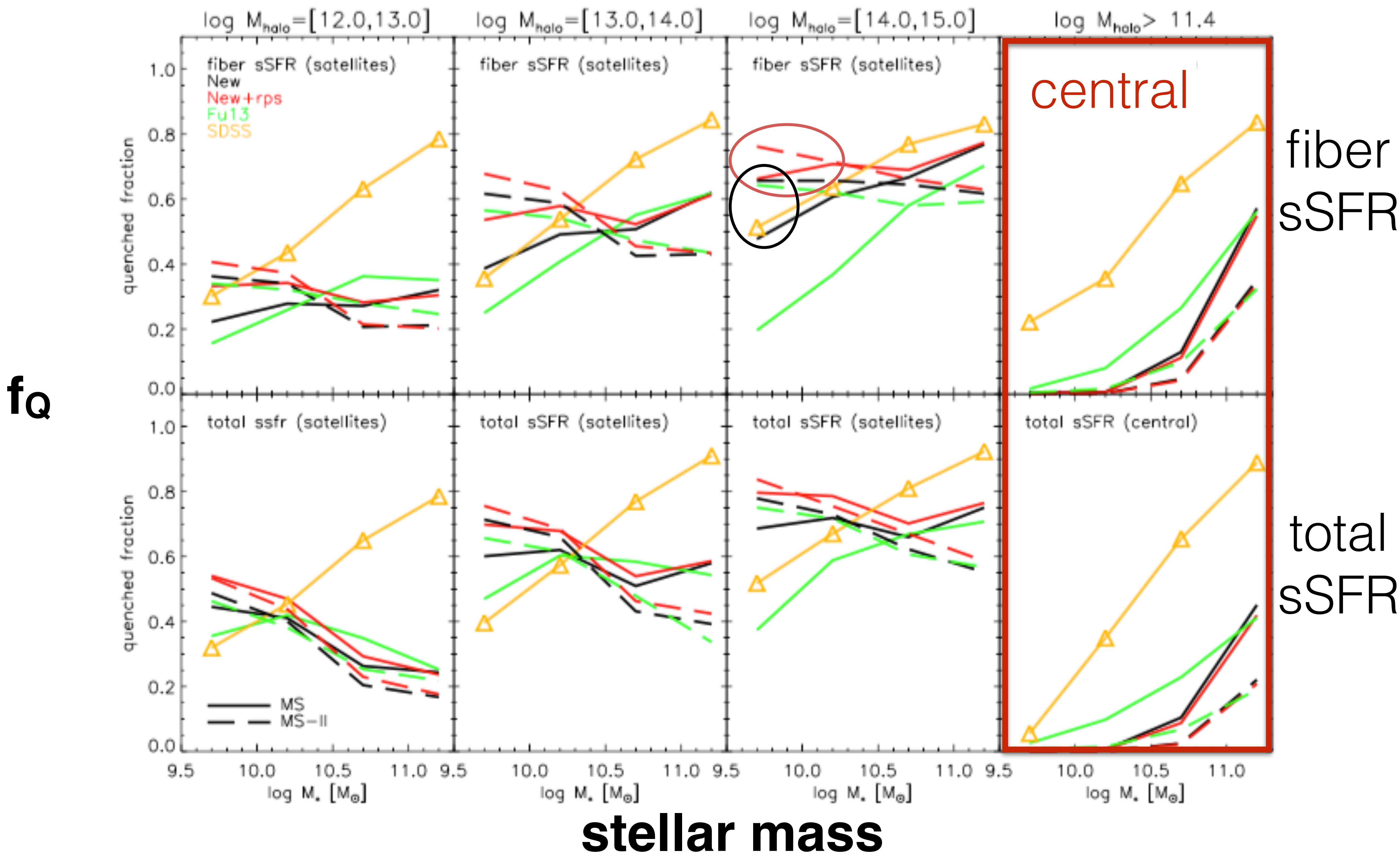

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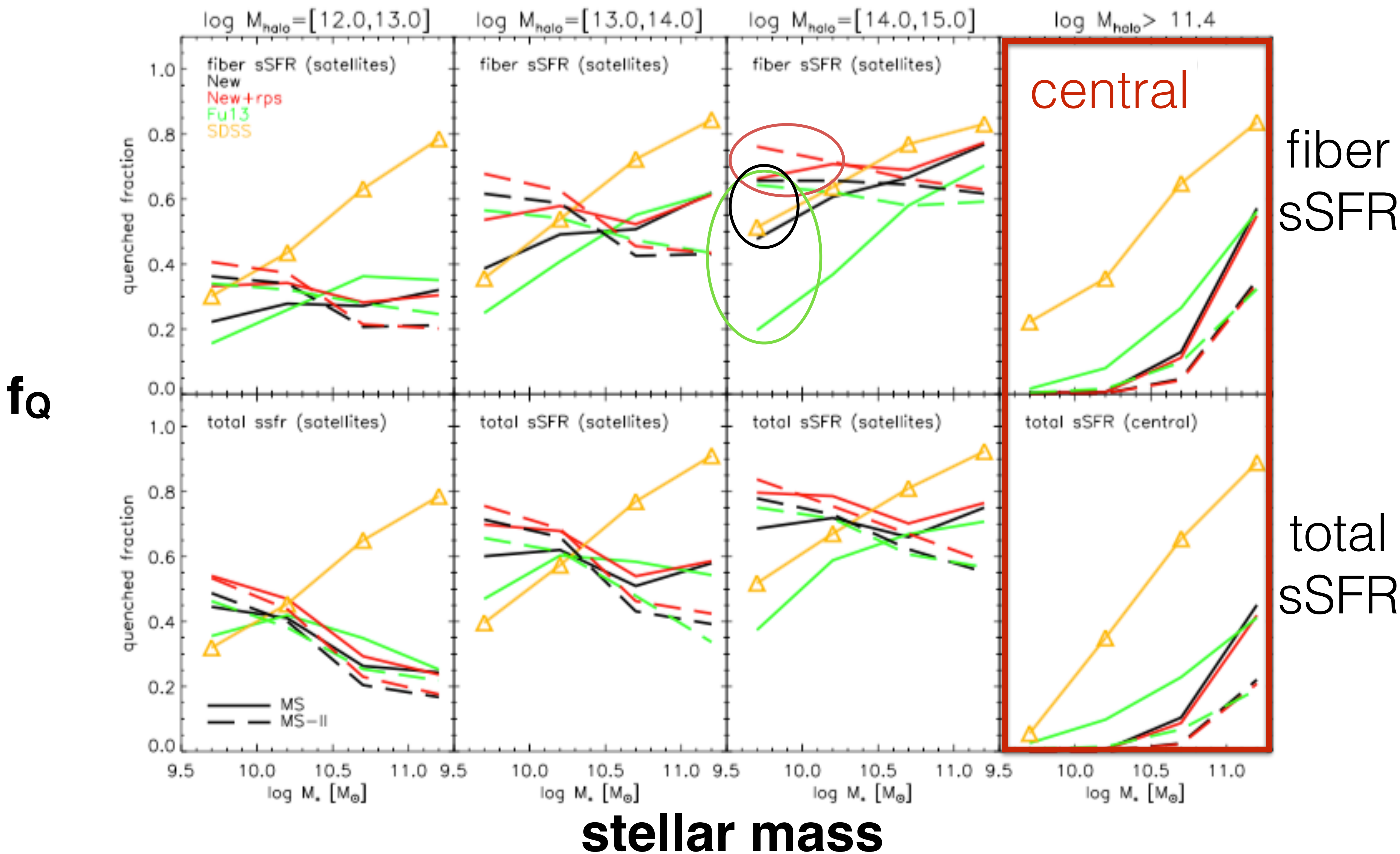

f_Q VS halo mass

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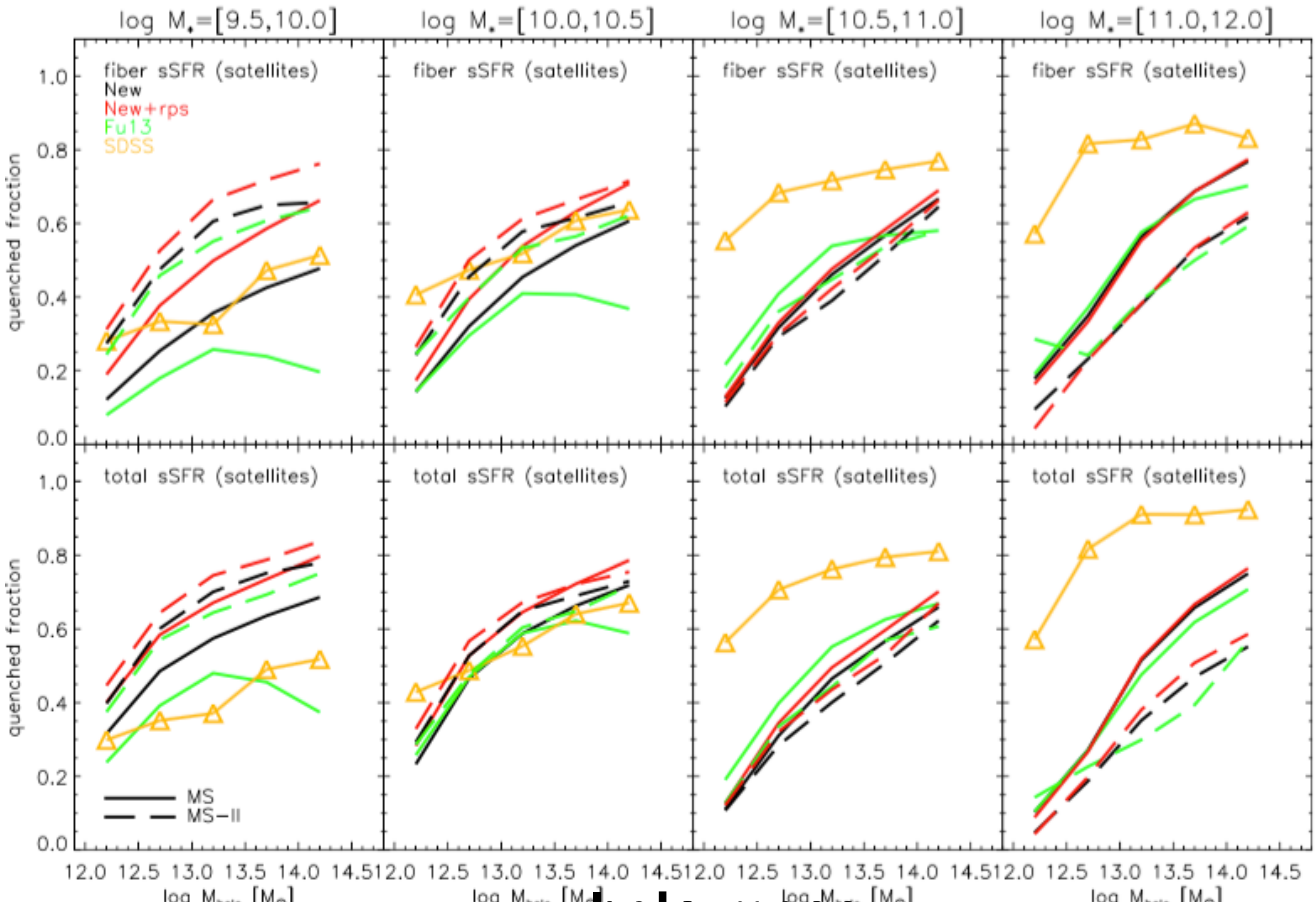
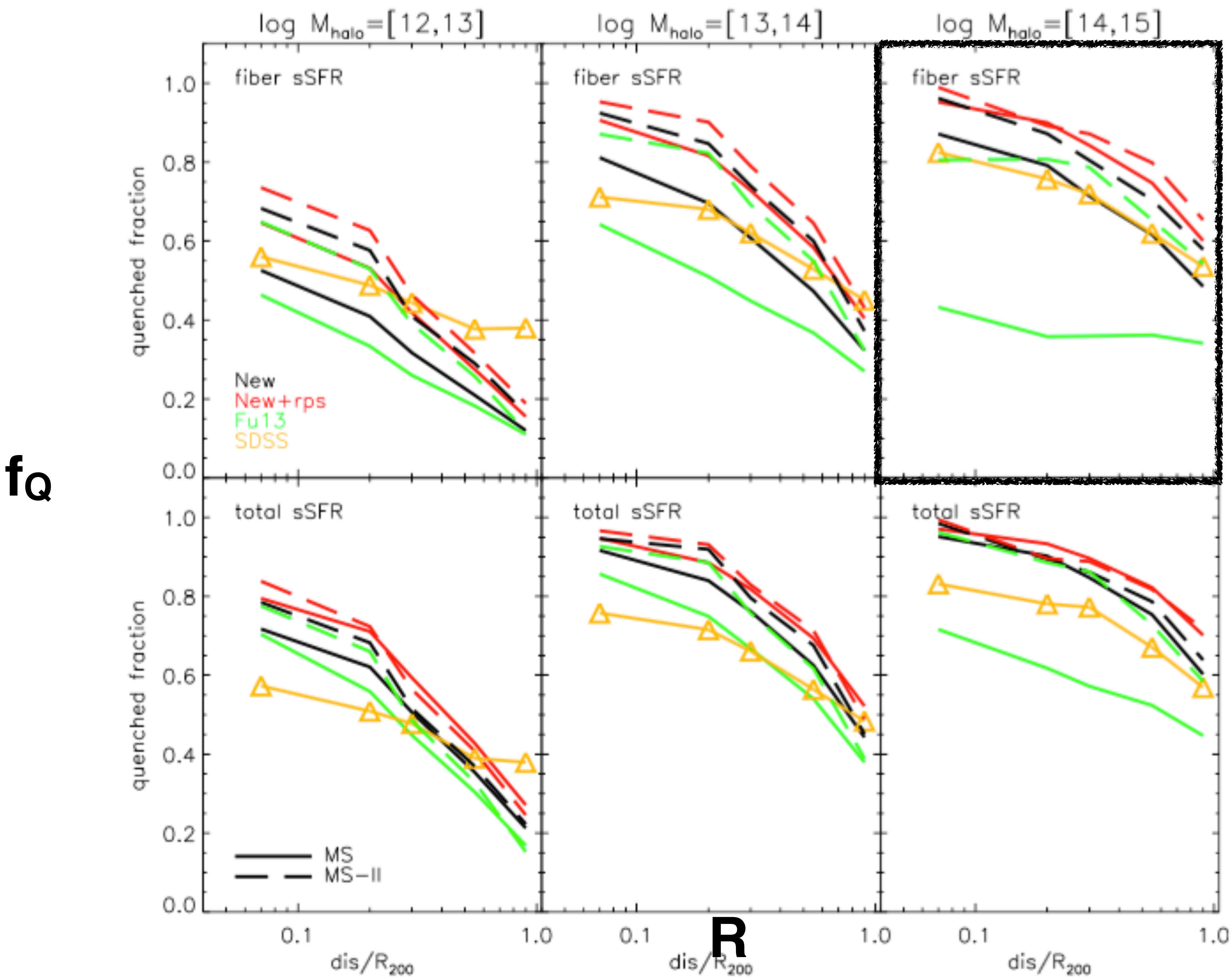


