Do close pairs always merge? How long does it take? Calibrating observational estimates of the galaxy merger rate.

Simon White and Manfred Kitzbichler

The Issue

- We believe that galaxy mergers occur, inducing AGN and star-formation activity while transforming galaxy morphology

- How can we estimate the *rate* of such mergers observationally?

The Idea

- All mergers must appear as close pairs of galaxies shortly before they merge

$$\longrightarrow \quad \dot{n}_{merge} = n_{close\_pair} \times F_{merge} \, / \, T_{merge}$$

The Problem

- How do we estimate $F_{merge}(z)$ and $T_{merge}(z)$?

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  (i) on the morphology of the interacting systems (E, S, Irr...);
  (ii) on the viewing angle;
  (iii) on the time when the interaction is seen;
  (iv) on the redshift of the system; and
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...AND SO...

- Since the abundance of morphologically detected interacting systems depends on all these highly uncertain factors, so also must the effective values of $F_{merge}(z)$ and $T_{merge}(z)$.

Our Solution

- Use the Millennium Simulation to create virtual samples of close pairs directly analogous to real observed surveys

- Measure $\dot{n}_{merge}(z)$ and $n_{close\_pair}(z)$ in the mock survey

- Use these to estimate $F_{merge}(z)$ and $T_{merge}(z)$

- Do not require any morphological signatures of interaction in either the simulated or the observed catalogues

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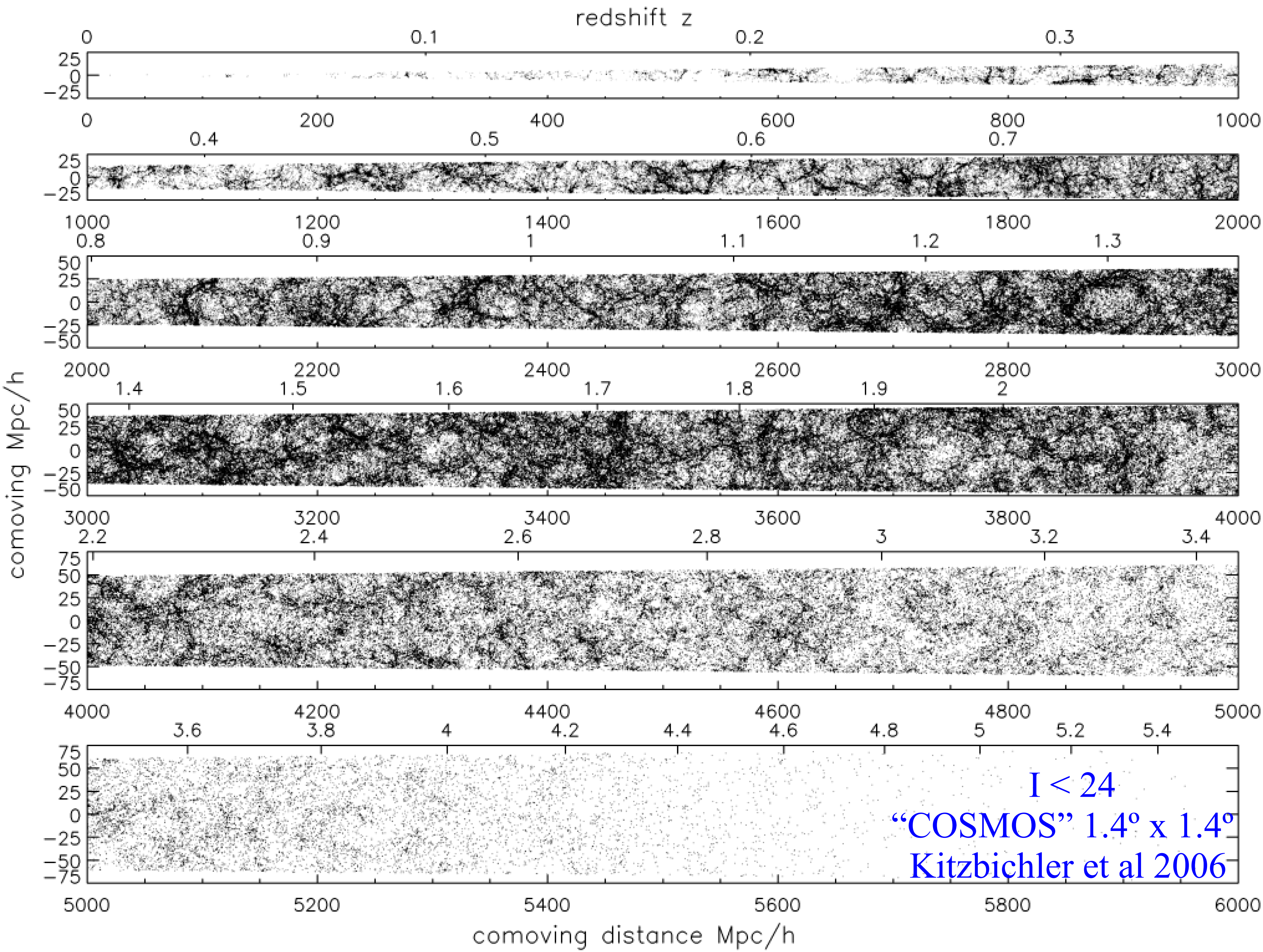
Caveat

- Dynamical evolution in the Millennium Simulation must be realistic on the relevant scales (30 to 50 kpc).


redshift z
comoving Mpc/h
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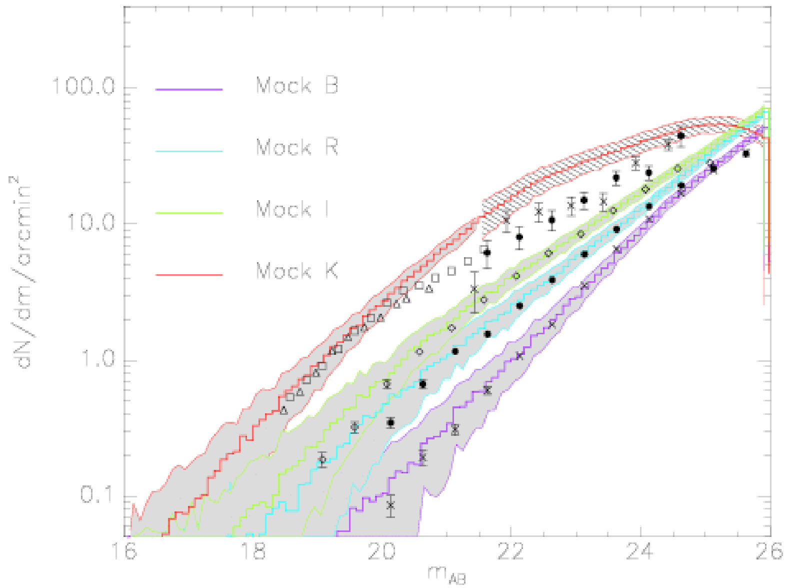
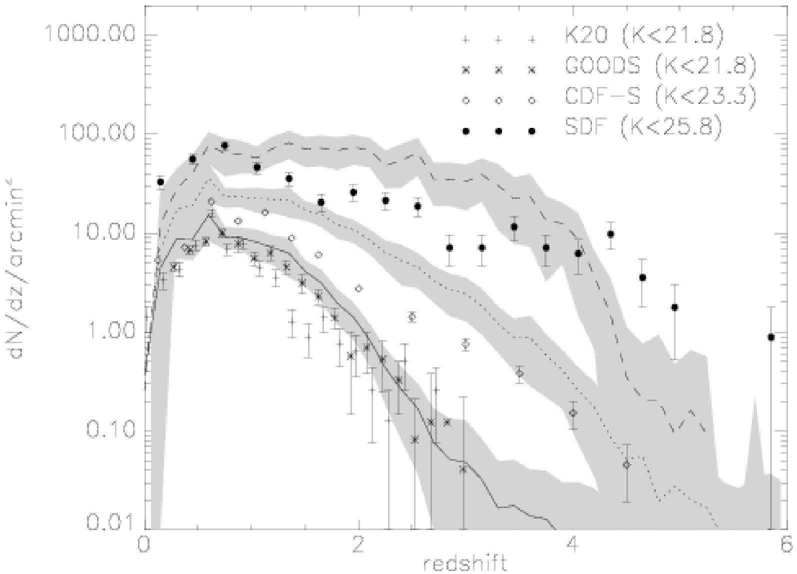
"COSMOS" 1.4º x 1.4º
Kitzbichler et al 2006

Does the MS produce the right number of faint galaxies?



Counts agree in the optical but not in the K-band



Redshift distributions are approximately OK but numbers high at all z

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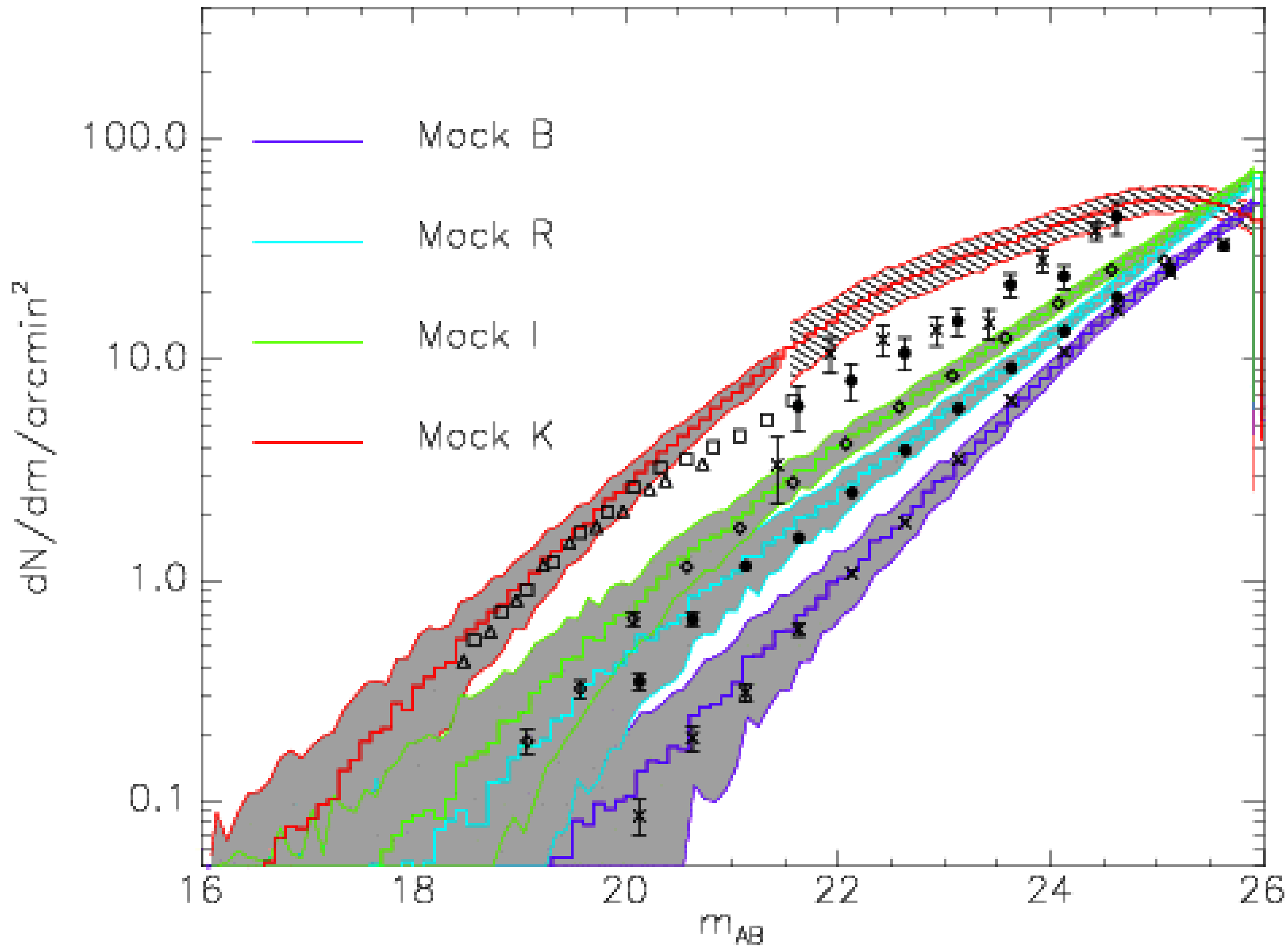

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Too many faint red galaxies → galaxy formation too early?

