Evolution of the brightest galaxies:

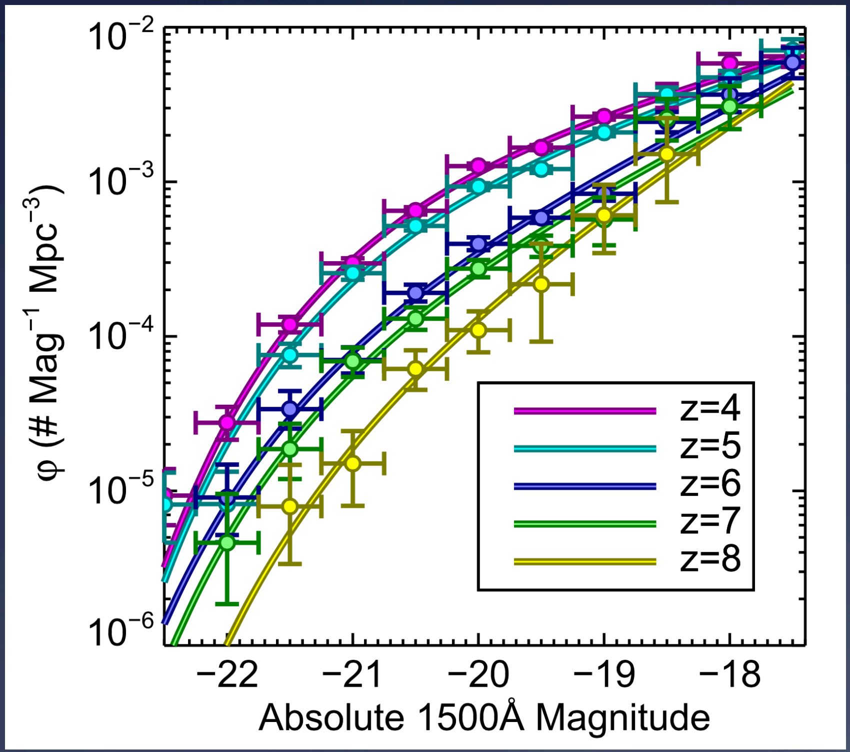
what controls the turnover of the luminosity function?

Henry Ferguson

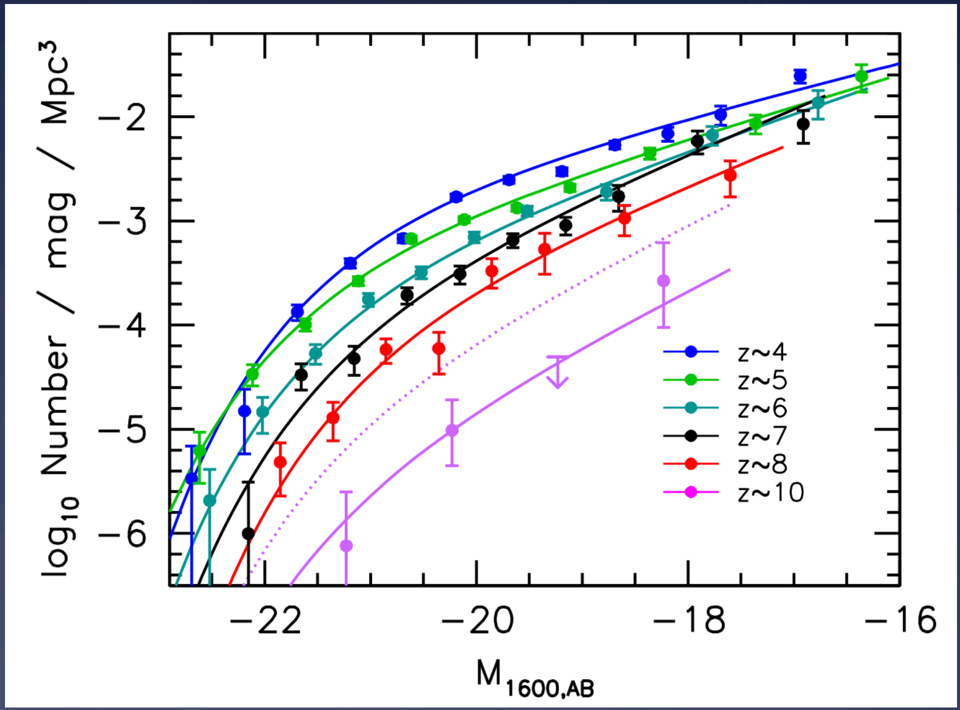
Community astrophysics with WFIRST
February 29, 2016