f_Q

halo mass

f_Q VS projected distance to center at fixed halo mass

model: central density of hot gas in lower mass haloes is too high



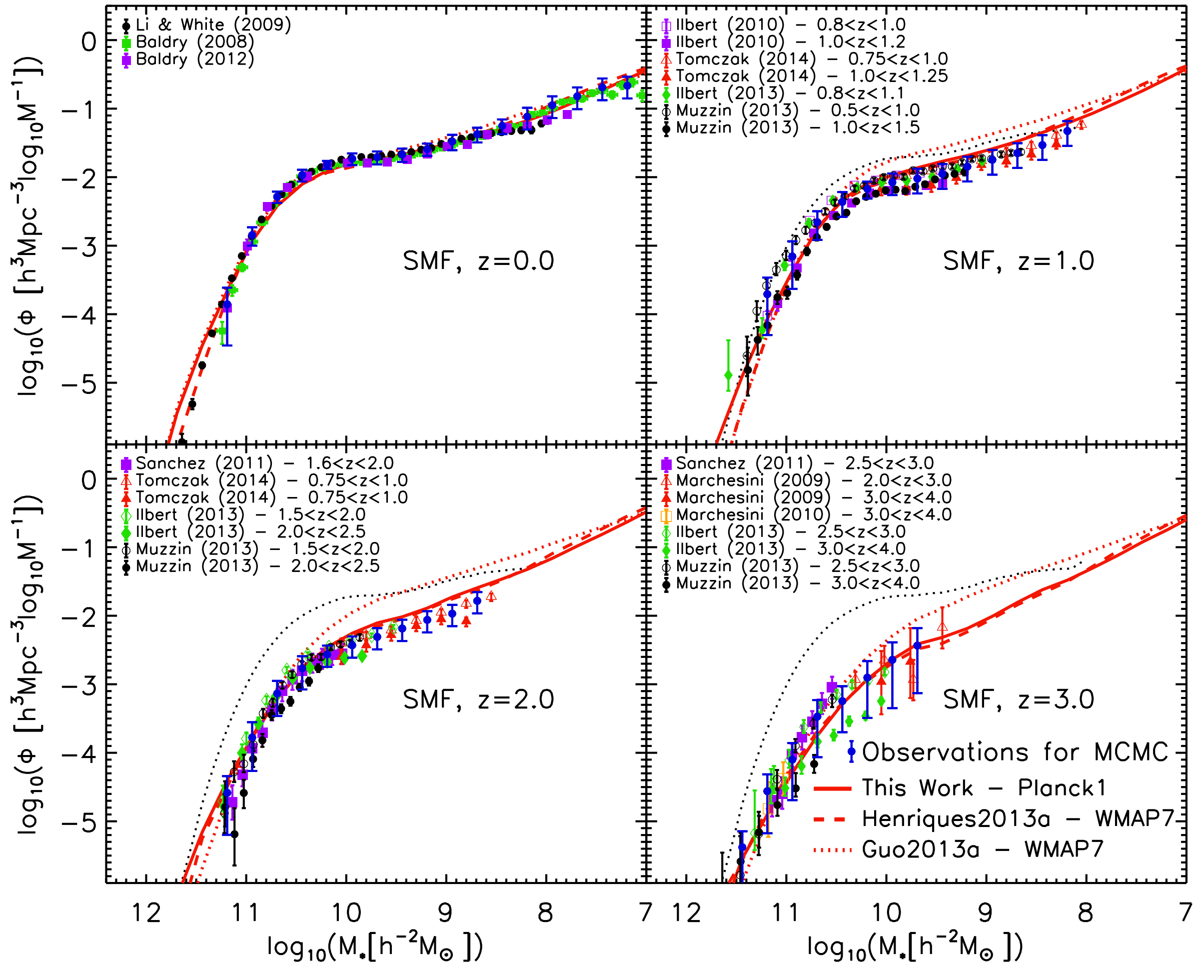
Summary 1

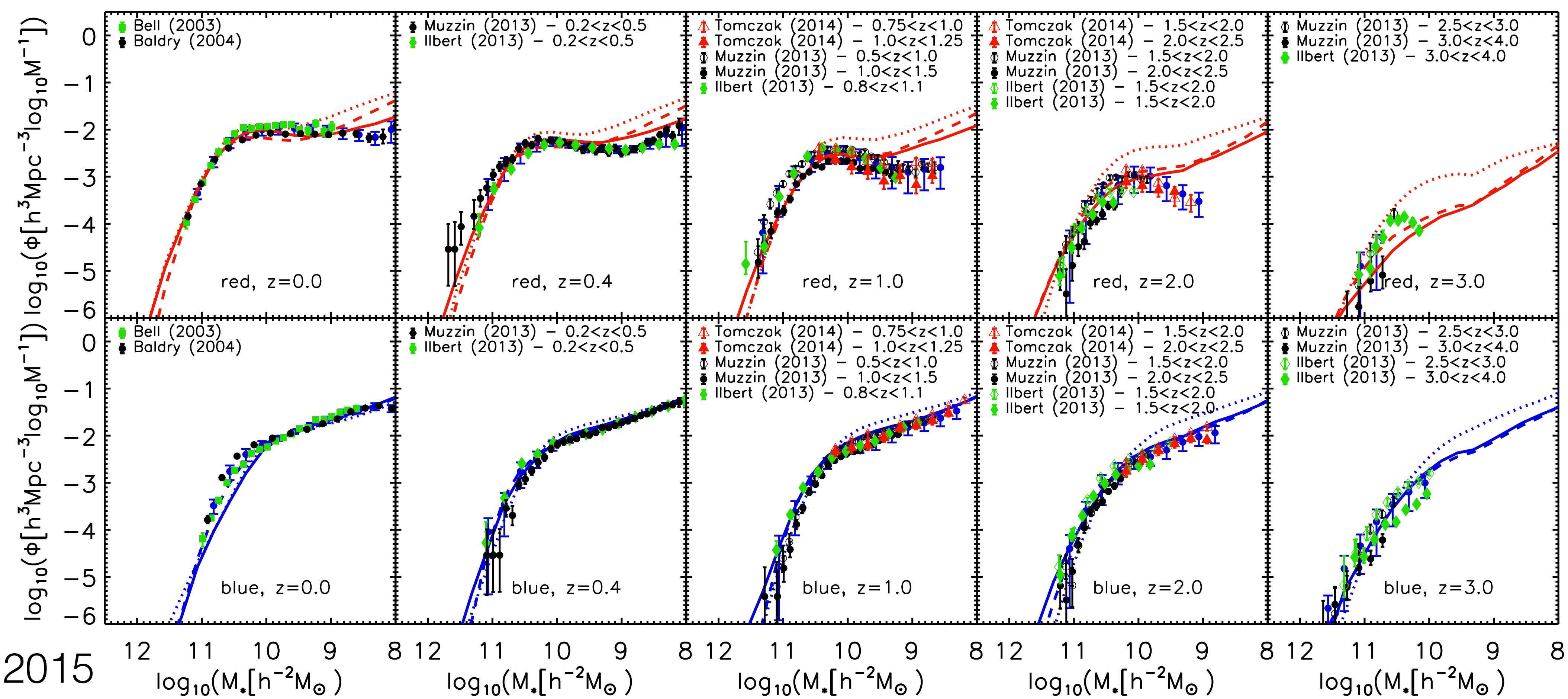
- Resolution-independent SAM.
- RP can effectively remove cold gas from low mass satellite galaxies in massive halo.
- More than 50% of galaxies have experienced cold gas stripping by RP, **10%** of galaxies suffered **strong** RPS of cold gas in the massive halos.
- The model: influence of the ***halo mass*** on star formation history is ***primary*** and the influence of ***stellar mass*** is ***secondary***. But it is **opposite** to the **observation**.
- Over-prediction of red satellites is still **not** solved.

Luo et al. 2016

Henriques+2015

- L-Galaxies (MCMC) + Planck first-year cosmology
- Solved problems: The overly **early formation** of **low-mass** galaxies and the overly large fraction of them that are **passive** at late times
- Matching the observed evolution of SFRs, colours and stellar masses from $z = 3$ down to $z = 0$





Henriques+2015

Modifications in H15

- delay the reincorporation —> low mass galaxies form slowly.
- lower the threshold for turning cold gas into stars —> keep star forming in low mass galaxies.
- eliminate ram-pressure stripping in halos less massive than ~ 10^14 M⊙ —> decrease gas loss in low mass satellites
- increase the radio-mode feedback —> suppress central galaxies growth
- …