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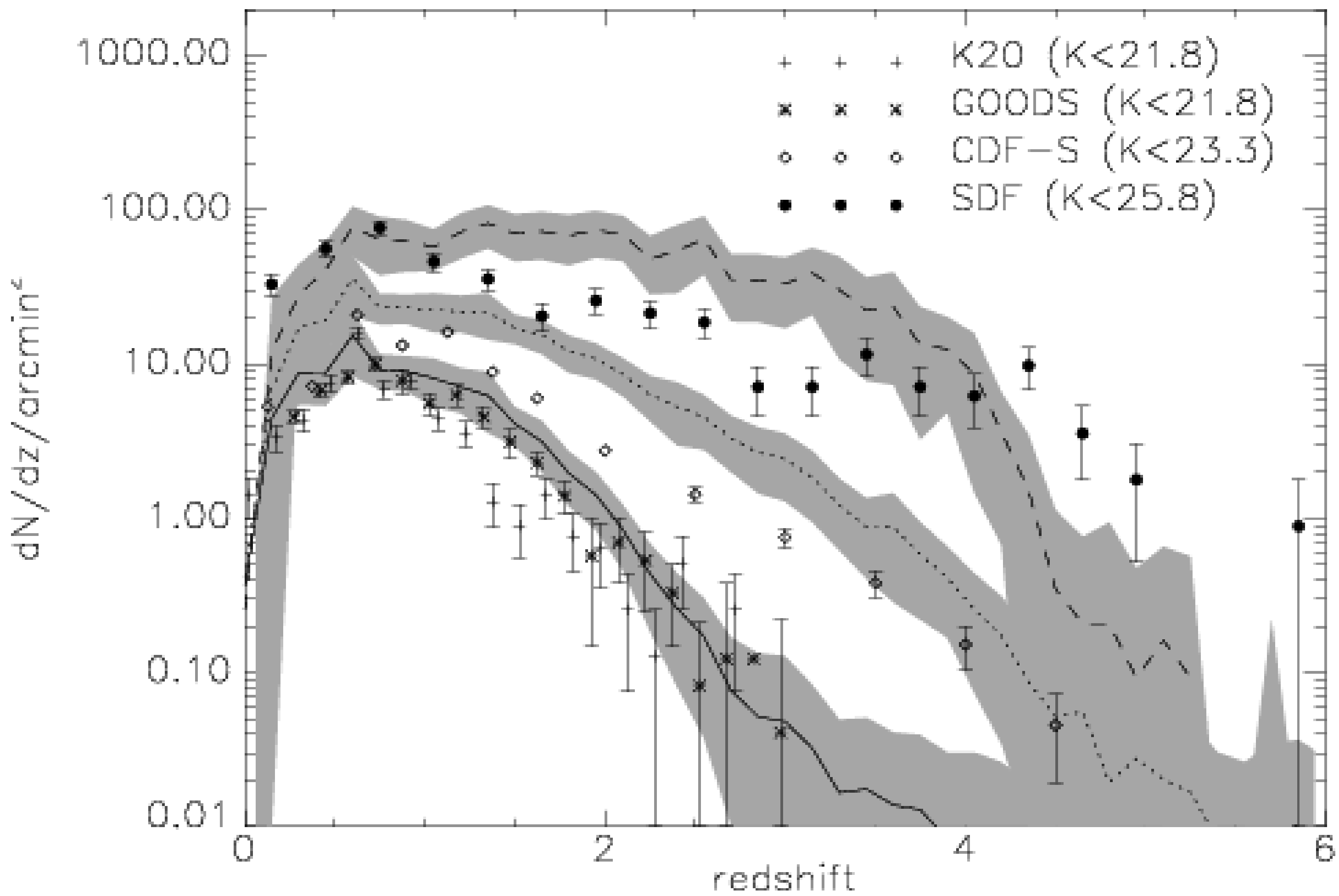

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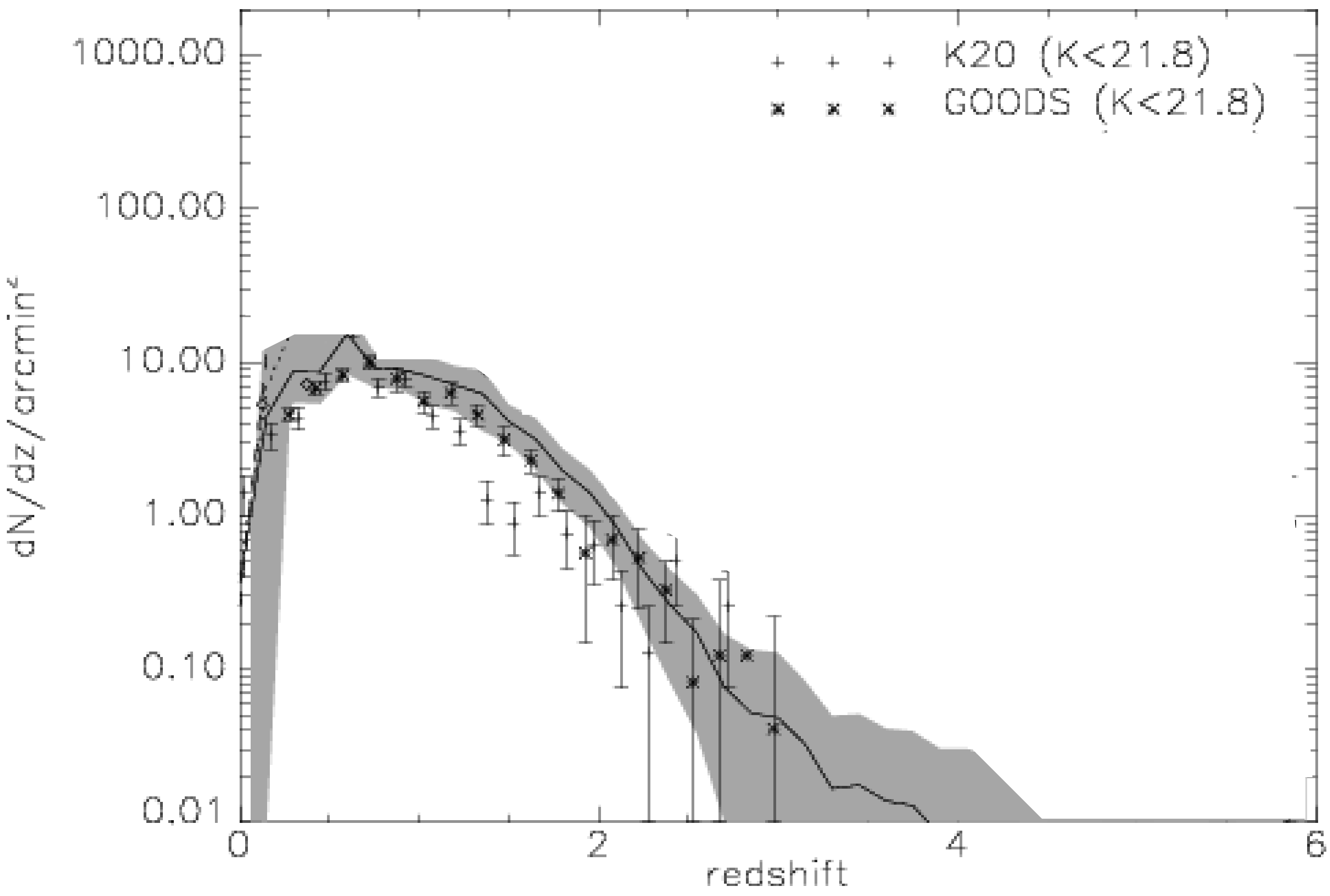

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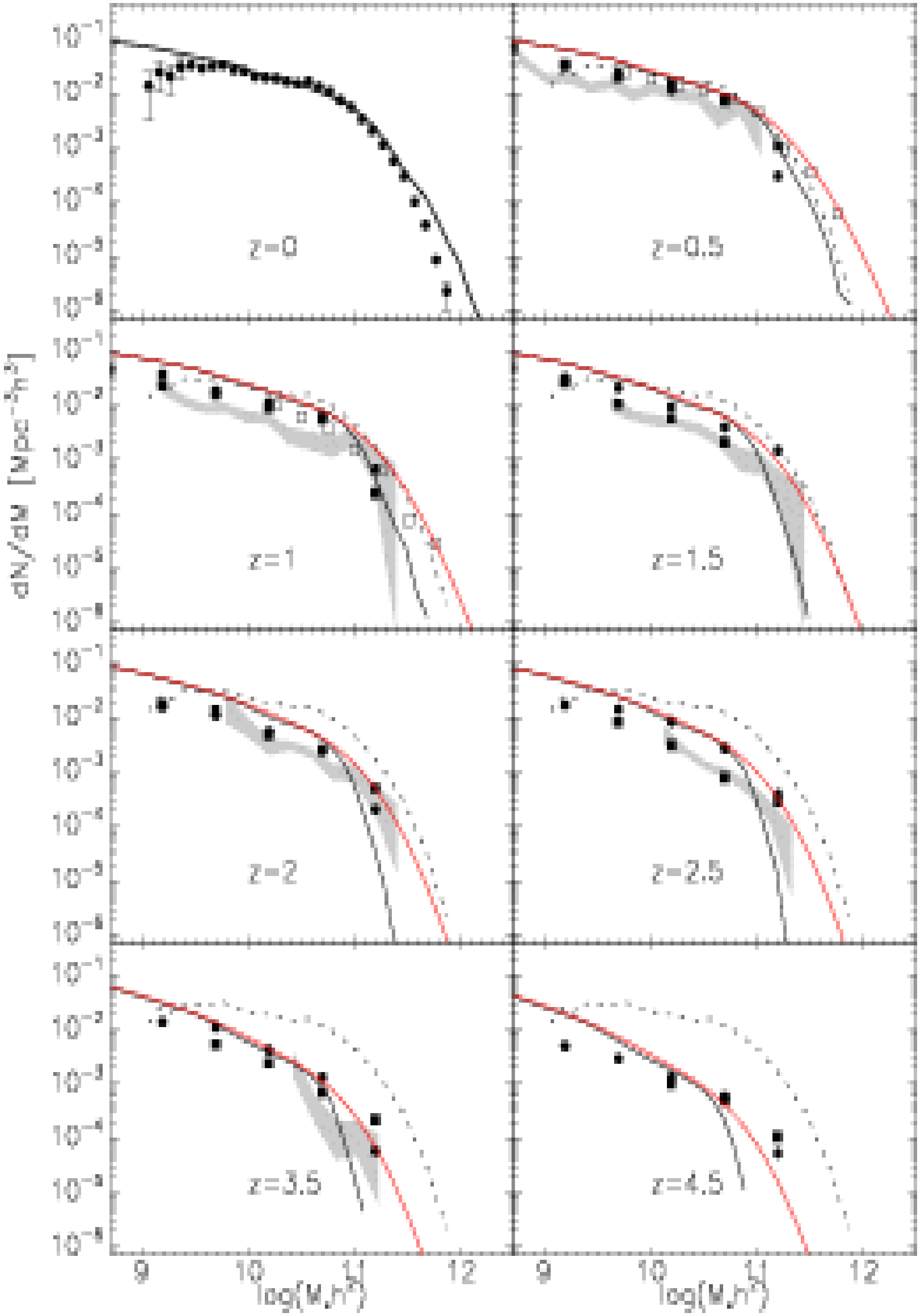

Evolution of the mass function of galaxies in the MS compared to observation

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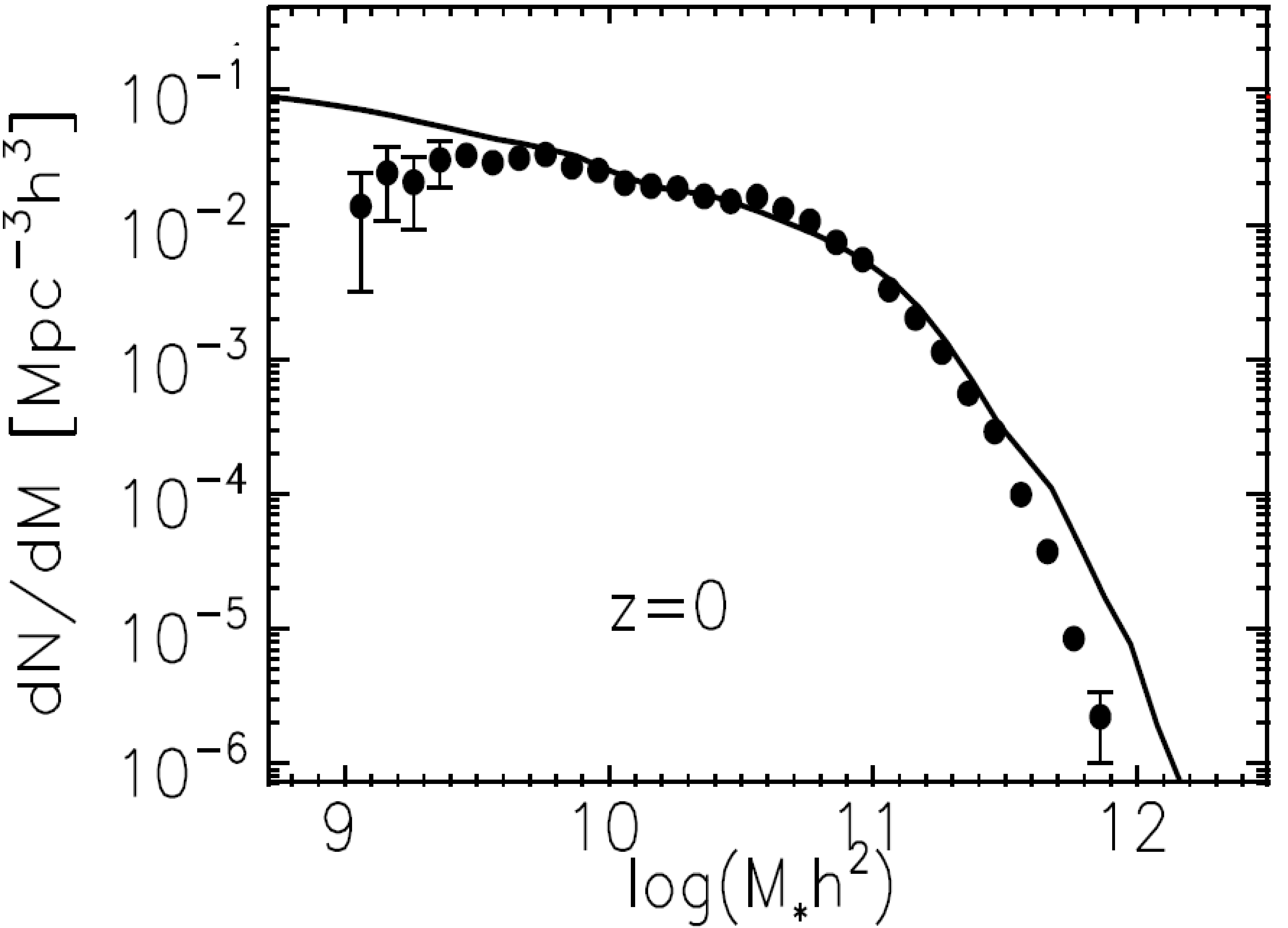