- Questions
- Measurements
- Considerations for WFIRST

UV LF measurements to z~8

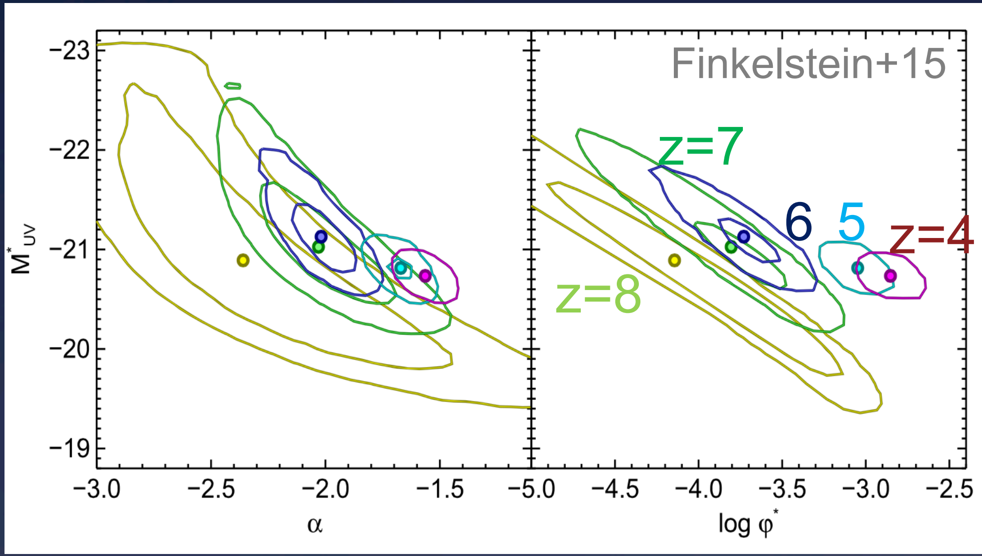


Finkelstein+15



Bouwens+15

LF parameter evolution



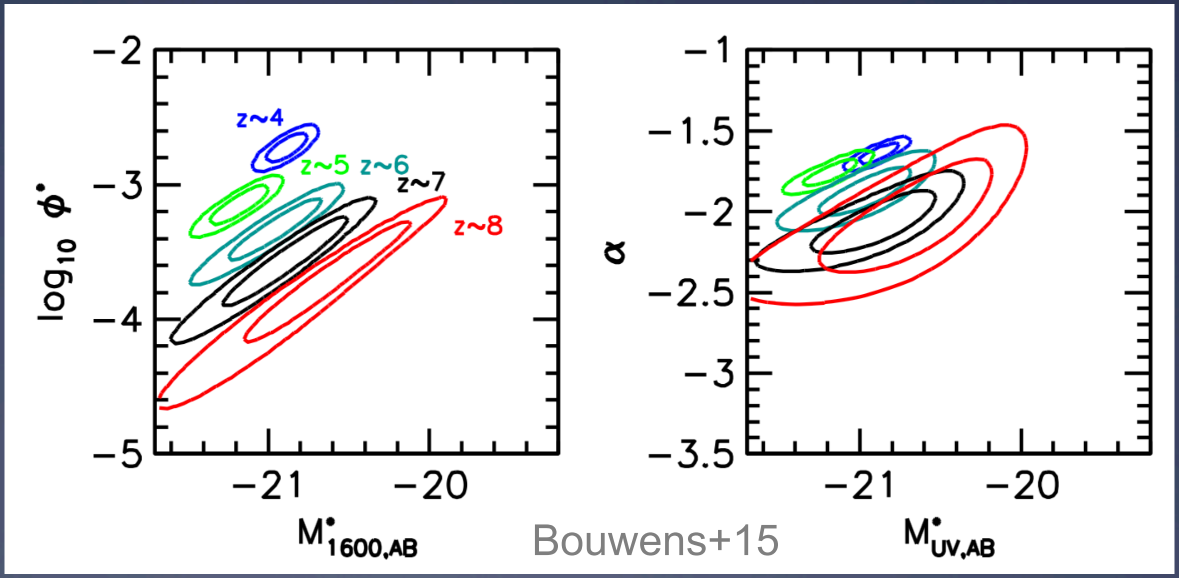
Primarily density evolution at z>4

Steepening faint-end slope?