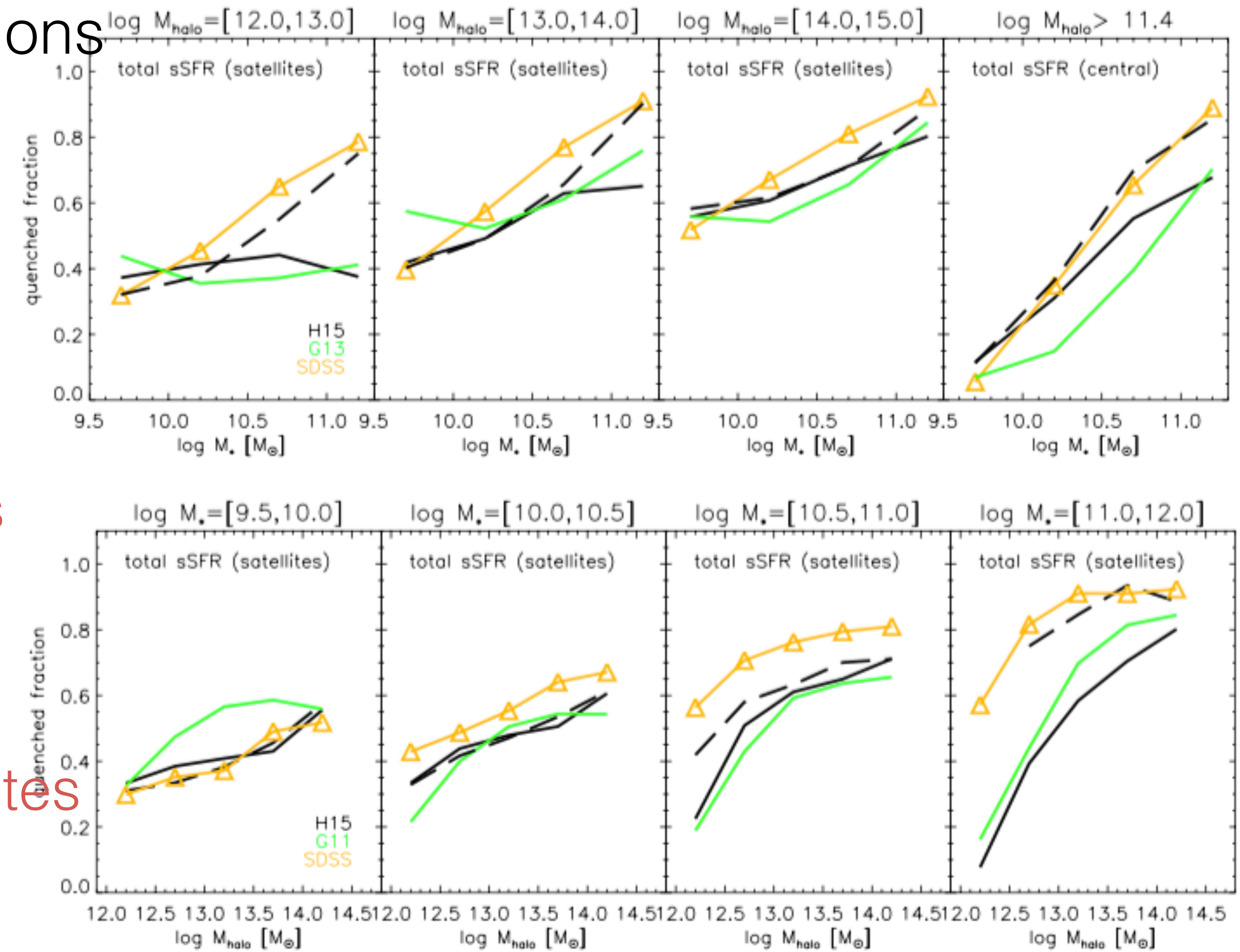
Results

☆ Quenched fractions

—more quenched centrals than G13

—less quenched *low* mass satellites than G13

—less quenched *middle* mass satellites than SDSS



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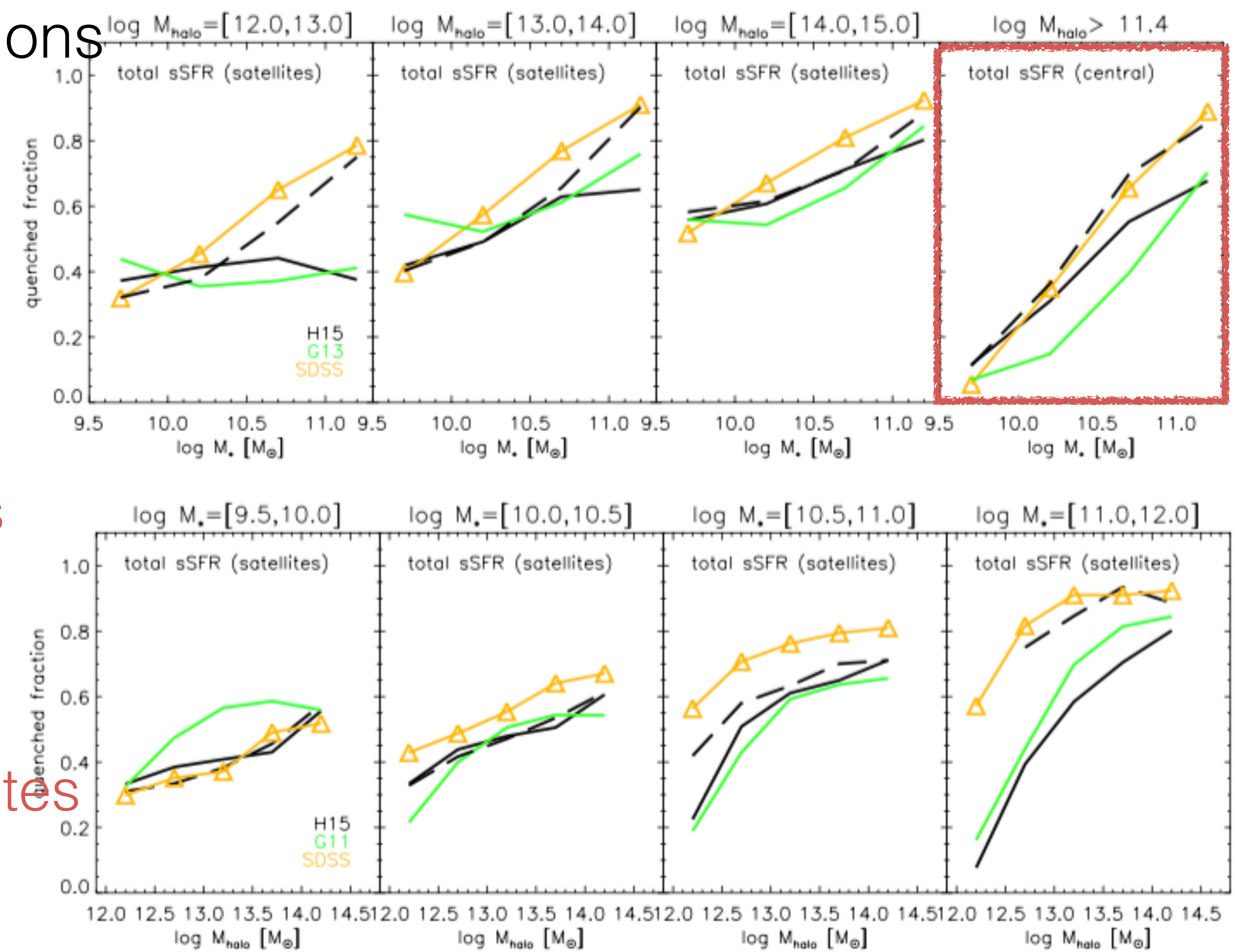

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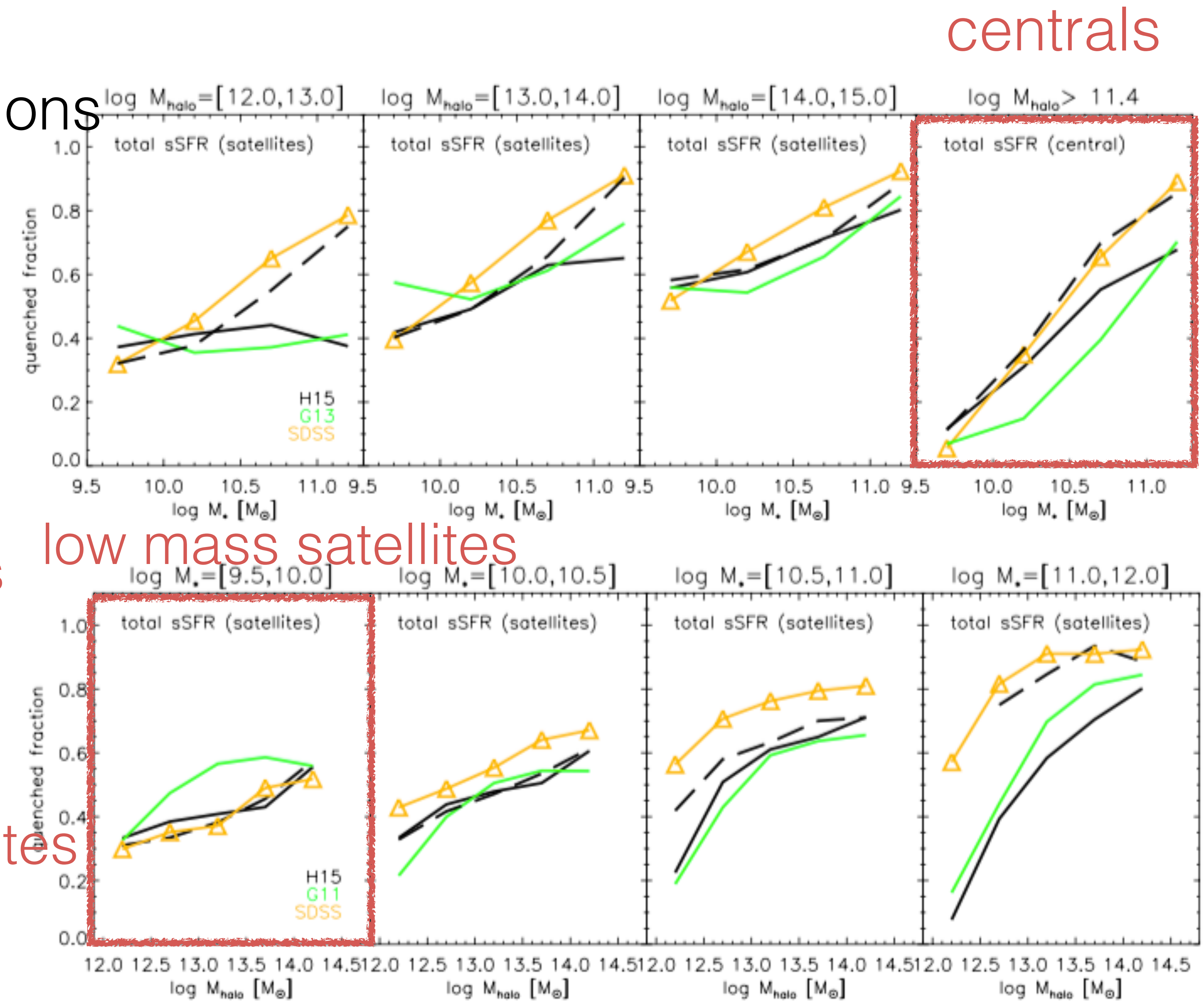