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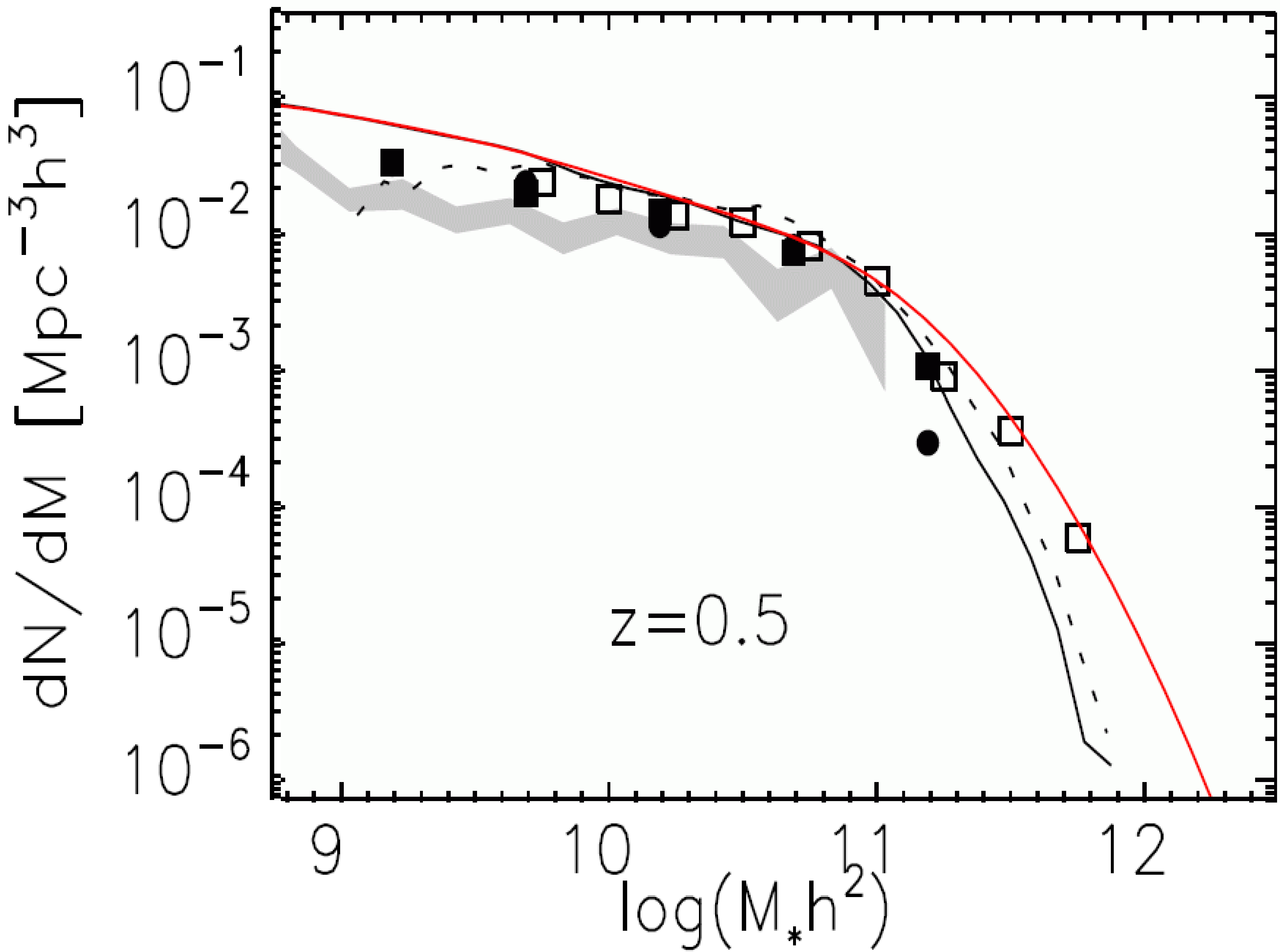

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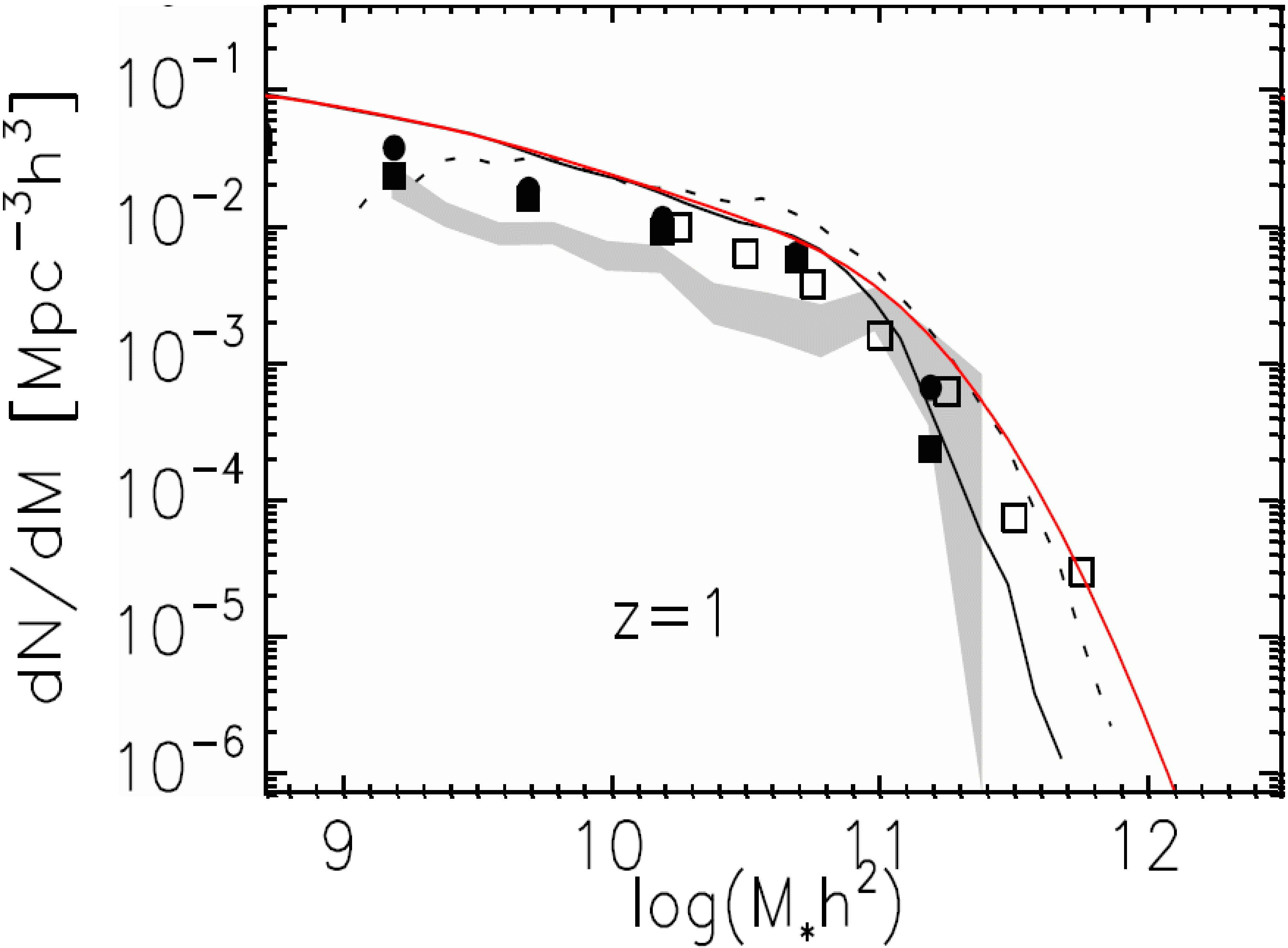

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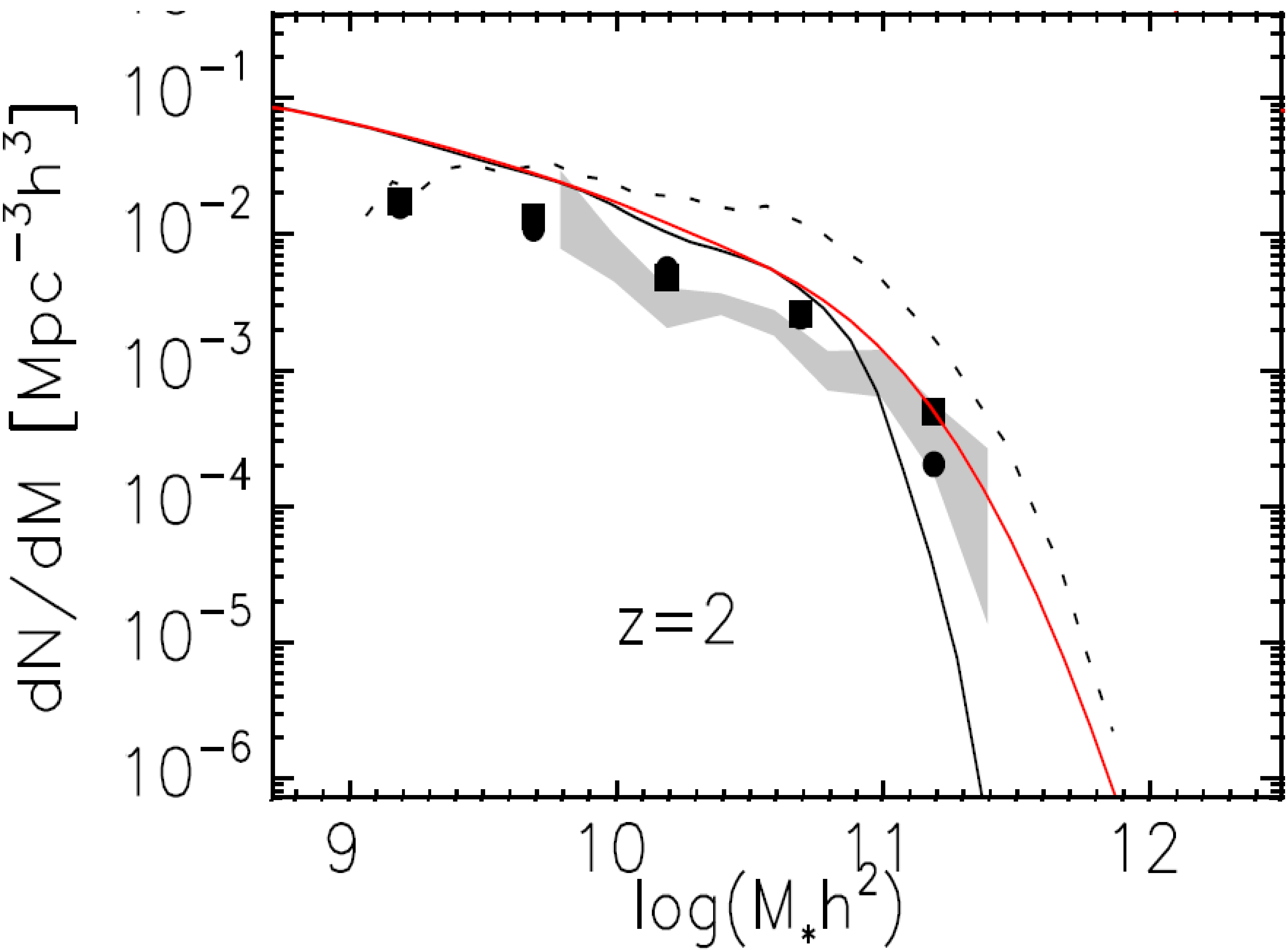

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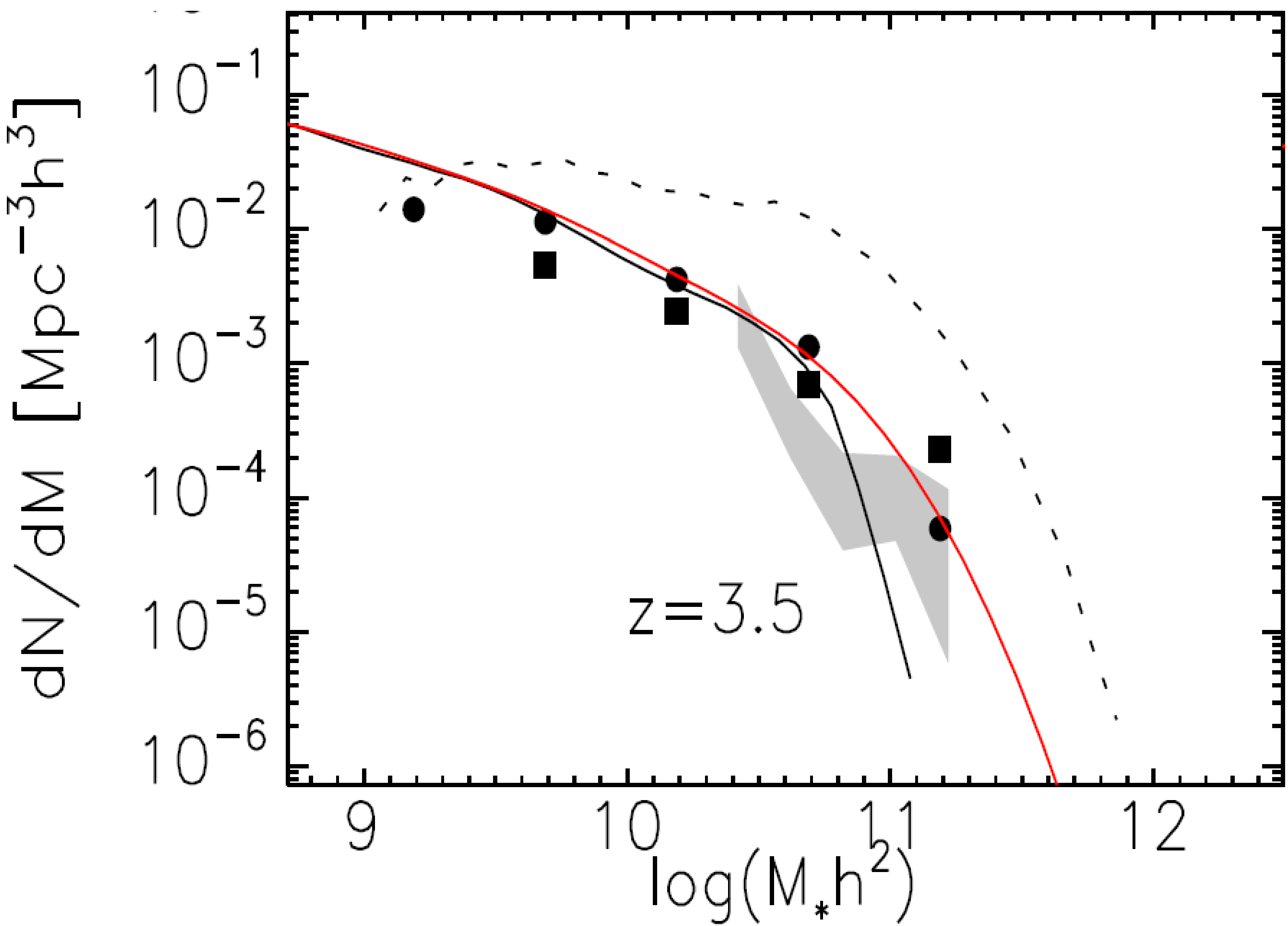
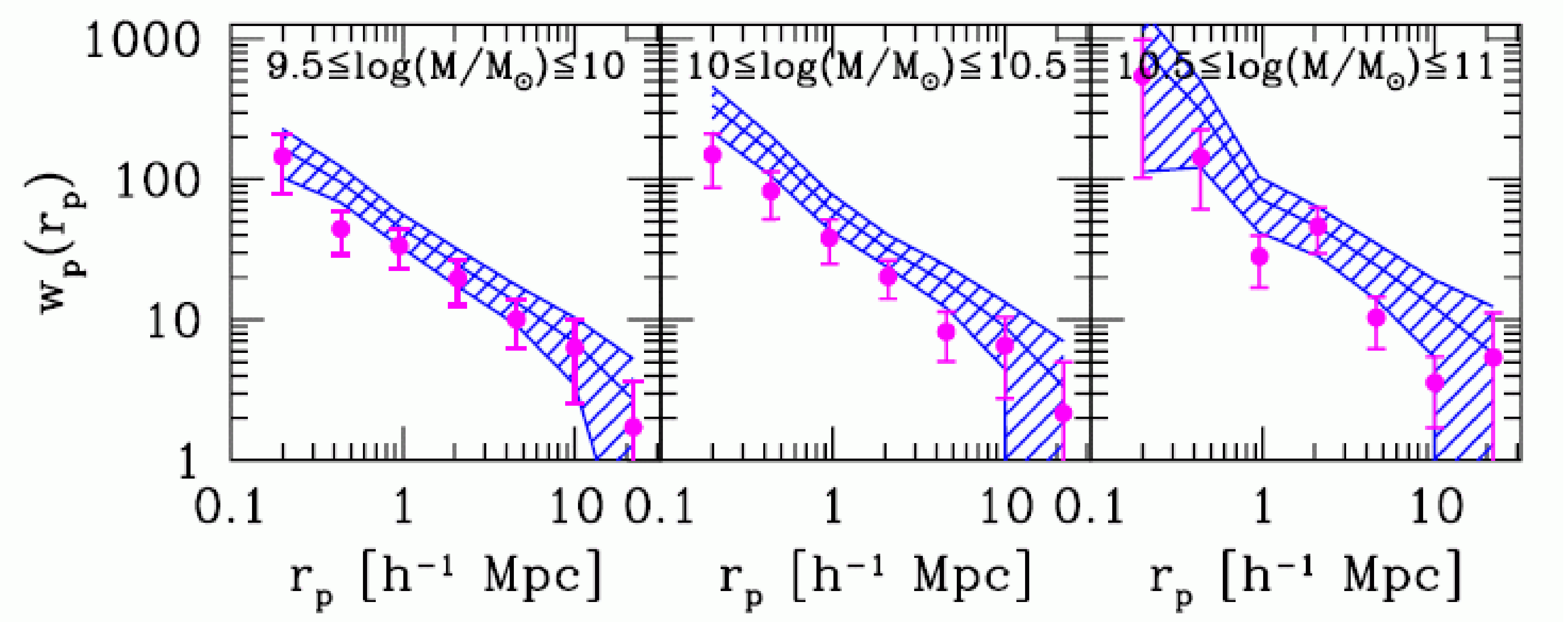


Comparison with VVDS survey $w_p(r_p)$

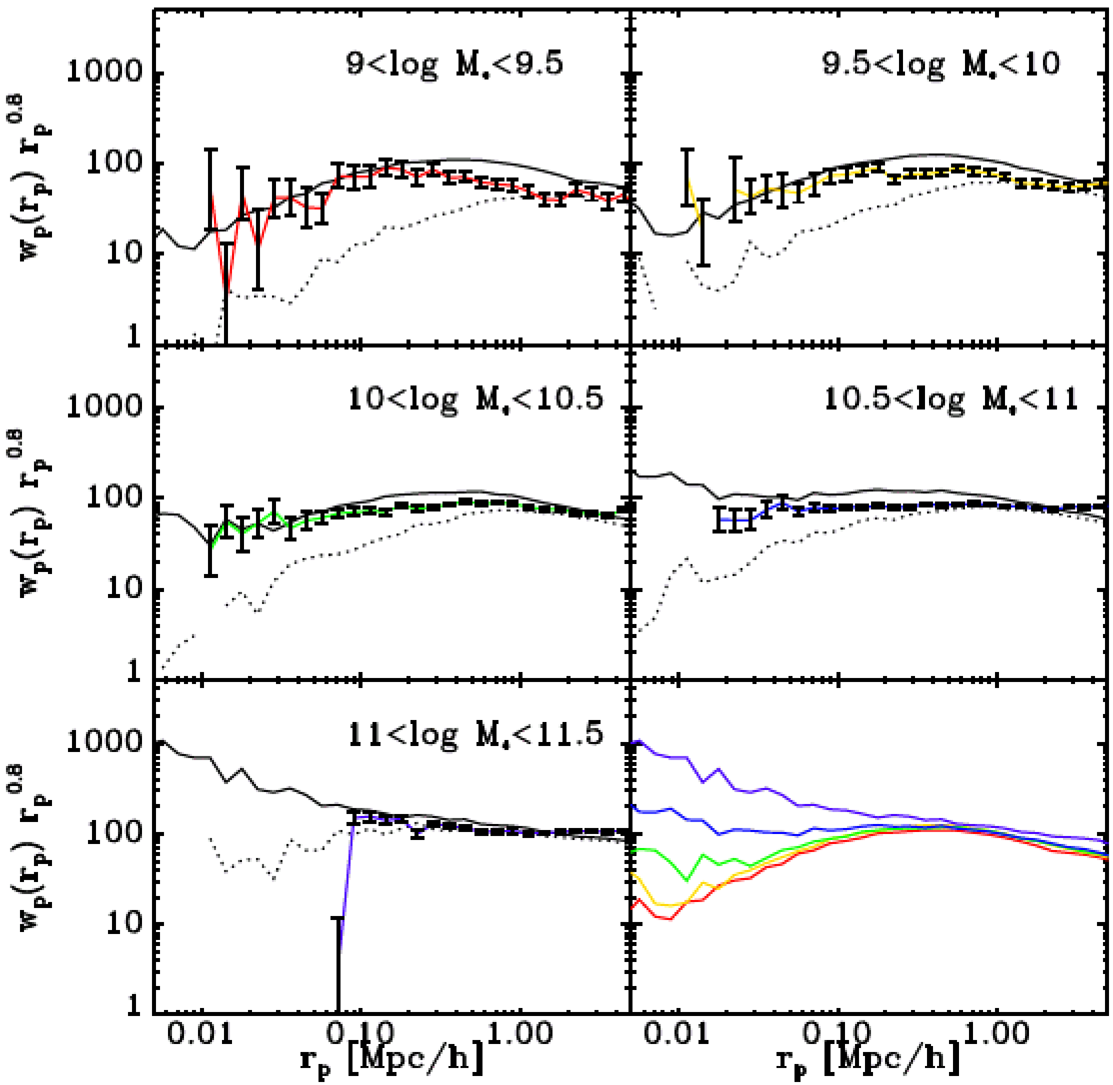
Meneux et al 2007

$\langle z \rangle \sim 0.6$



The Millennium Simulation approximately reproduces the observed abundance of pairs on scales ~ 200 kpc at z ~ 0.6