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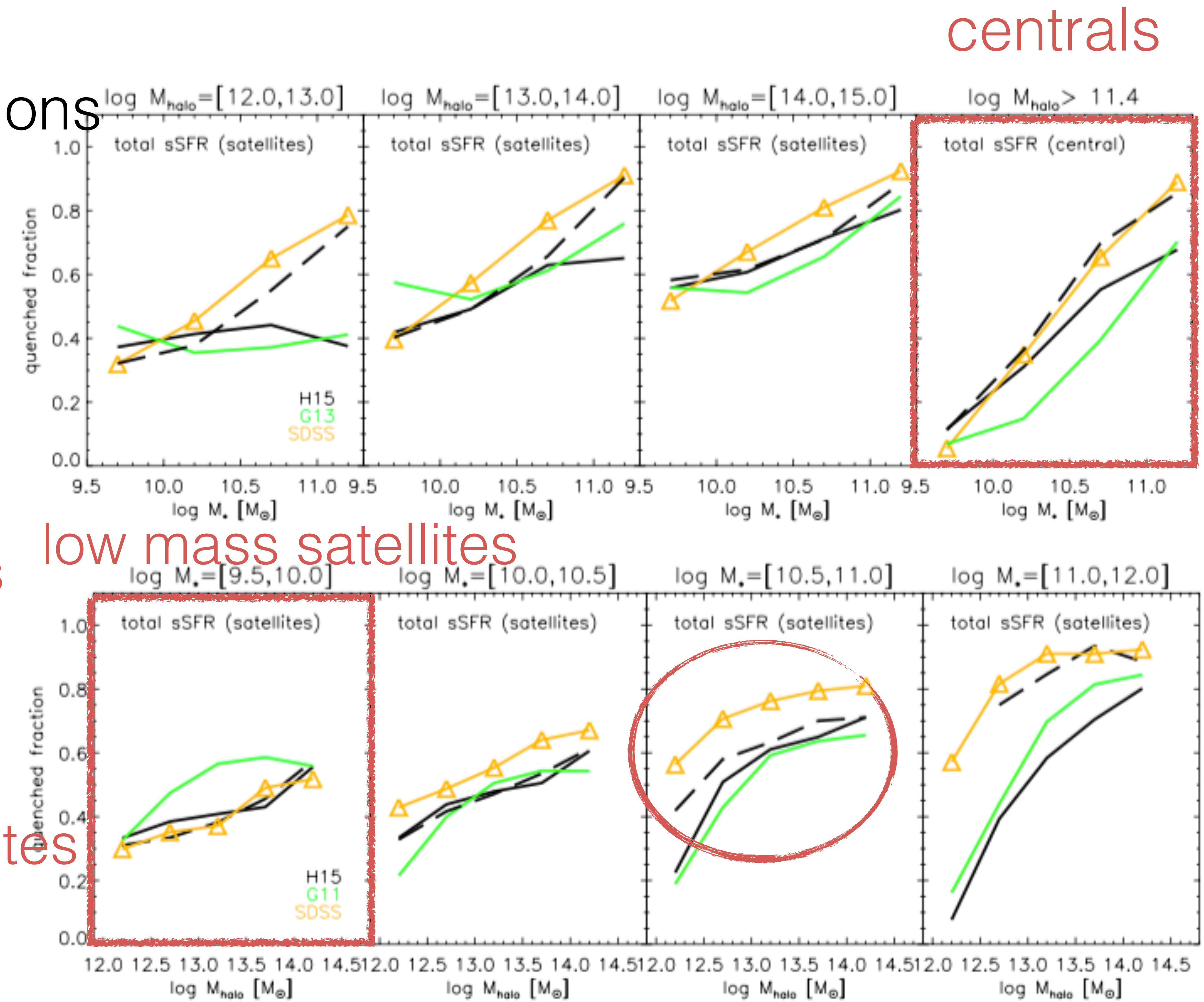
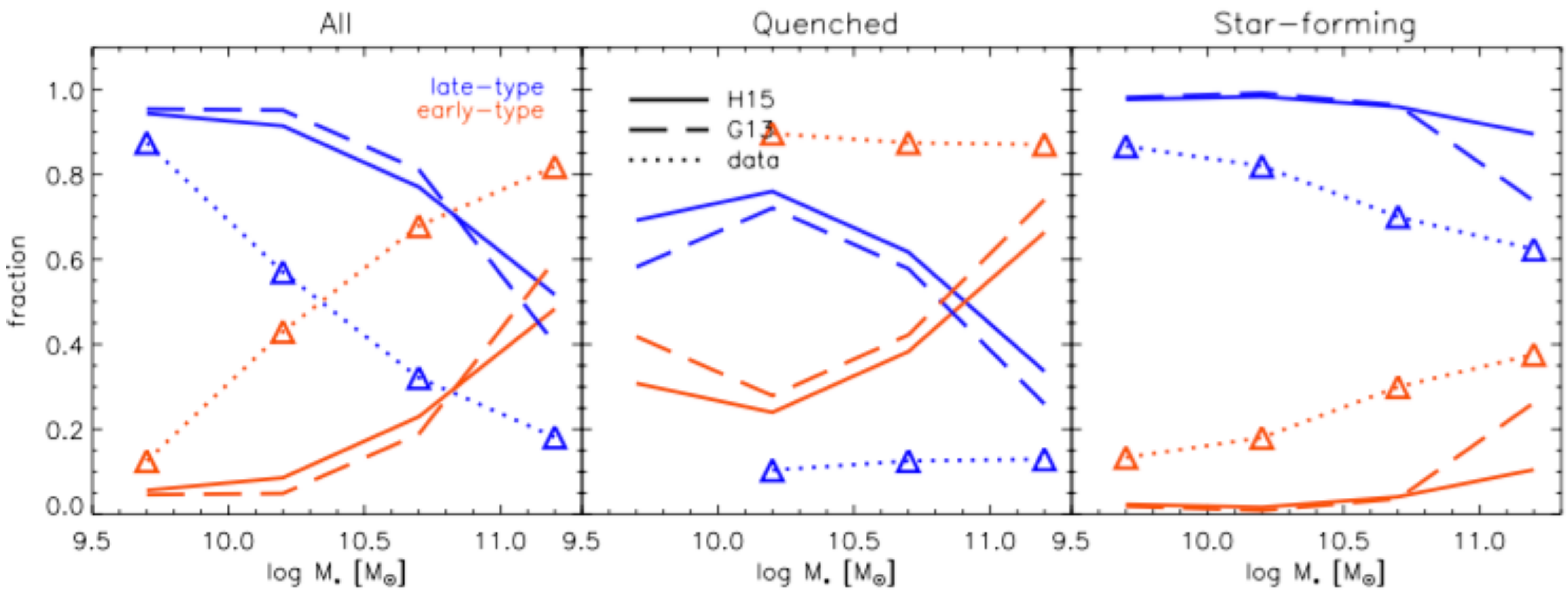


☆ Morphology of central galaxies (B/T or f_dev ~ 0.7)

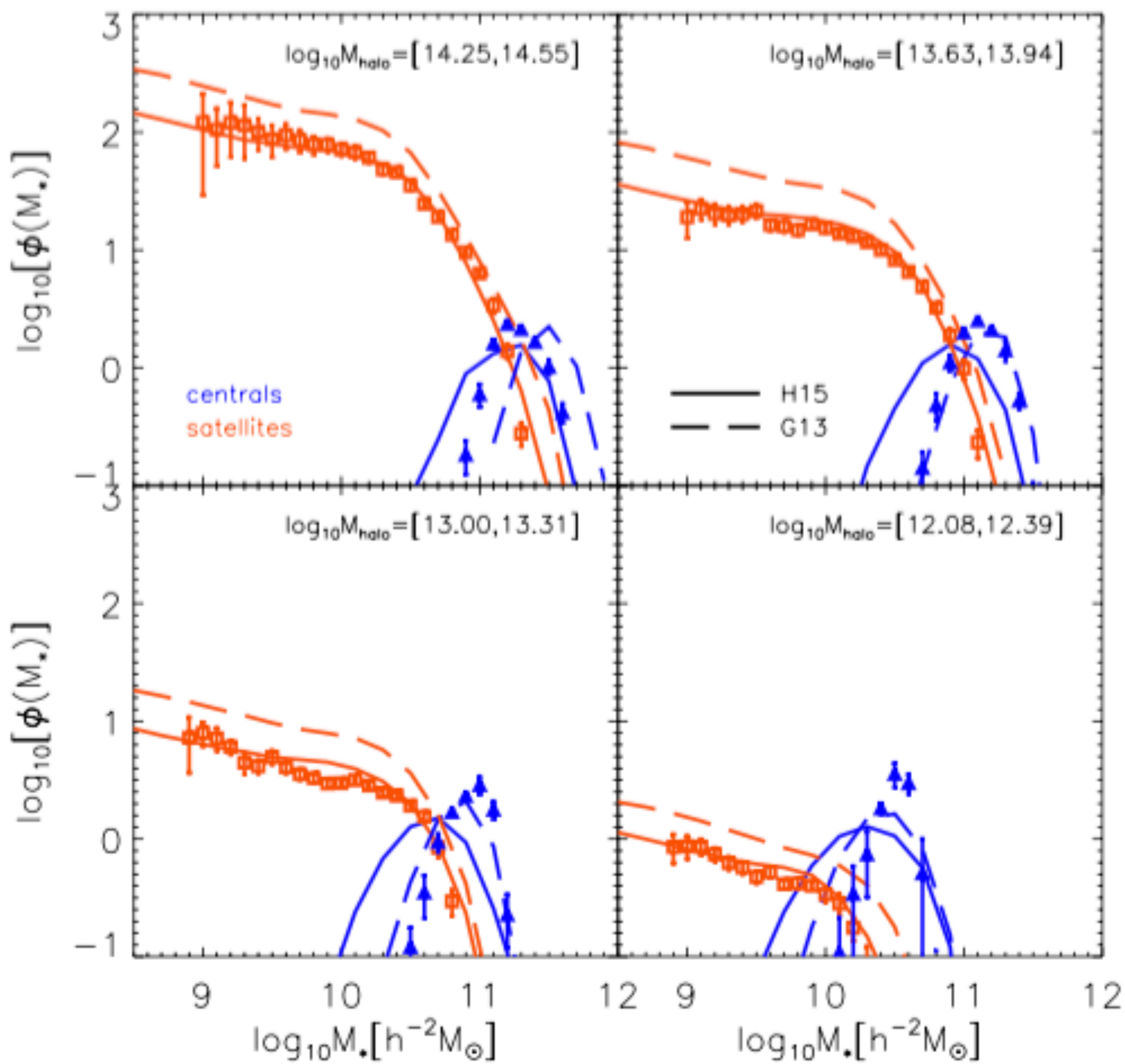
—Too *much* late type galaxies are quenched



☆ CSMF

—central galaxies

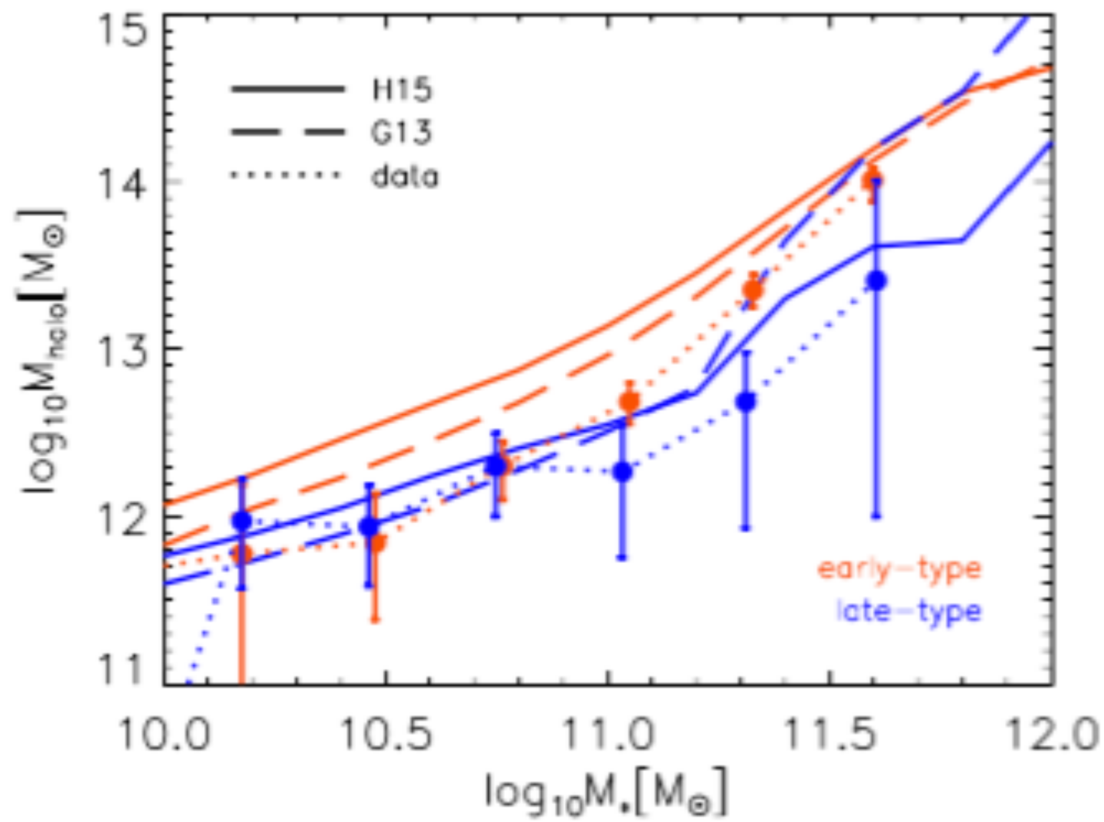
have lower stellar mass

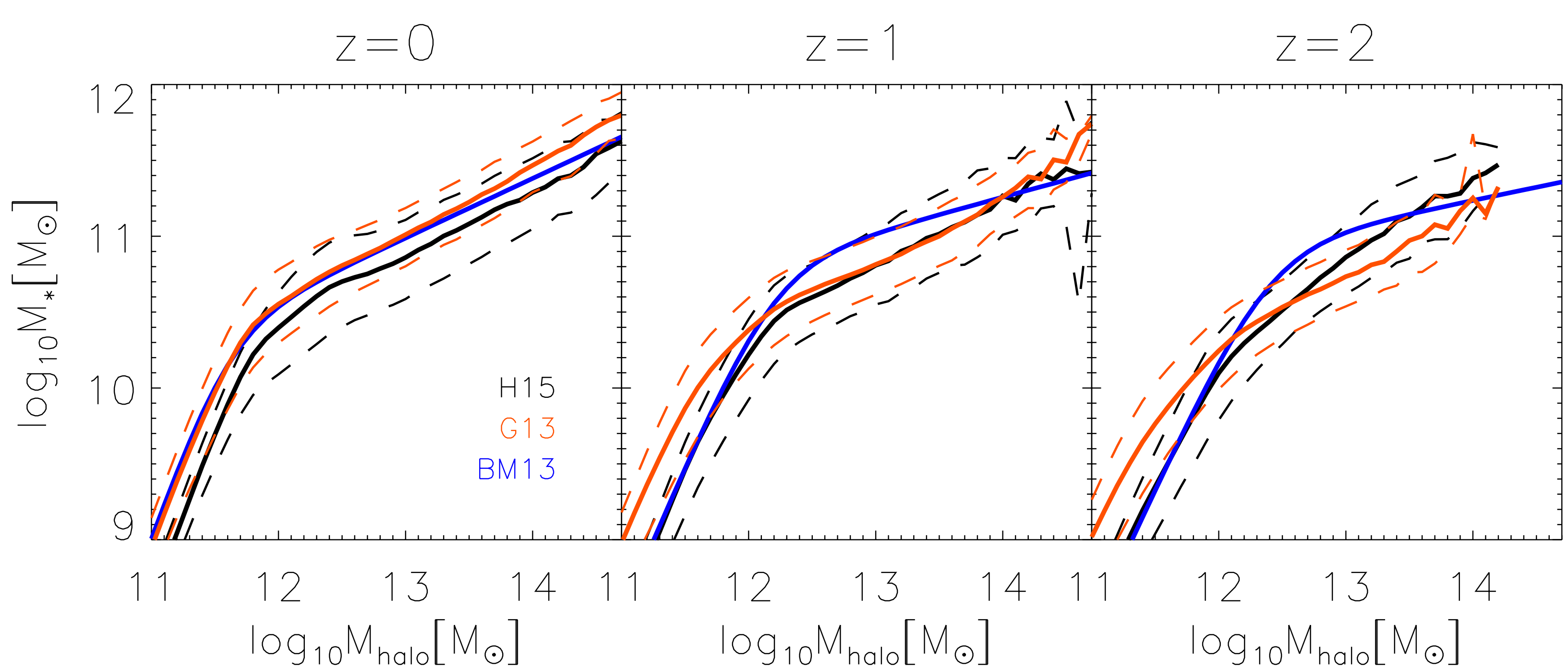


☆ SMHM relation

—central galaxies

growth insufficient





Summary 2

- H15 reproduced observed **red fraction** of **central** galaxies and **low mass satellites** . But ***failed*** at logM_*=[10,11] for ***satellites***.