Small-scale correlations in the MS versus SDSS



Kitzbichler & White 2008

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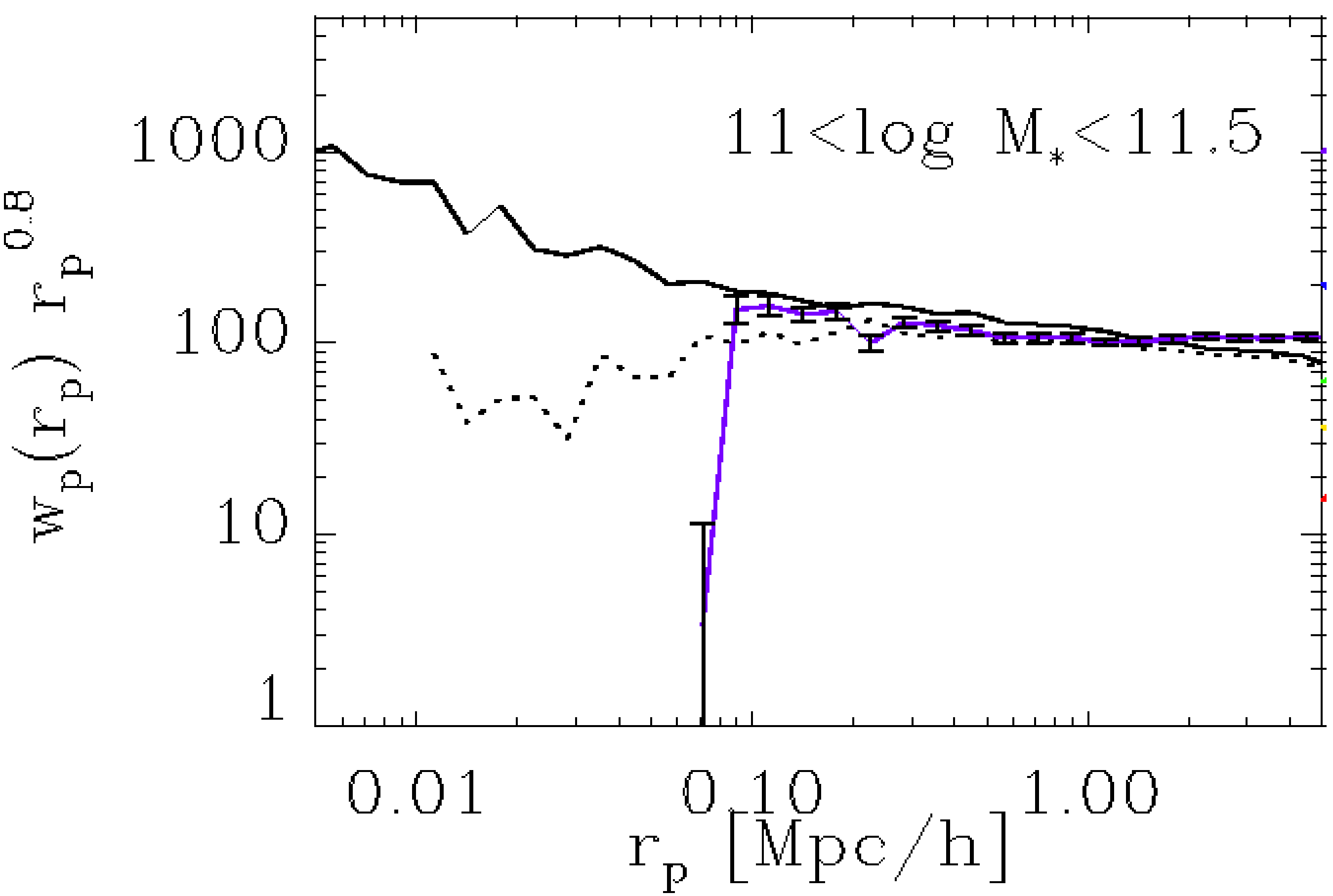

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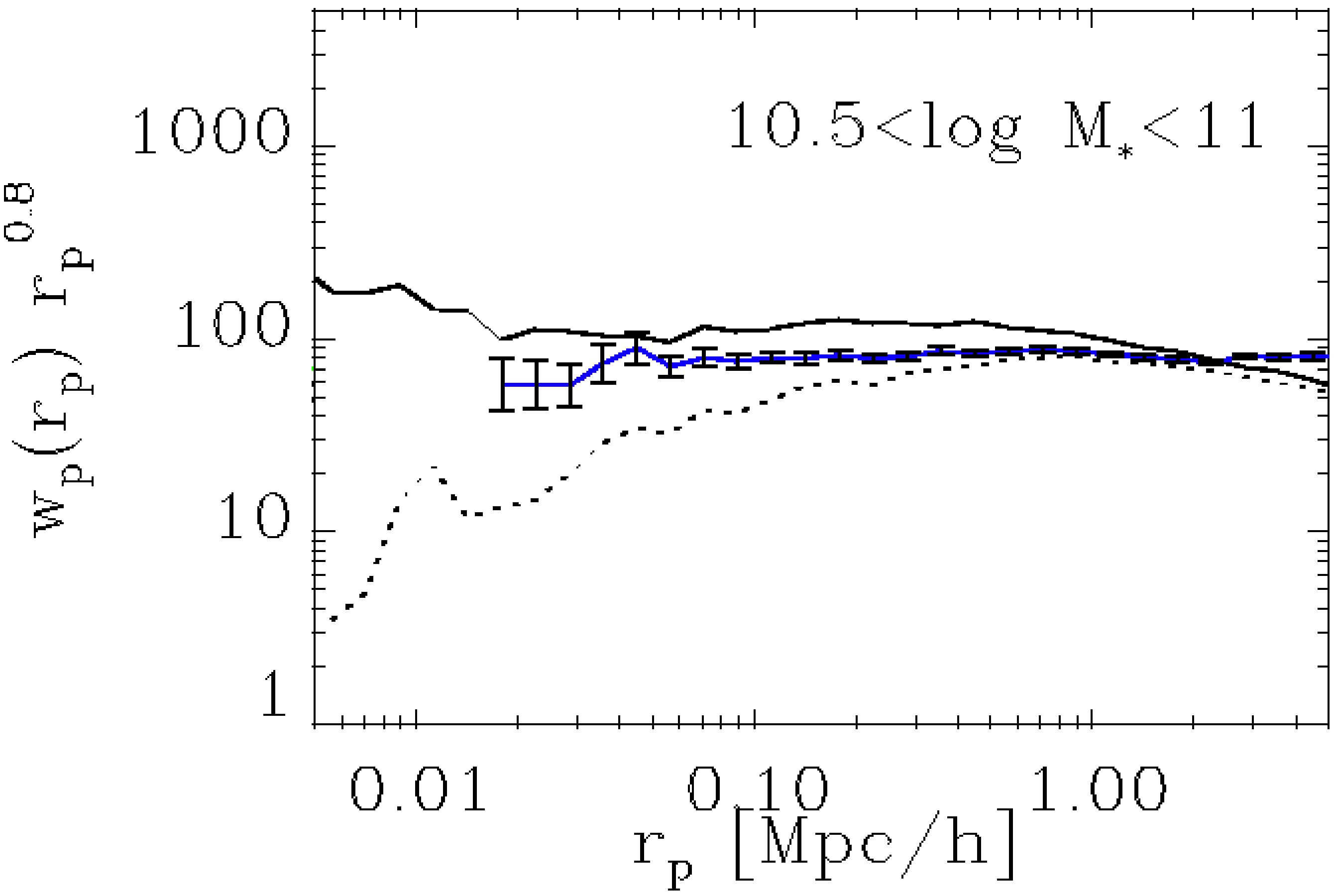

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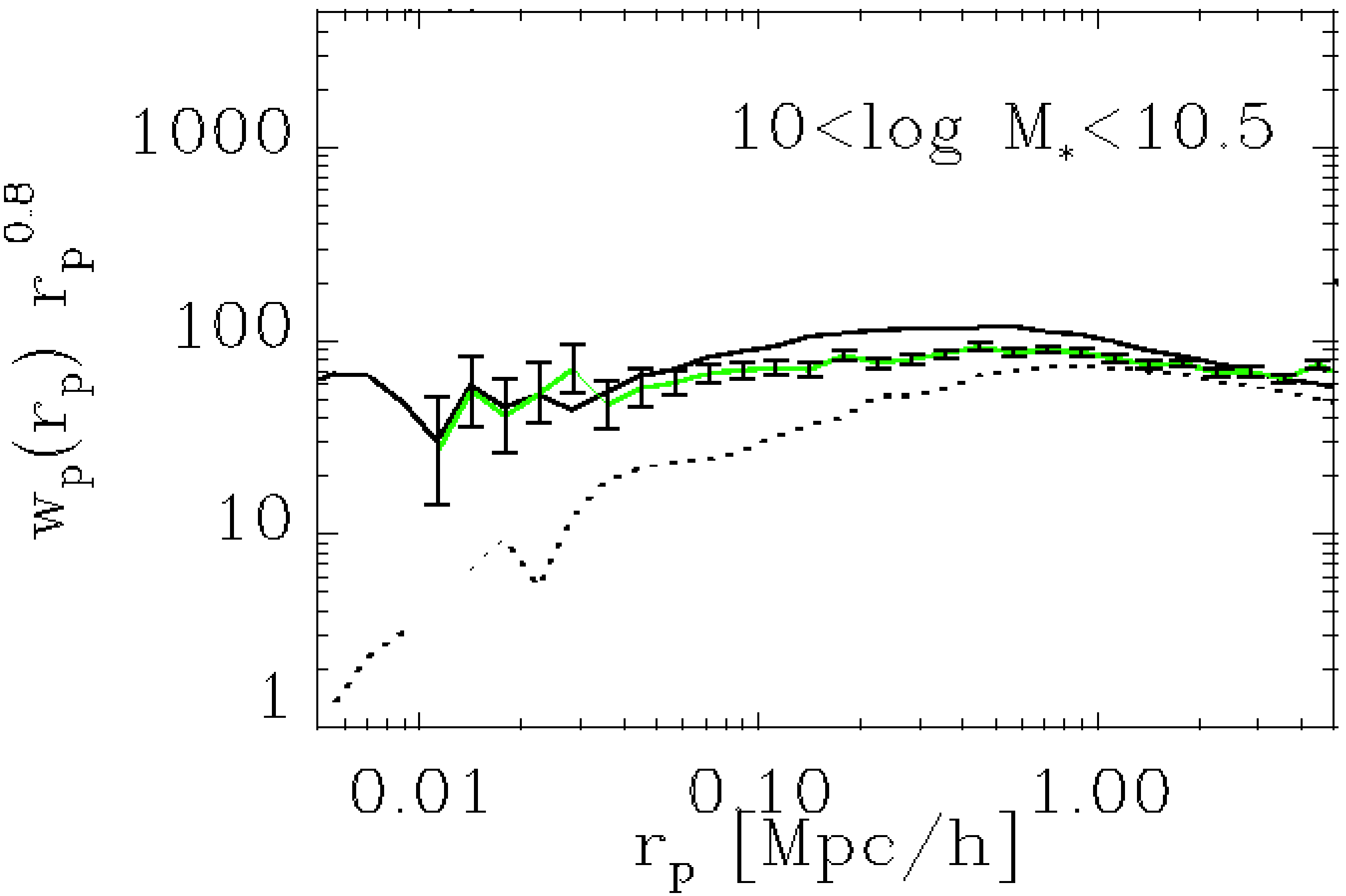

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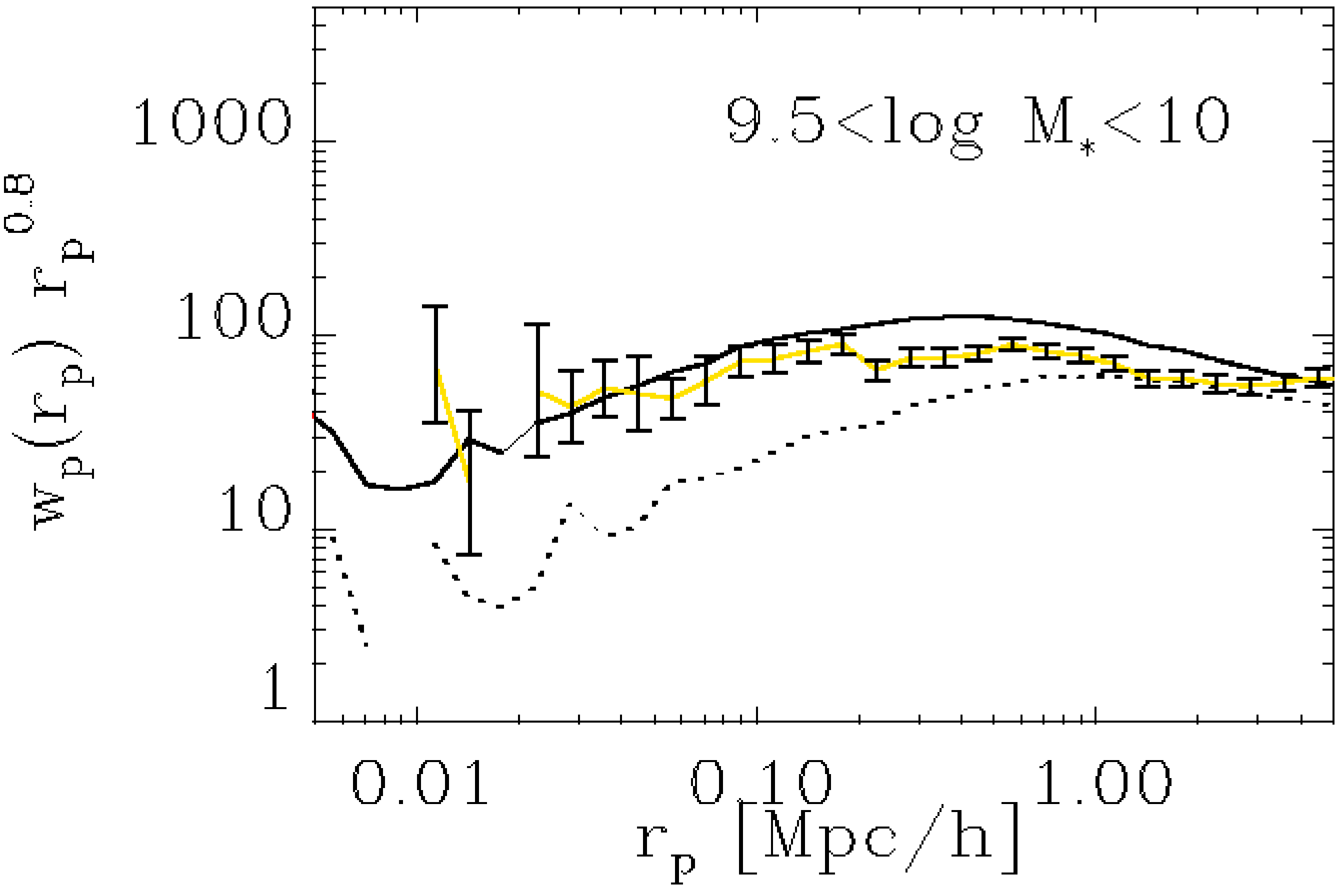

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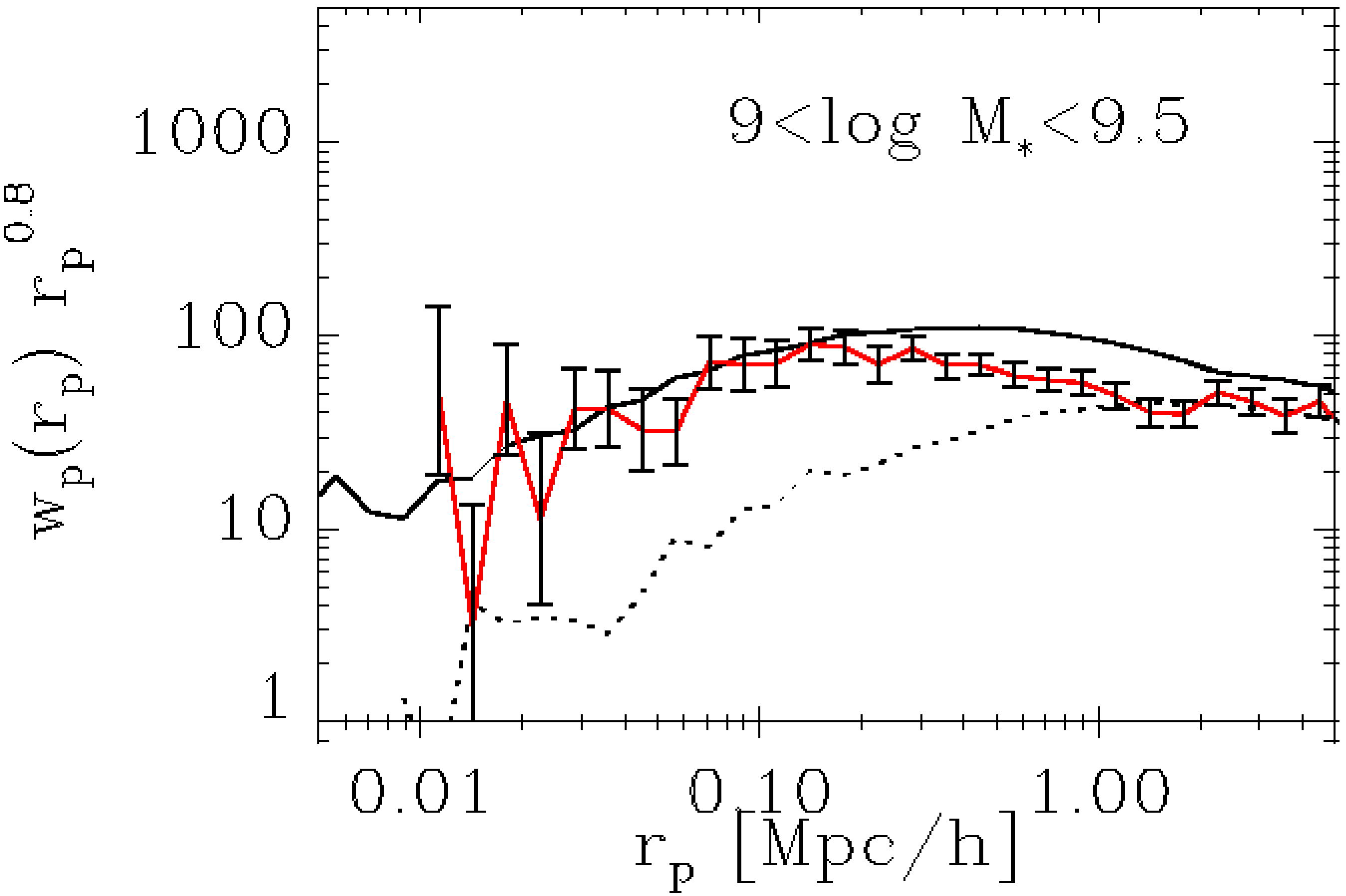
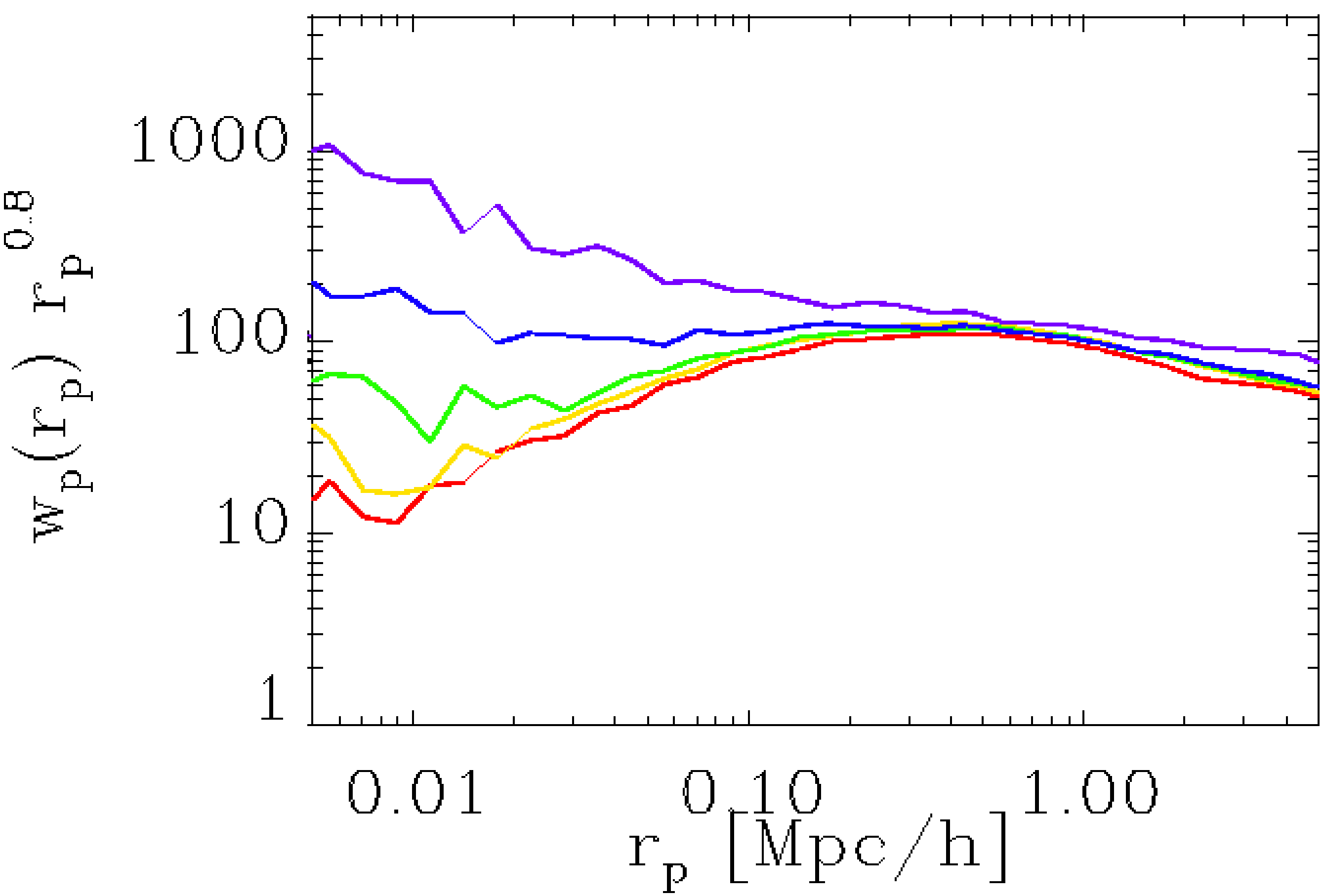


- The Millennium Simulation reproduces the observed abundance of pairs on 30 to 50 kpc scales at z ~ 0.1
- The "orphan" galaxies are critical to getting this right

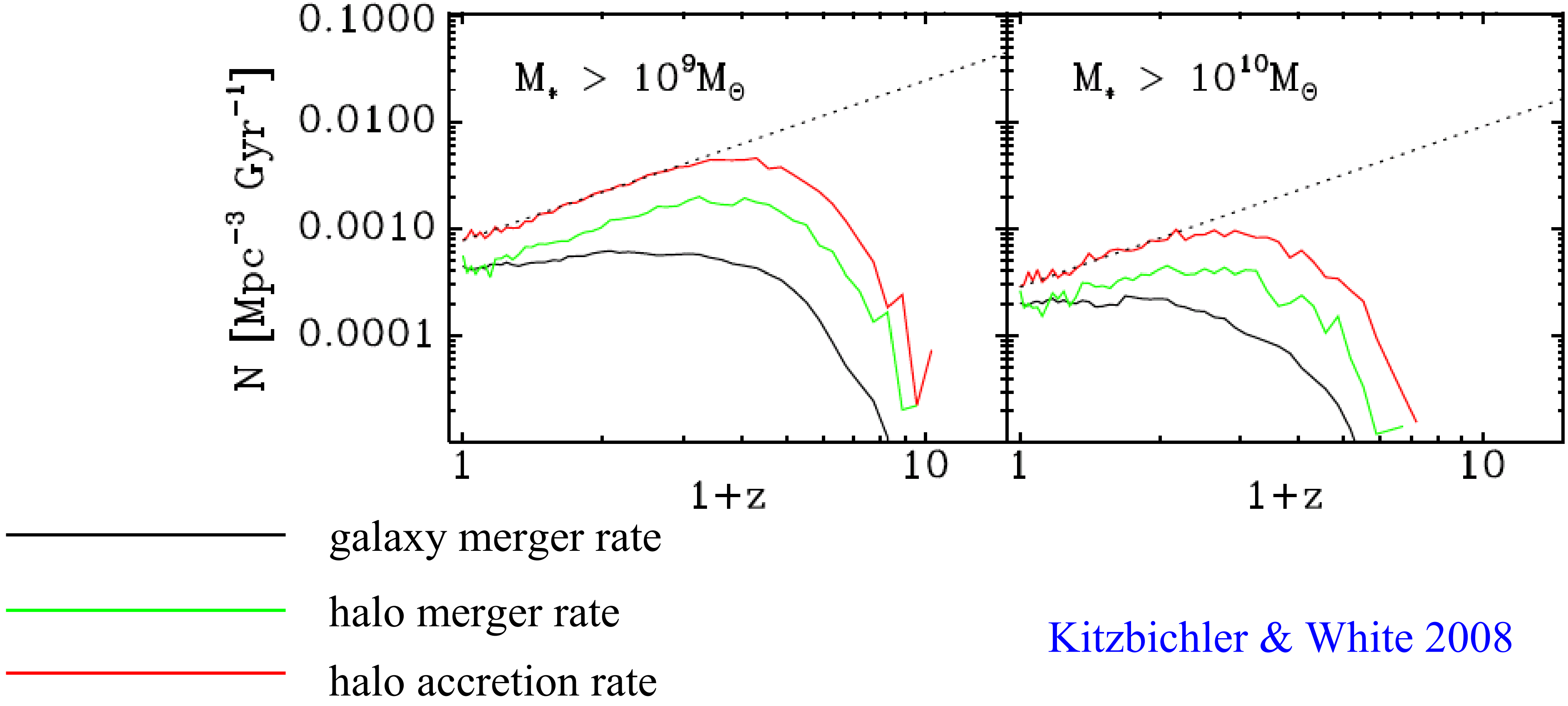
Small-scale correlations in the MS versus SDSS



According to the simulation (and the data!) the small-scale shape of the correlation function depends strongly on stellar mass