- Too ***many late-type***, too ***few early-type central*** galaxies. Too ***many late-type*** galaxies ***quenched*** at logM_*=[10,11] in H15

- H15 has **better** SMF of satellites ***worse*** SMF of ***central*** galaxies

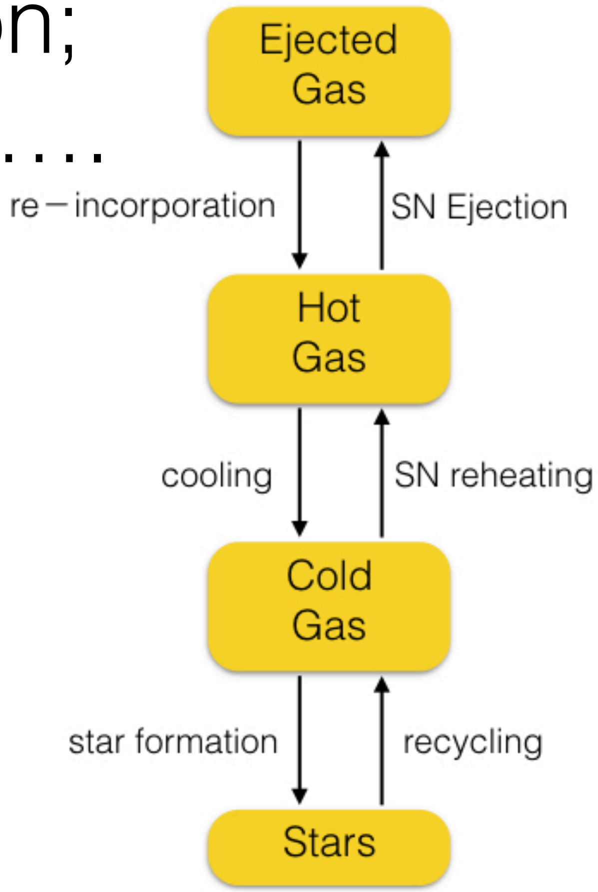
- ***Lower*** sm of ***central*** galaxies at fixed halo mass.

- Suggest to ***increase bugle growth***: disk instability and minor merger

Luo & Kang 2017

Future Work

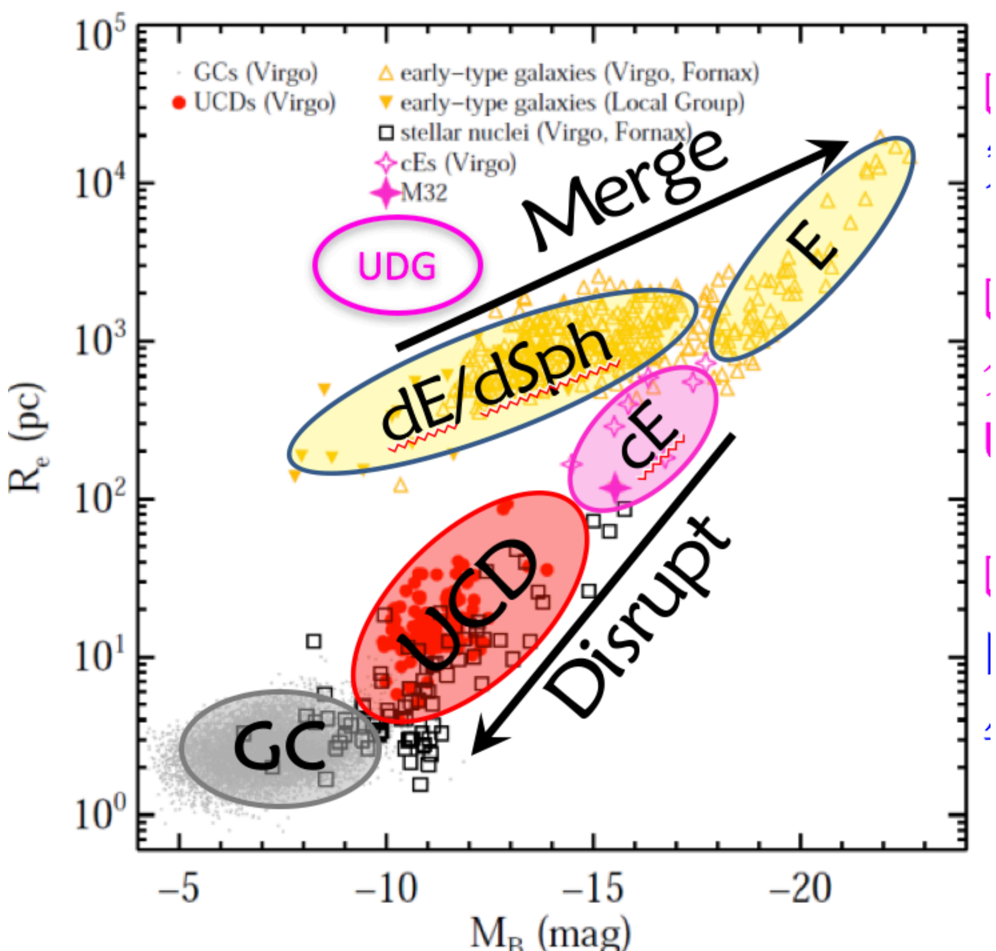
- To improve SAMs
  - ☆ increase bulge growth
  - ☆ more reliable gas cycle: hot gas distribution; gas cooling; AGN feedback; SN feedback….
  - ☆ combine Hydro-simulations



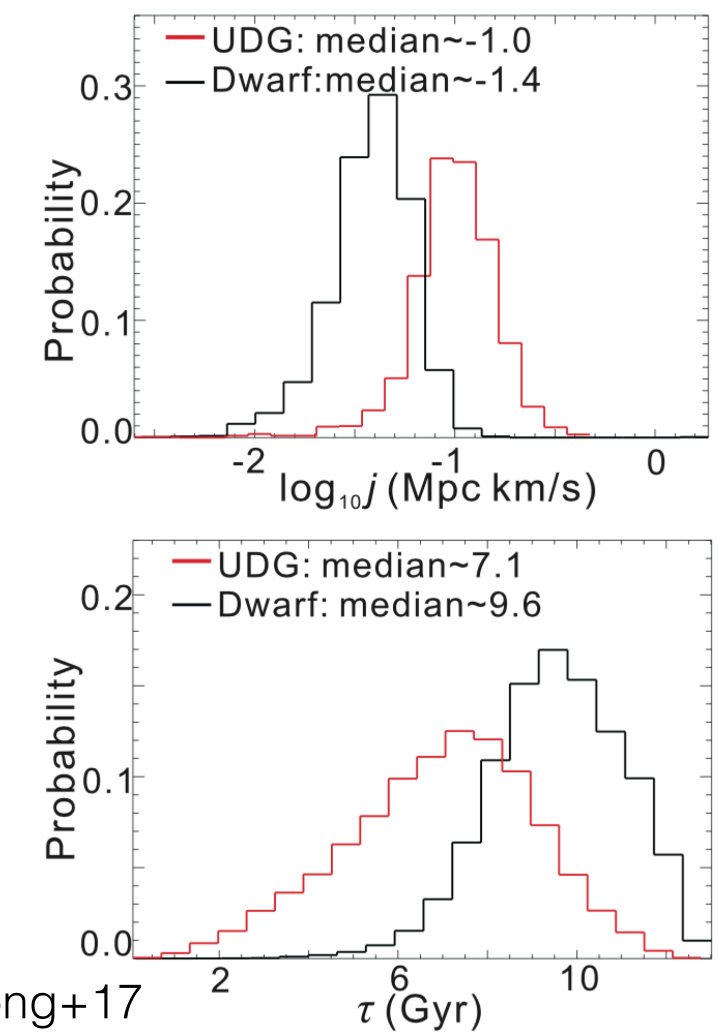
- Some work based on present SAMs

  ☆ Ultra Compact Dwarf: origin? stellar stripping? gas? DM?

  ☆ Ultra Diffuse Galaxies: origin? quenching?