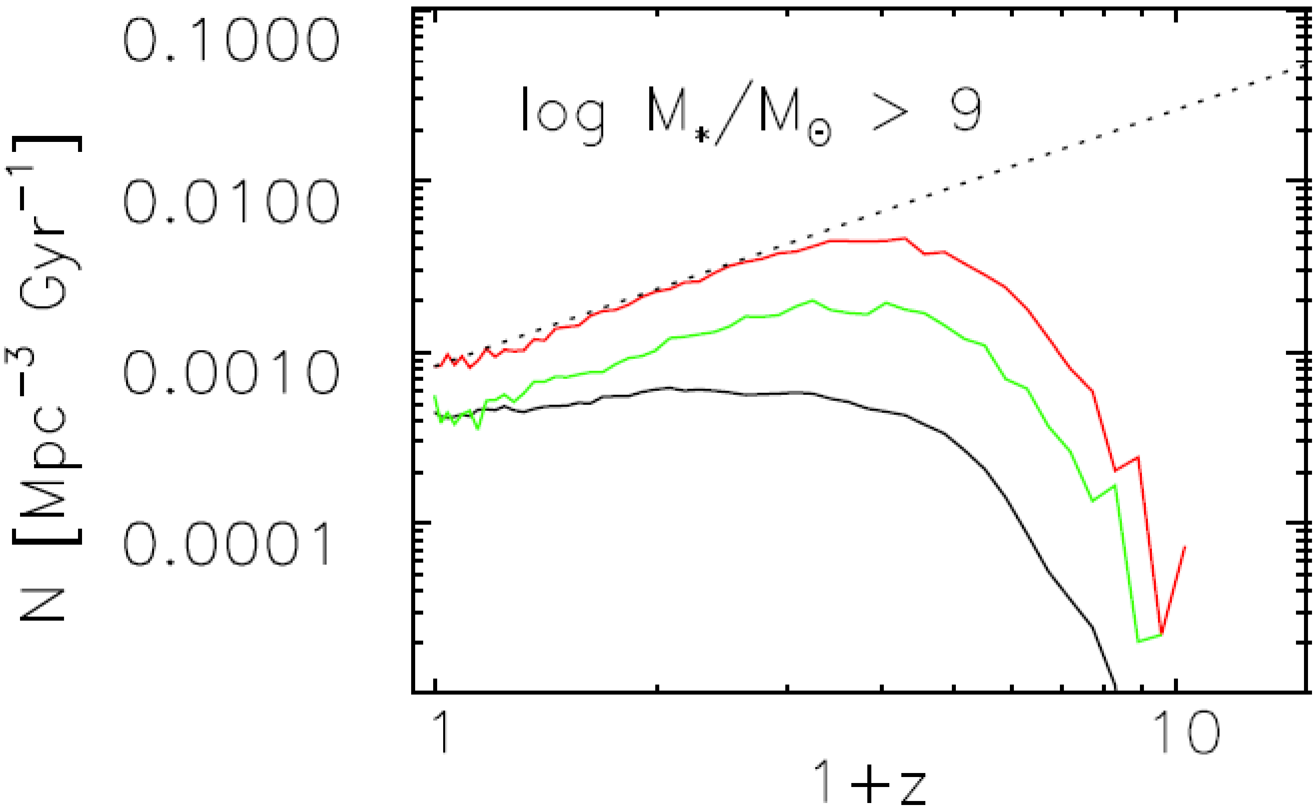
What constitutes a merger in the simulation?

- When two dark halos merge into a single halo?
- When the DM (sub)structure of one galaxy is disrupted within the halo of the other?
- When the code thinks dynamical friction has brought the visible galaxies together?



Kitzbichler & White 2008

Merger rates as a function of stellar mass and redshift



- Halo merger and disruption rates $\propto (1 + z)^{1.5}$ at low z, but galaxy merger rates are independent of z
- Halo merger rates are more than twice (sub)halo disruption rates

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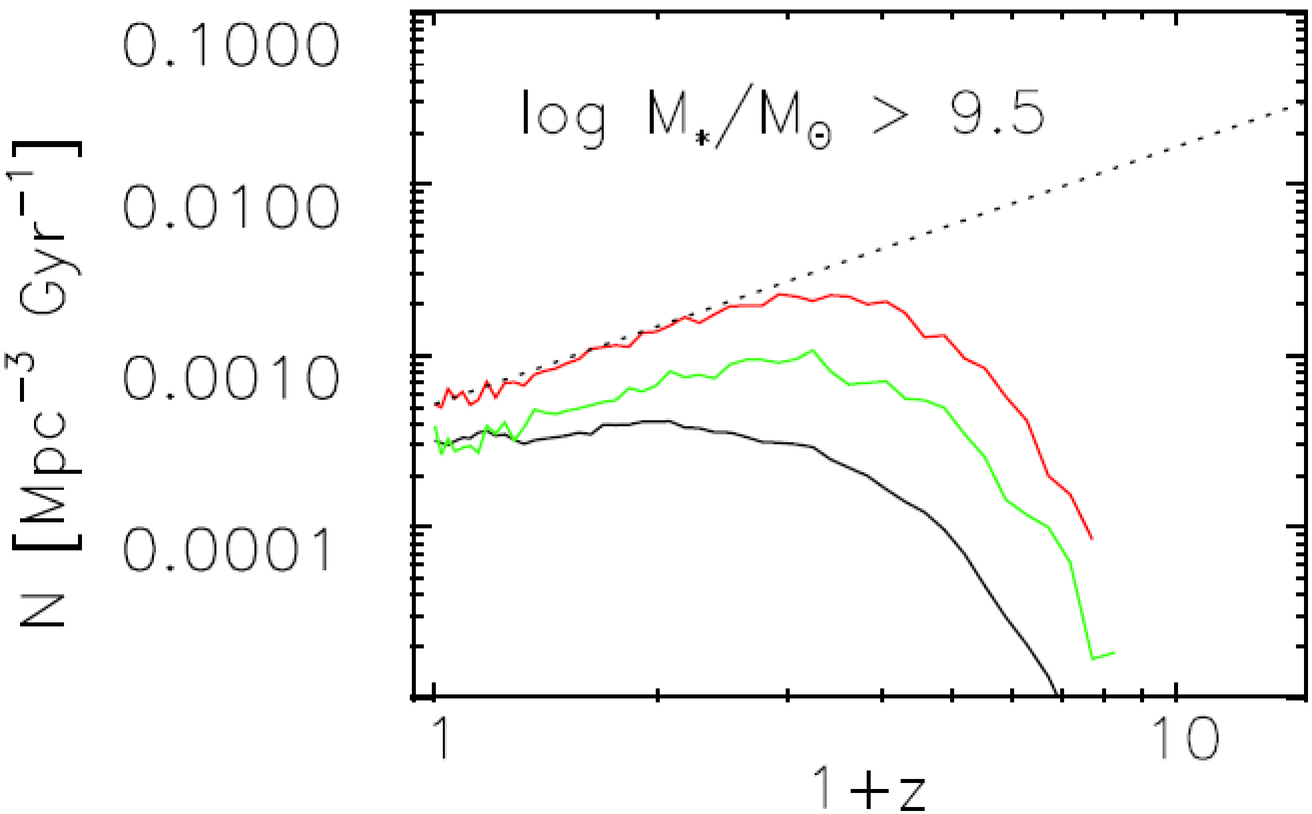

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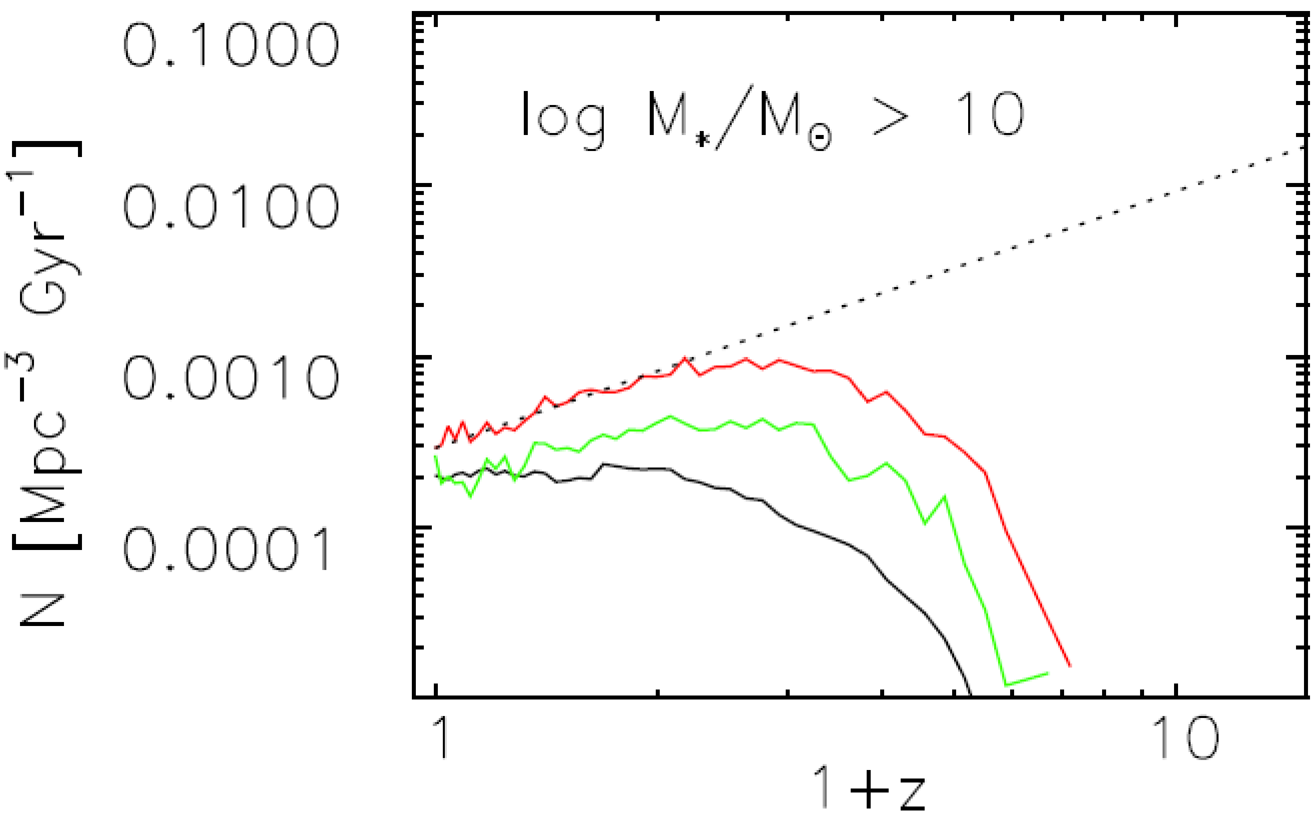

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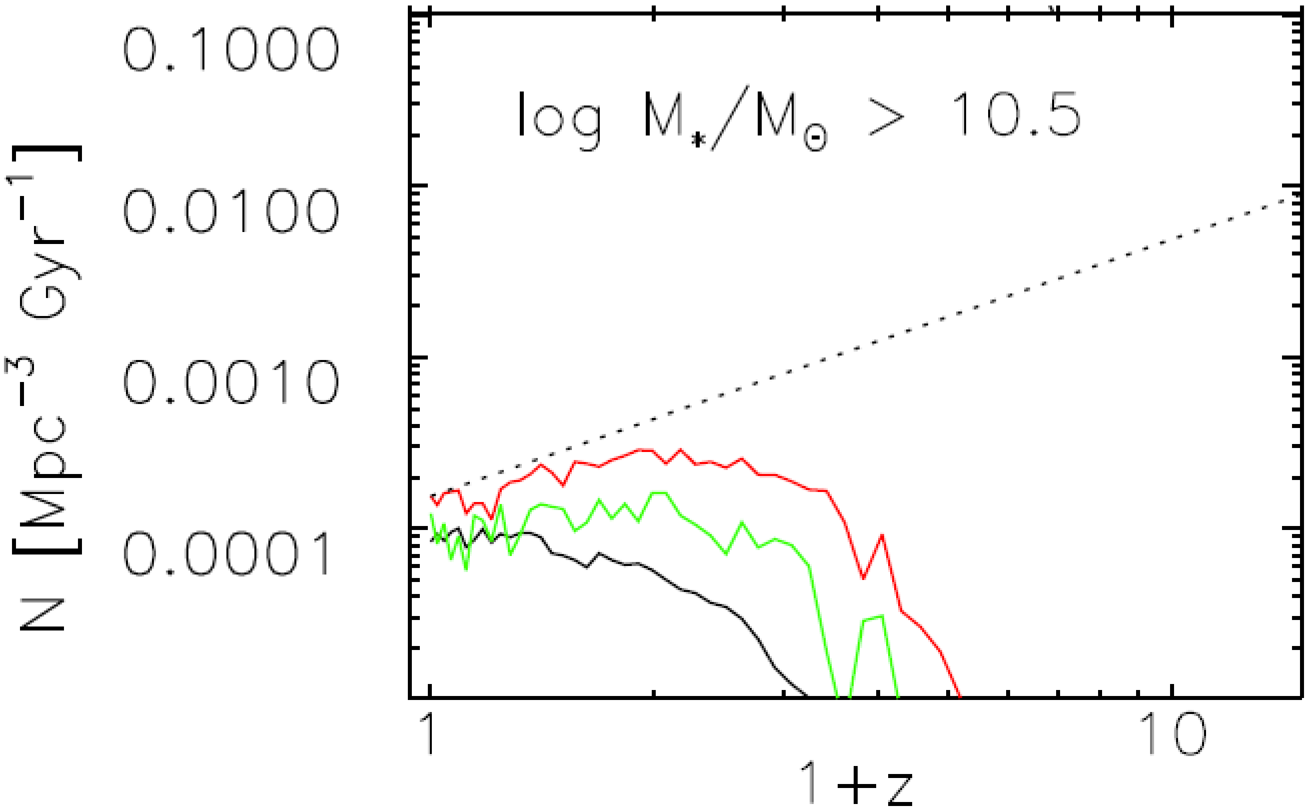

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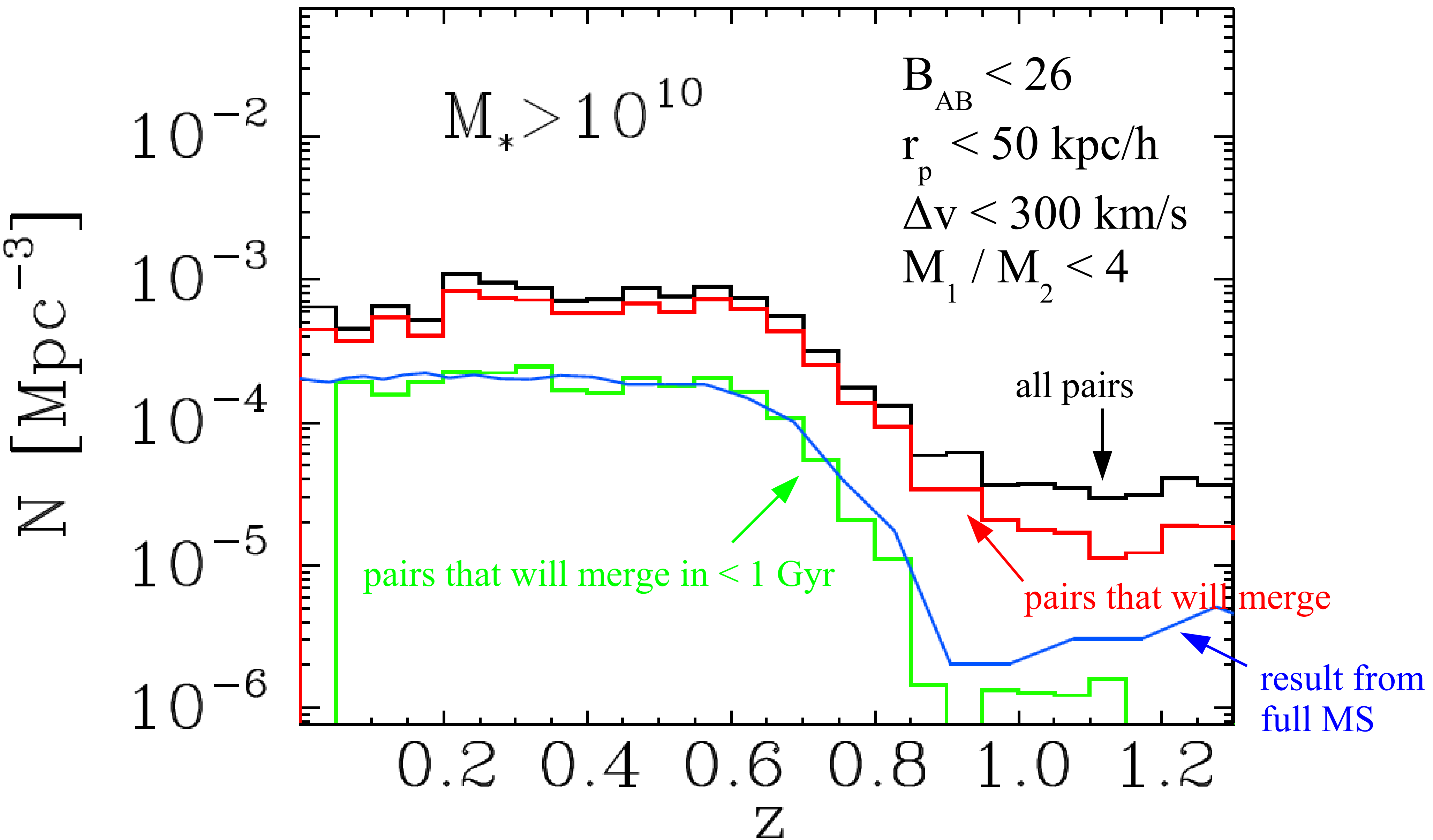
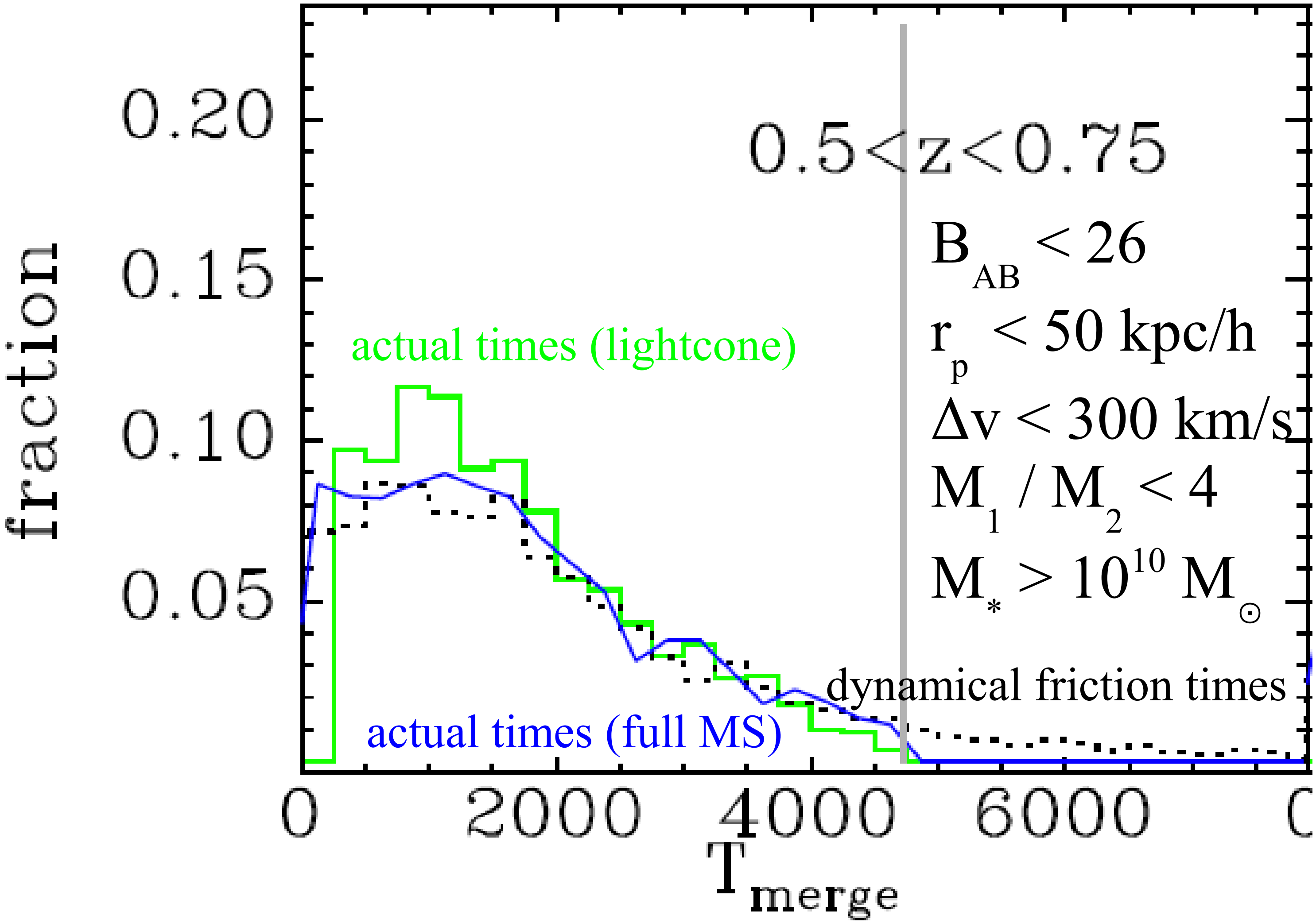
Do observed close pairs actually merge?



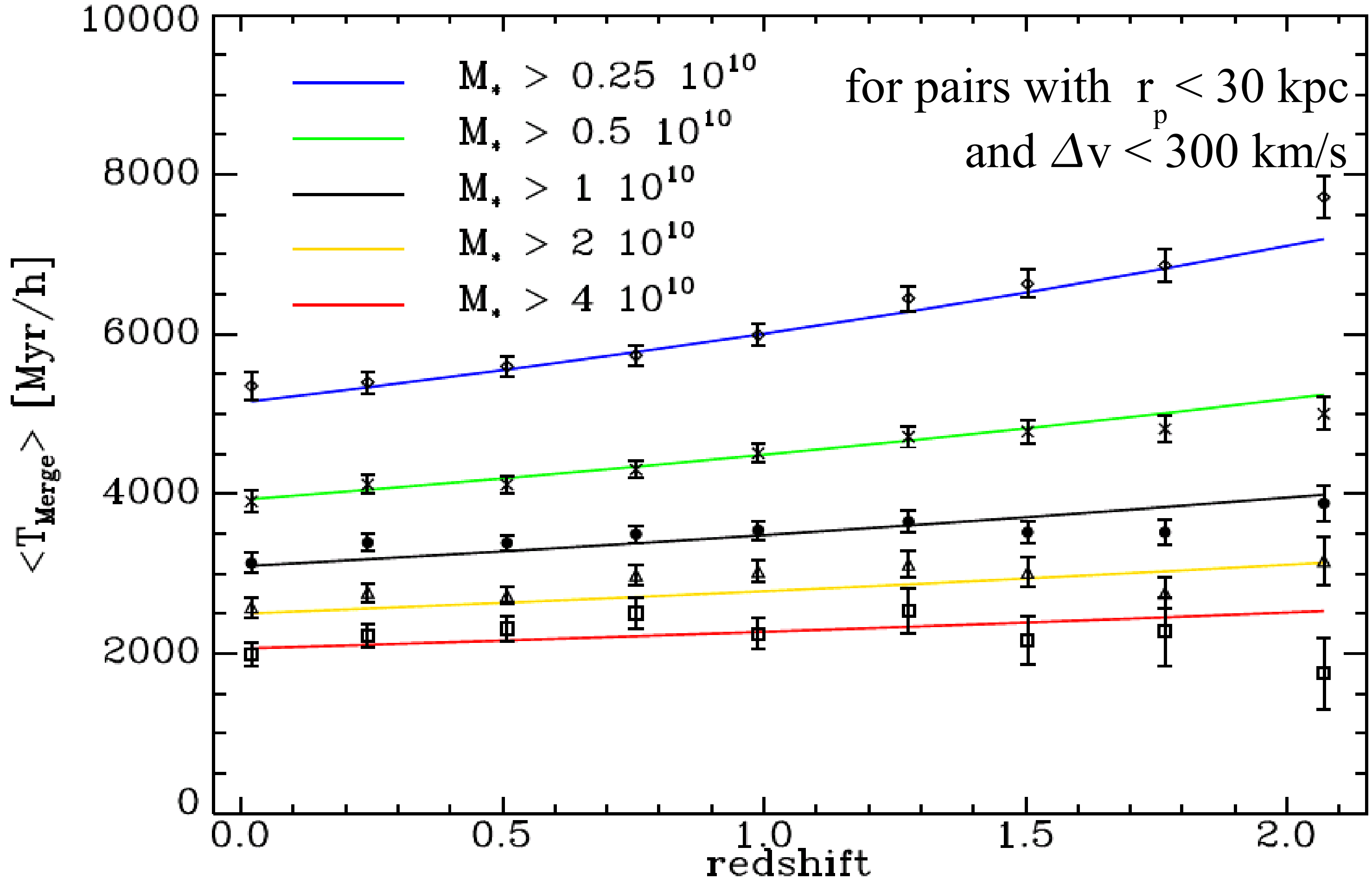
Most close pairs merge but they take a long time to do it!

How long do close pairs take to merge?



The median merger time is about 2Gyr with a broad distribution

Timescale for converting close pair counts into merger rates



T_{merge} = (Abundance of projected close pairs) / (Merger rate of such pairs)

$\propto r_p M^{-0.3} (8 + z)$

Kitzbichler & White 2008

How to estimate merger rates from pair counts

1 Count close pairs (r_p < 50 *or* 30 kpc) with well defined criteria on magnitude difference, stellar mass, etc.

2 Make completeness and background corrections to estimate abundance of pairs of chosen type at known z

3 Divide close pair abundance by the merger timescale to get merger rate (per unit volume) of the chosen pair type

e.g. for pairs of $\sim 10^{10}\ M_\odot$ galaxies at $z \sim 1$ with

$$r_p \leq 30\ \text{kpc/h}\ (\text{physical})\ \text{and}\ \Delta v < 300\ \text{km/s}$$

$$T_{merge} = 2.0\ \text{Gyr/h}$$

IN CONCLUSION

- Do NOT use morphologically selected samples to estimate merer rates
- Most close (r_p <50 kpc) pairs will merge
- The time they take to merge varies widely
- The appropriate average time is around 2 Gyr
- Merger rates are not expected to vary much with z
- Most previous observational estimates are too high