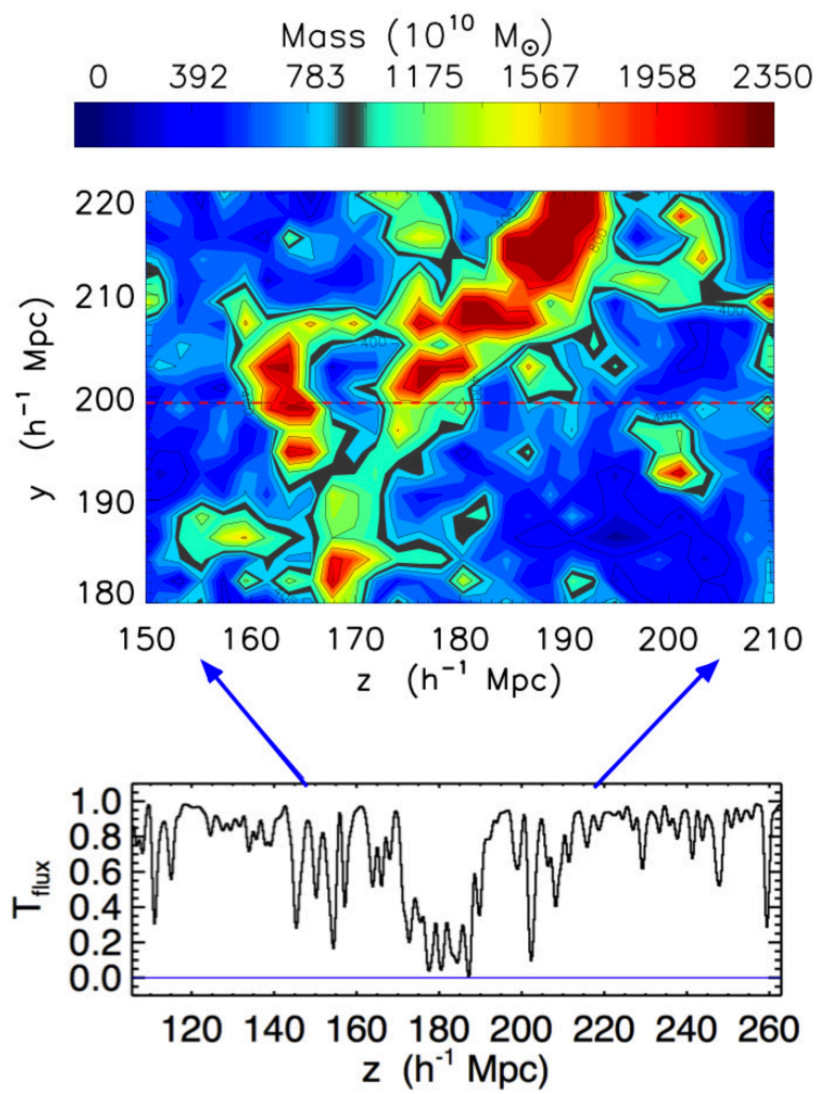
Liu+15

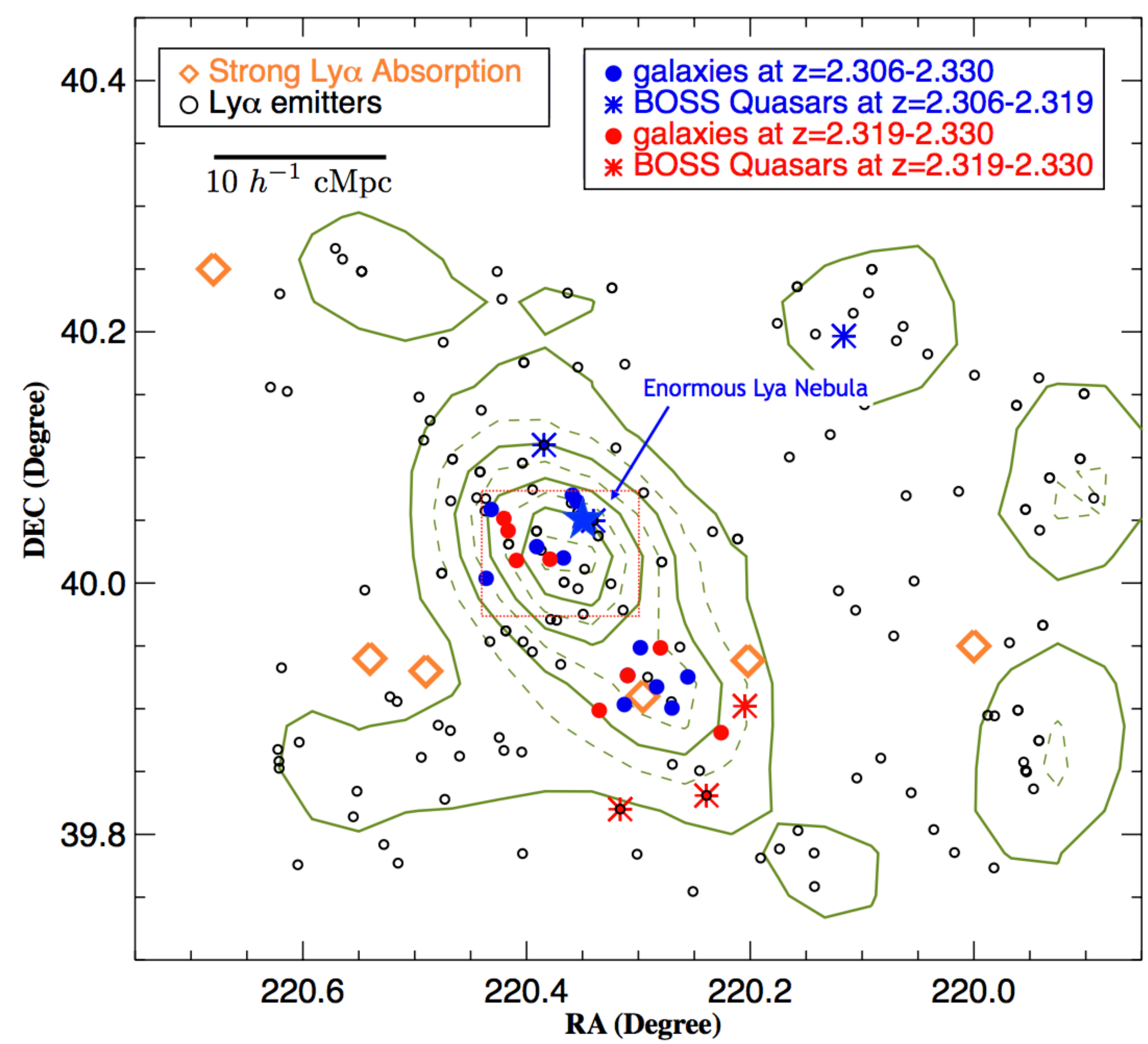


Rong+17

☆ Proto-clusters

- observation: find overdensity using like Coherently Strong intergalactic Lyα Absorption systems (Cai+16)
- SAM: whether and how it will be virialized

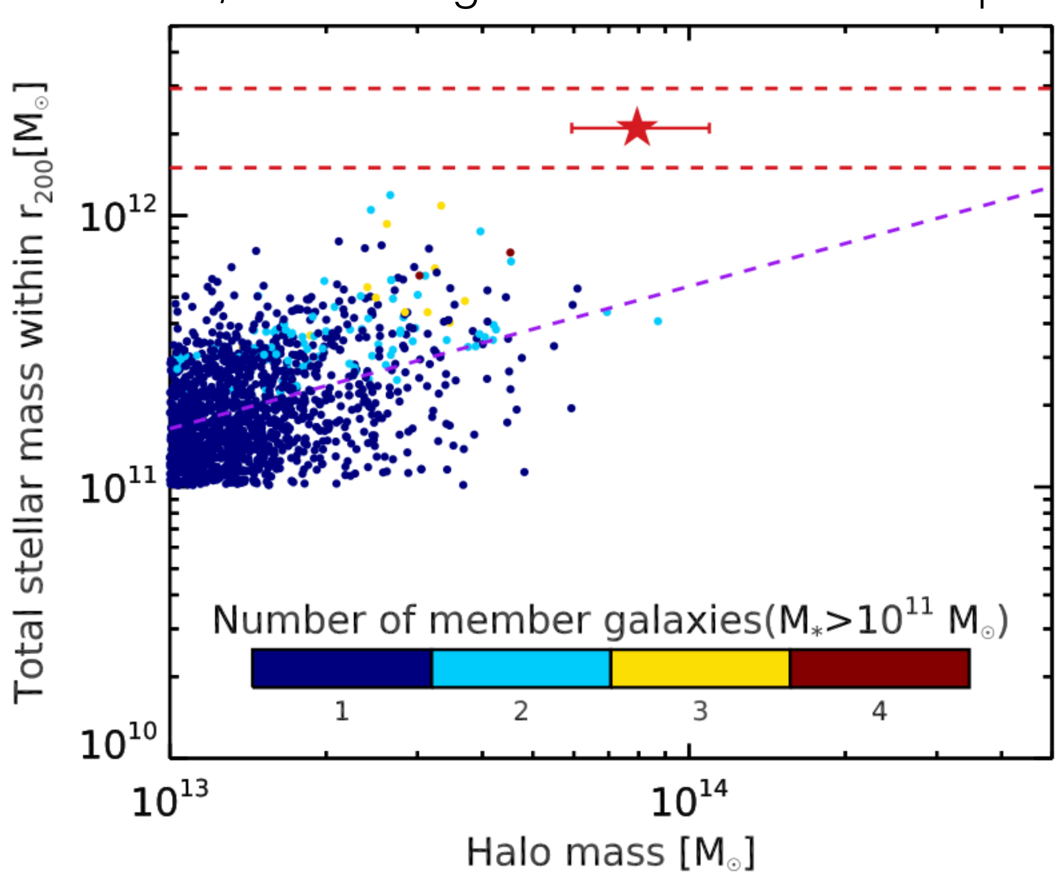




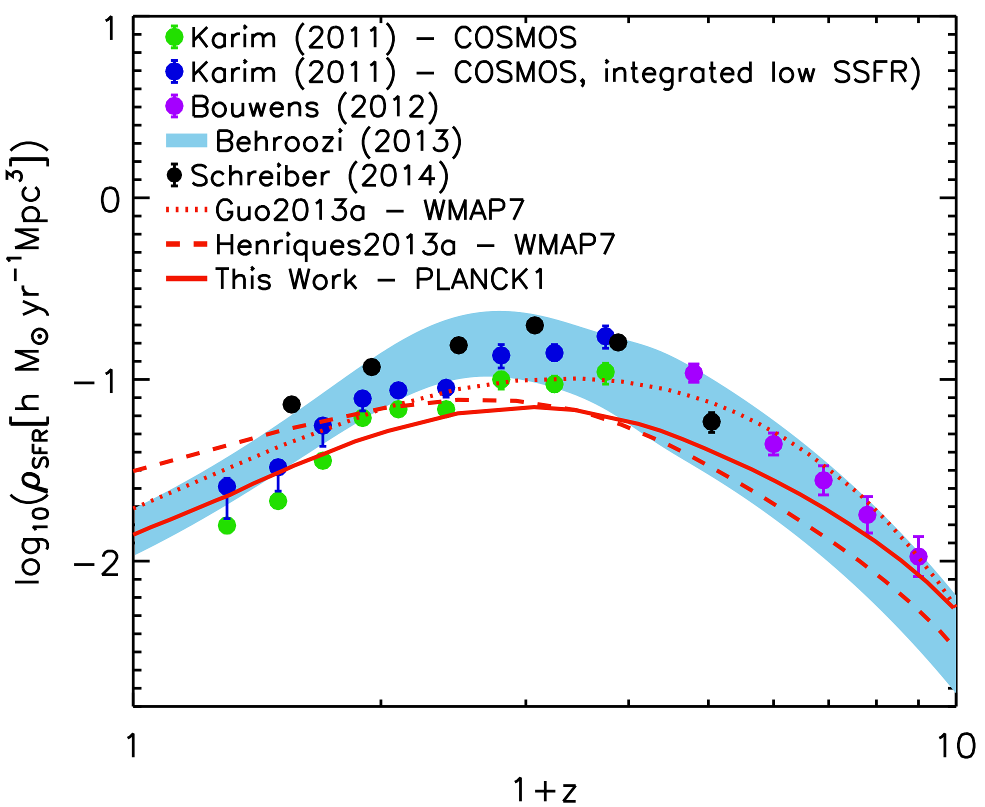
☆ Proto-clusters

- star formation in high redshift

9/11 are SF galaxies at z~2.5 in 80-kpc



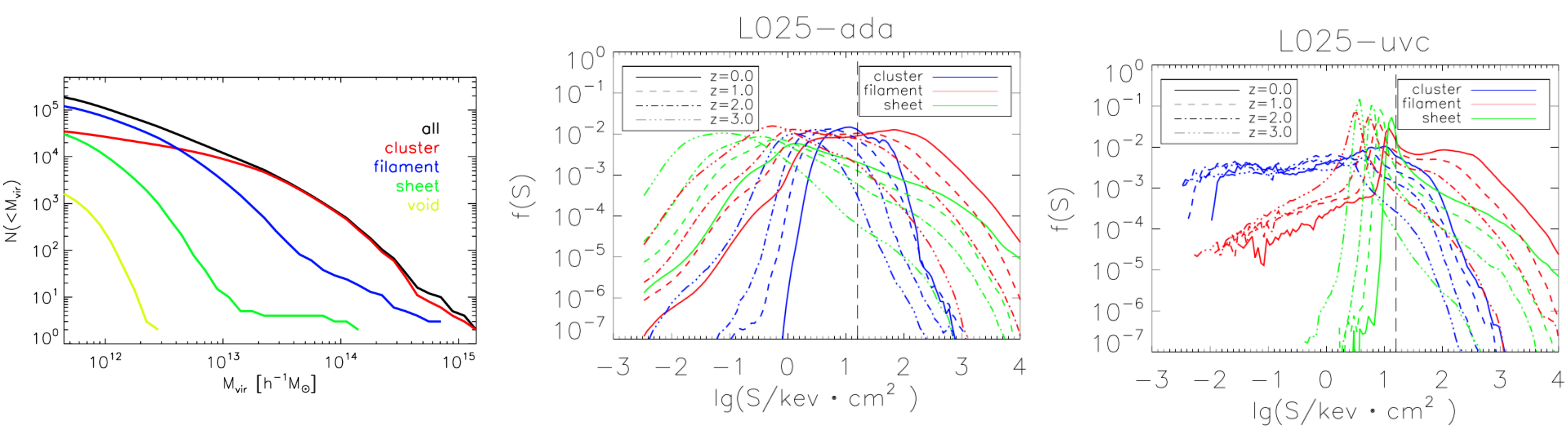
Wang et al. 2016



Henriques et al. 2015

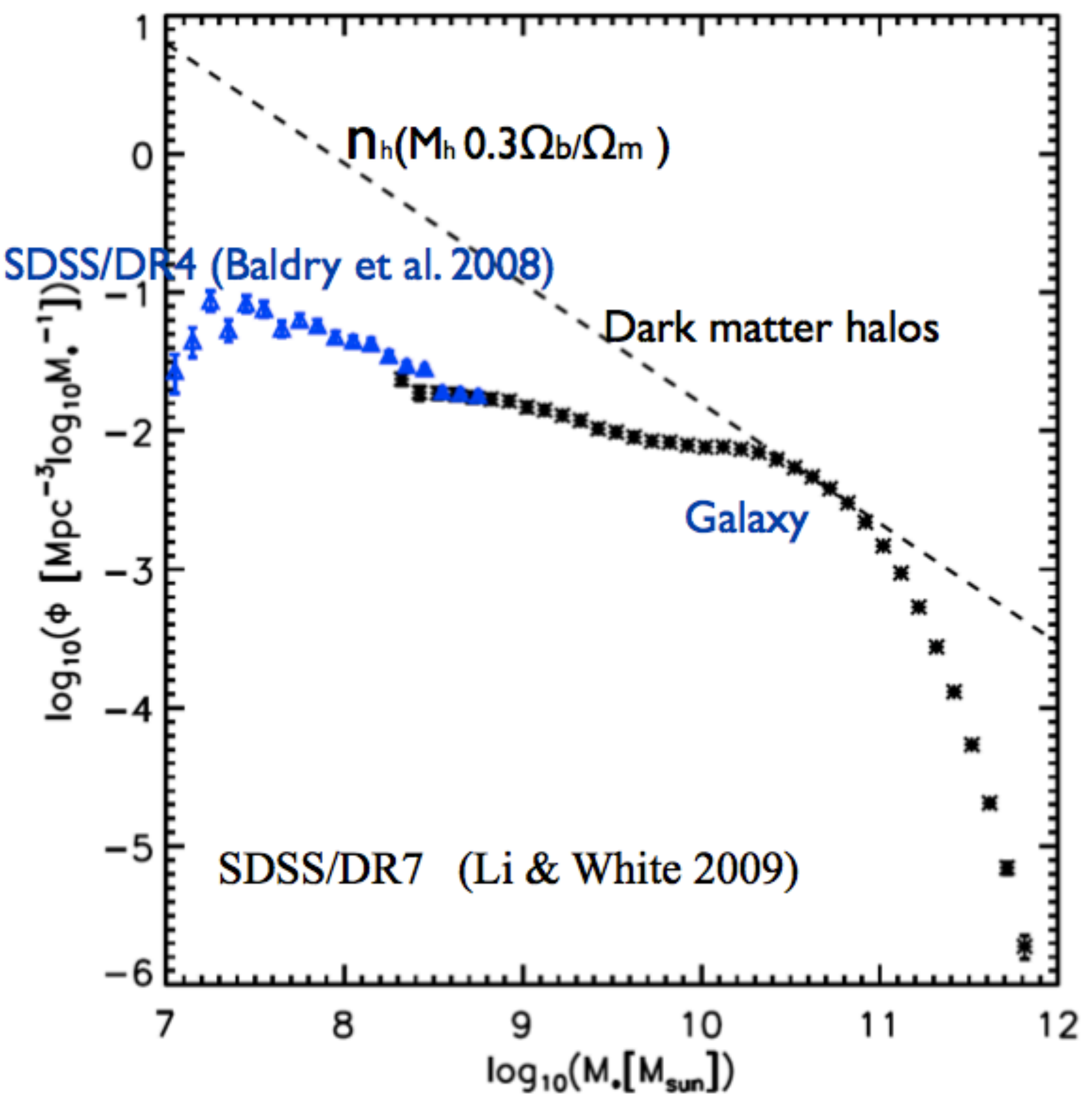
☆ Conformity on large scale structure

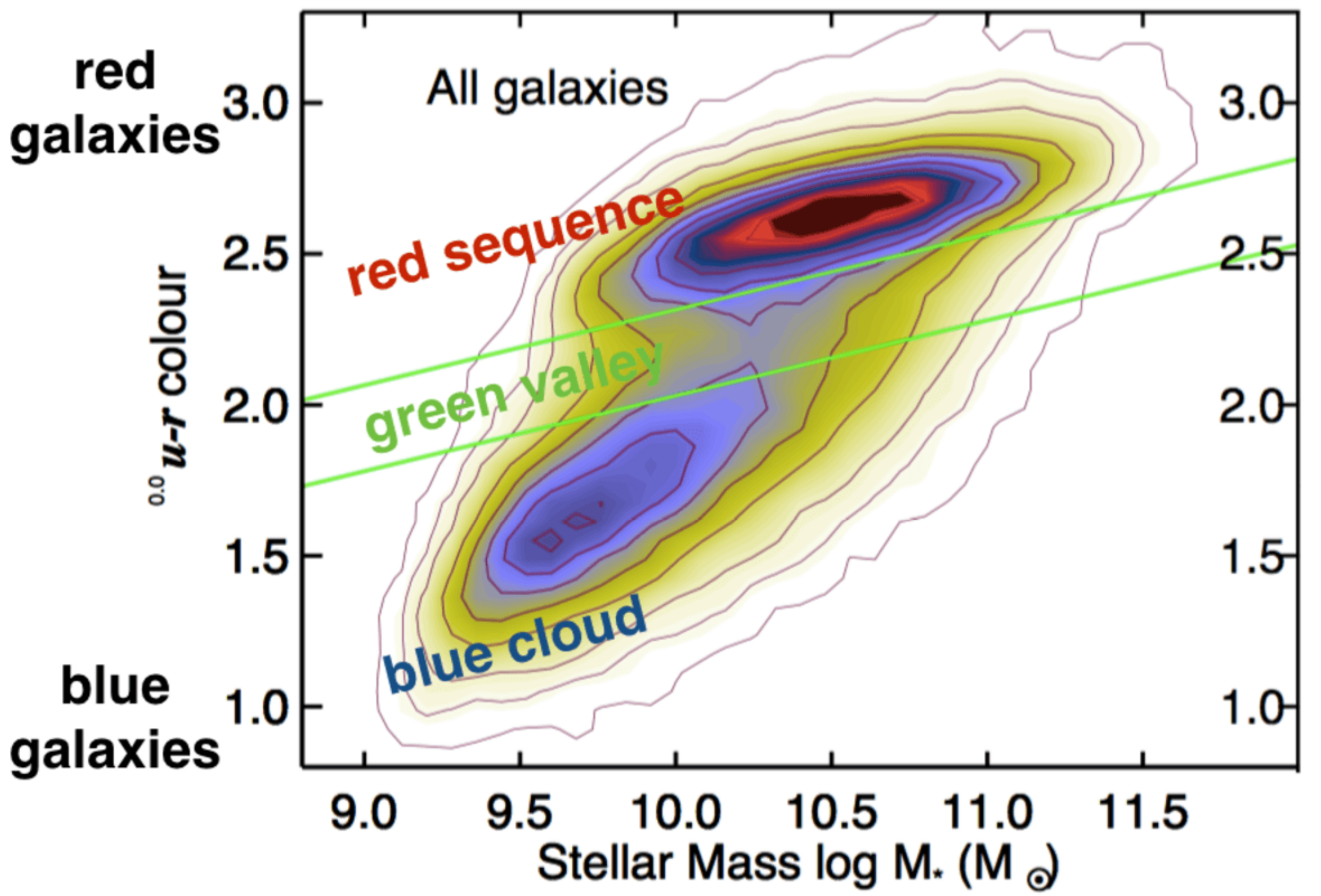
- ‘assembly bias’ or ‘pre-heating’ ?
- pre-heating source: feedback(Kauffmann 2015)? gravitational pancaking (Mo et al. 2005)? or …?
- test conformity on different LSS environments?



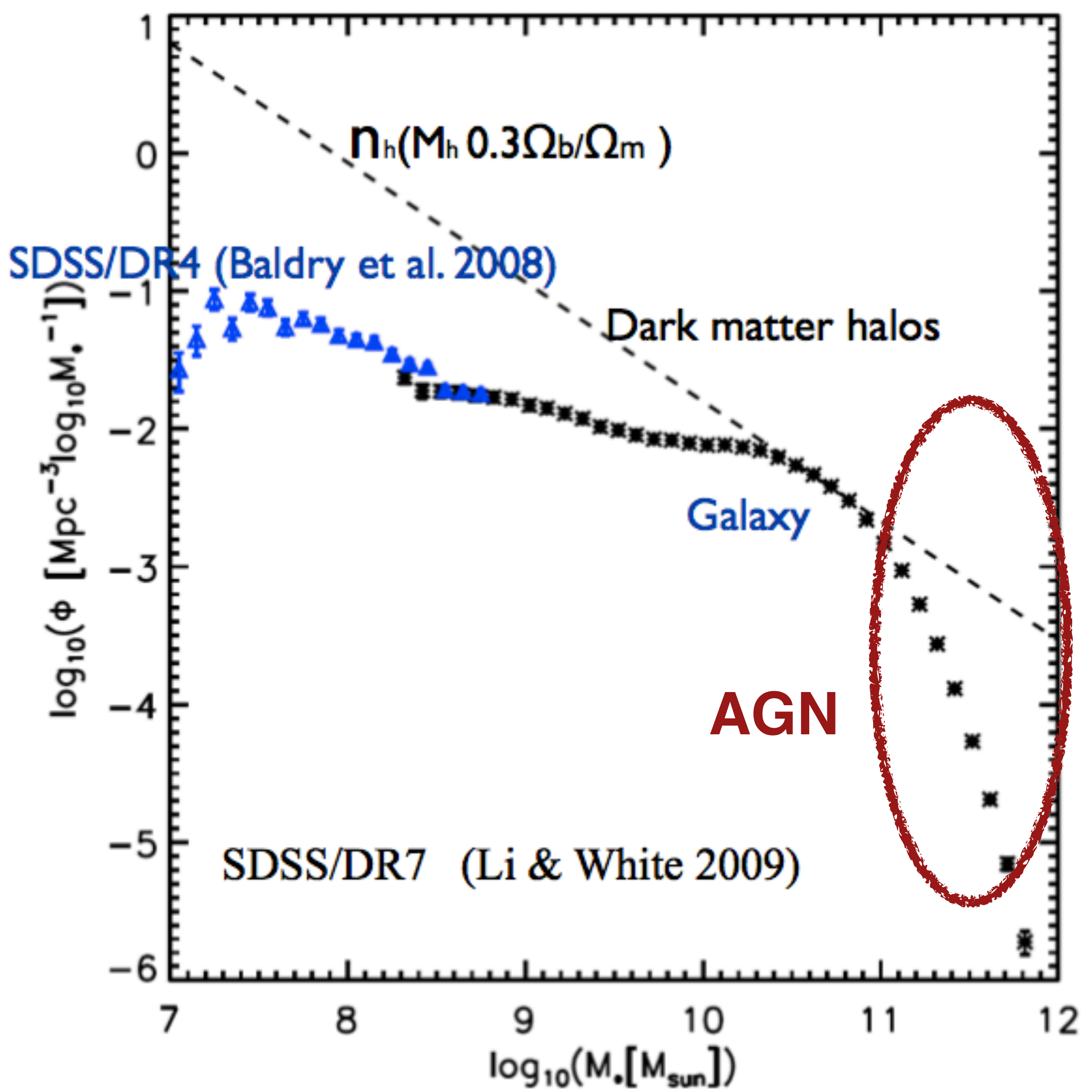
Zhu+2017

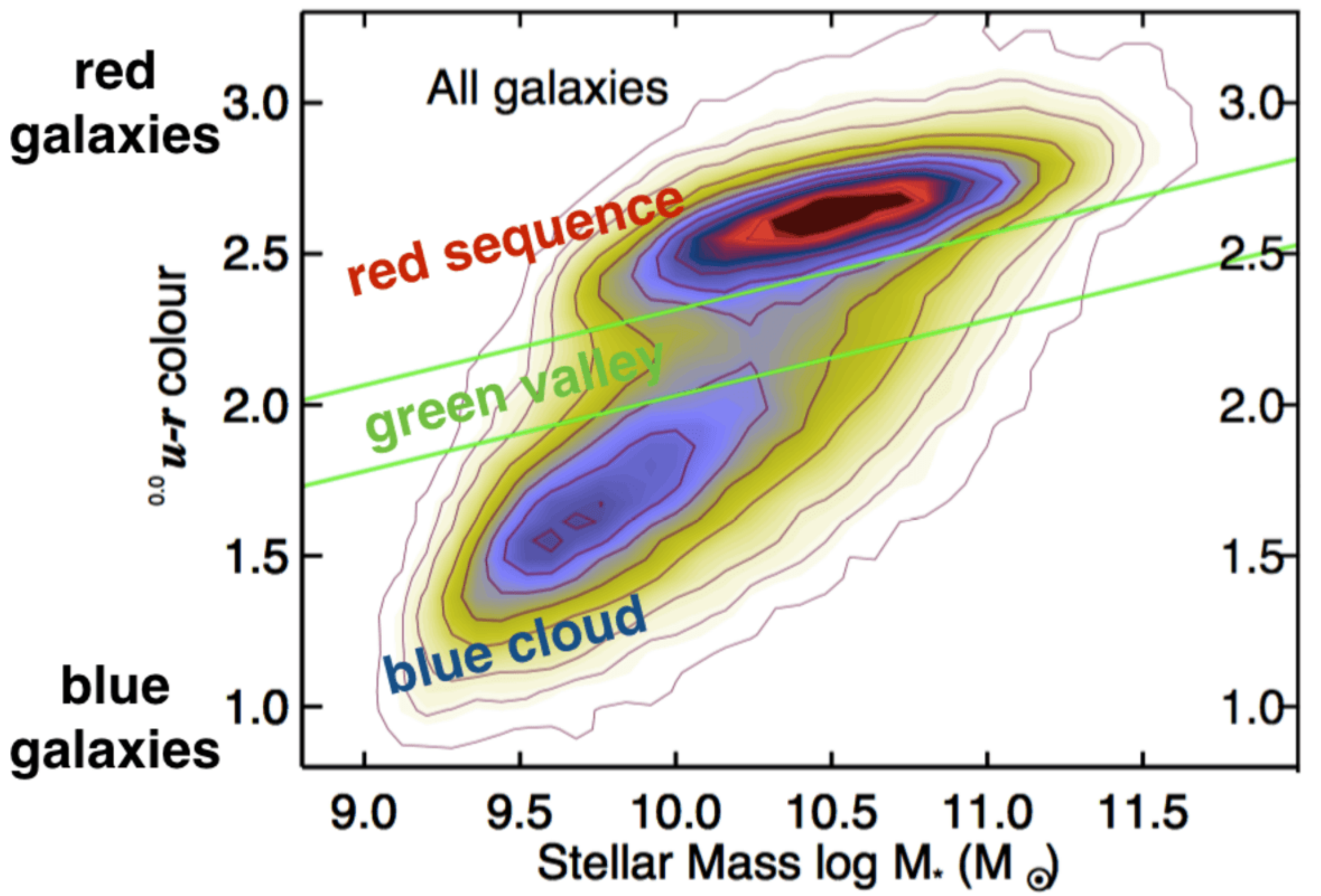
To improve our understanding of galaxy formation



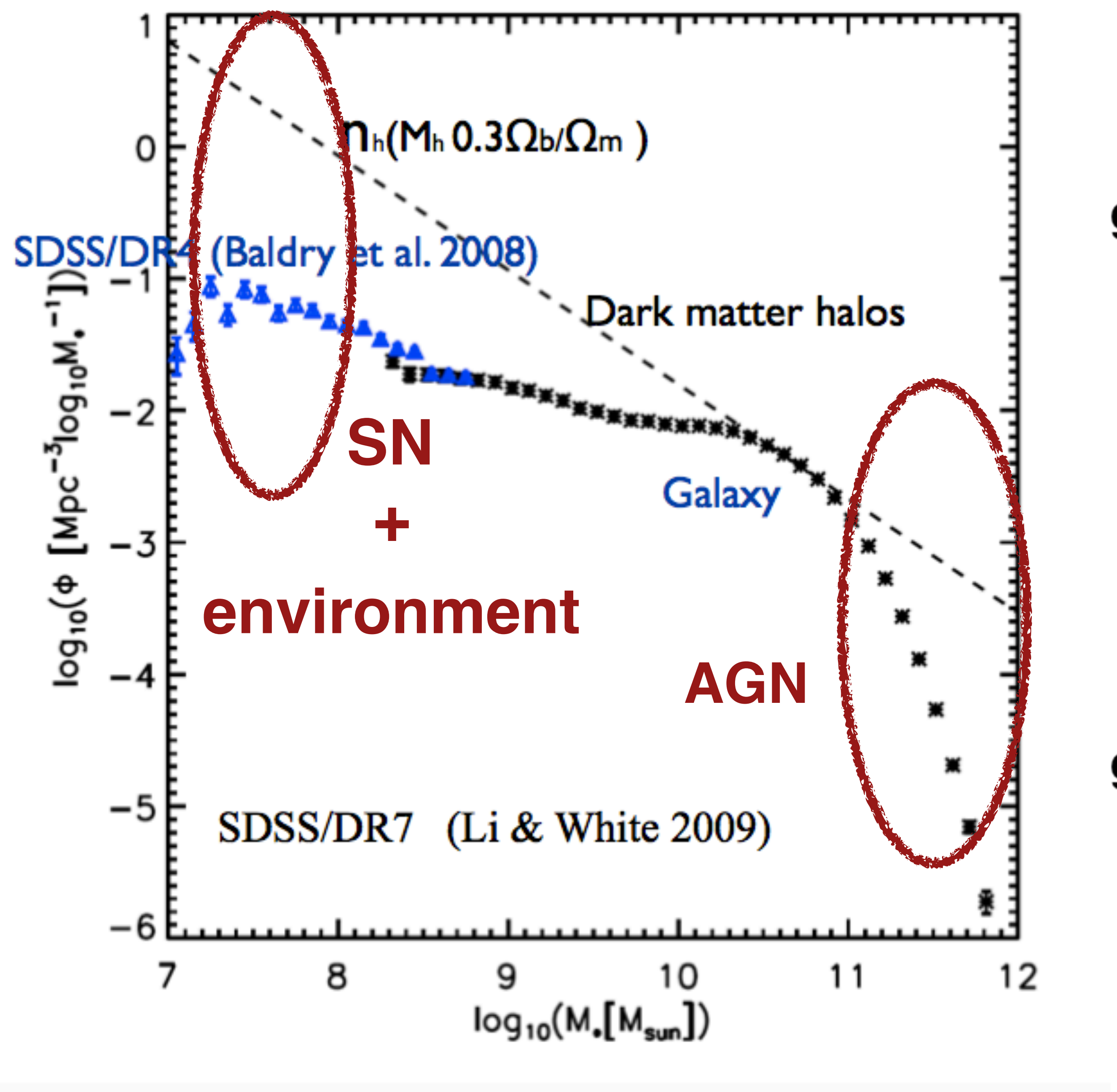


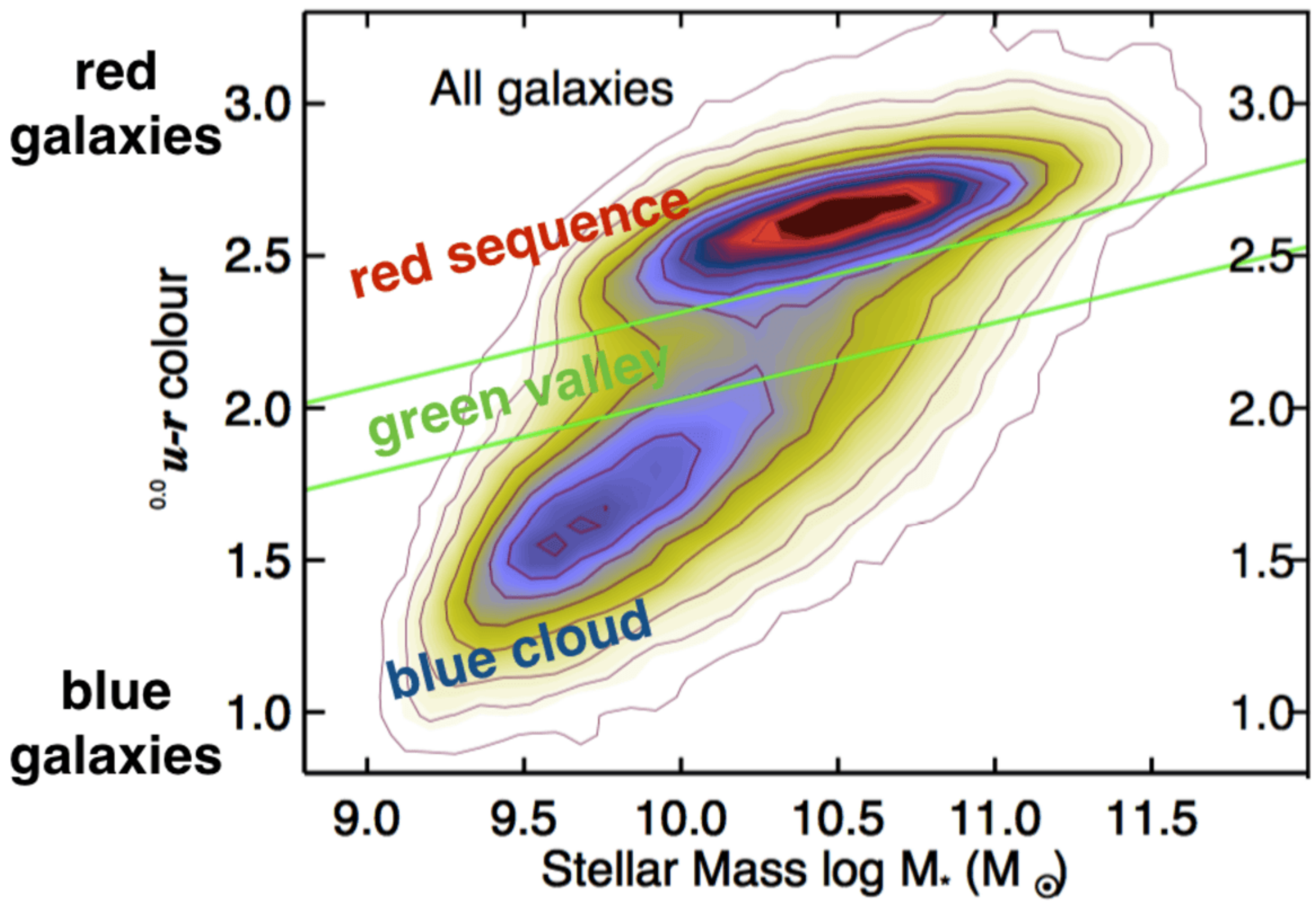
To improve our understanding of galaxy formation



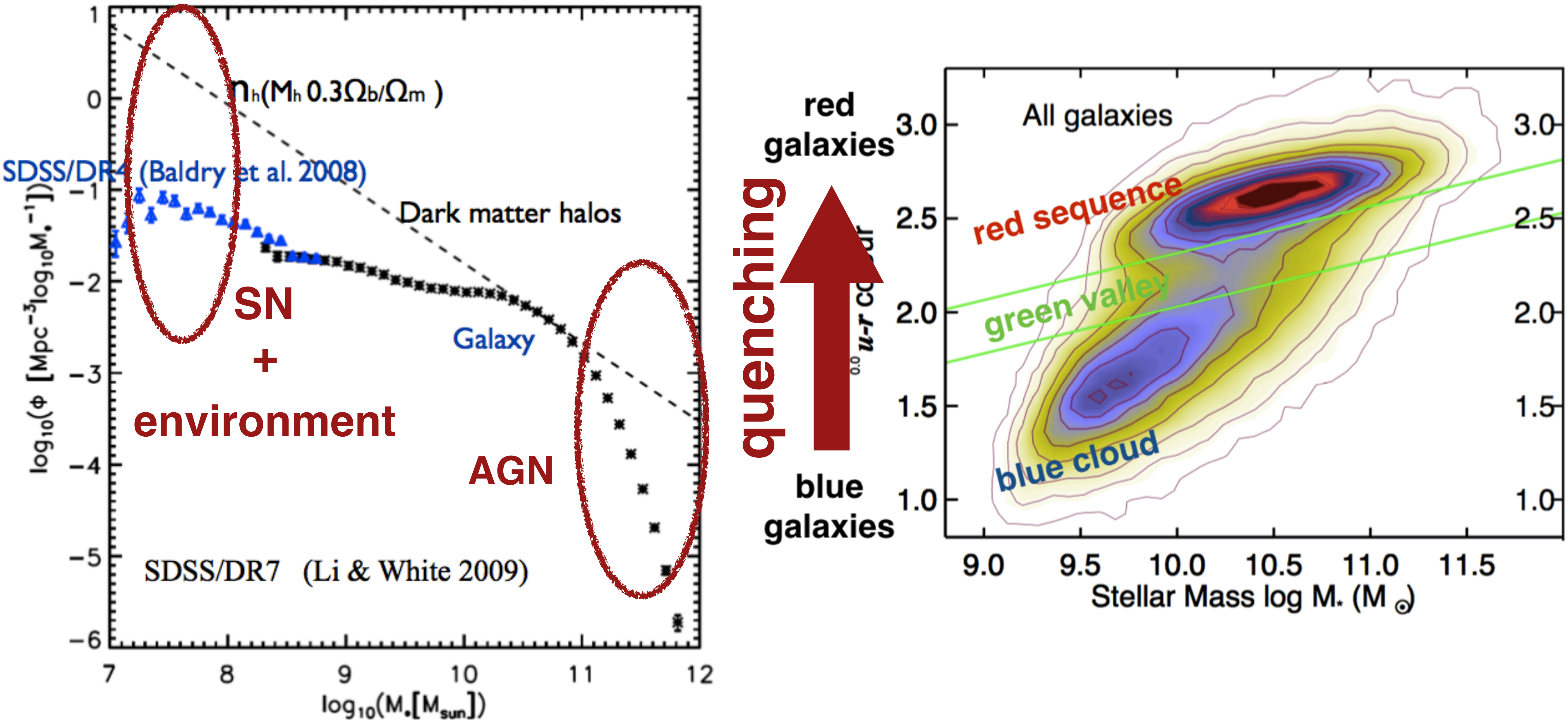


To improve our understanding of galaxy formation





To improve our understanding of galaxy formation



Thank You !