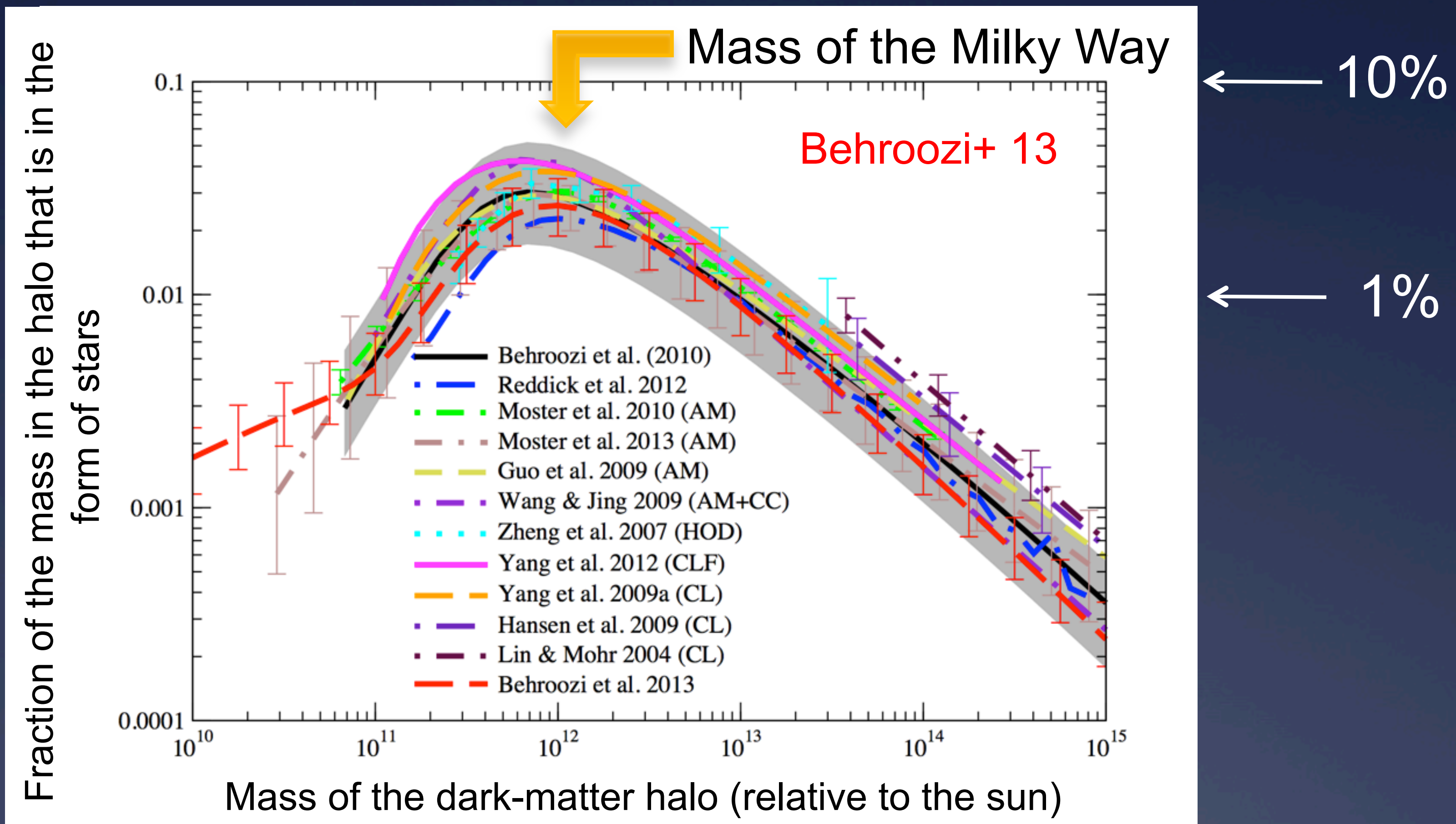
WFIRST limits:

HLS: L~L* @ z=3

SN deep:
L~L* @ z=9.8



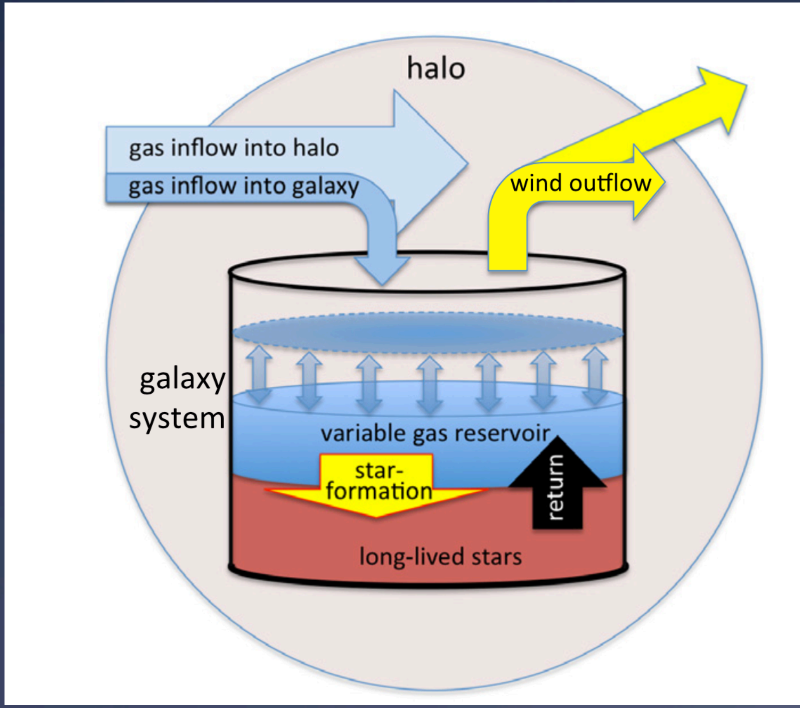
Baryon conversion efficiency



The conversion of gas into stars is inefficient for high-mass and low-mass dark-matter halos

Basic picture

SFR regulated by gas accretion rate on the main sequence



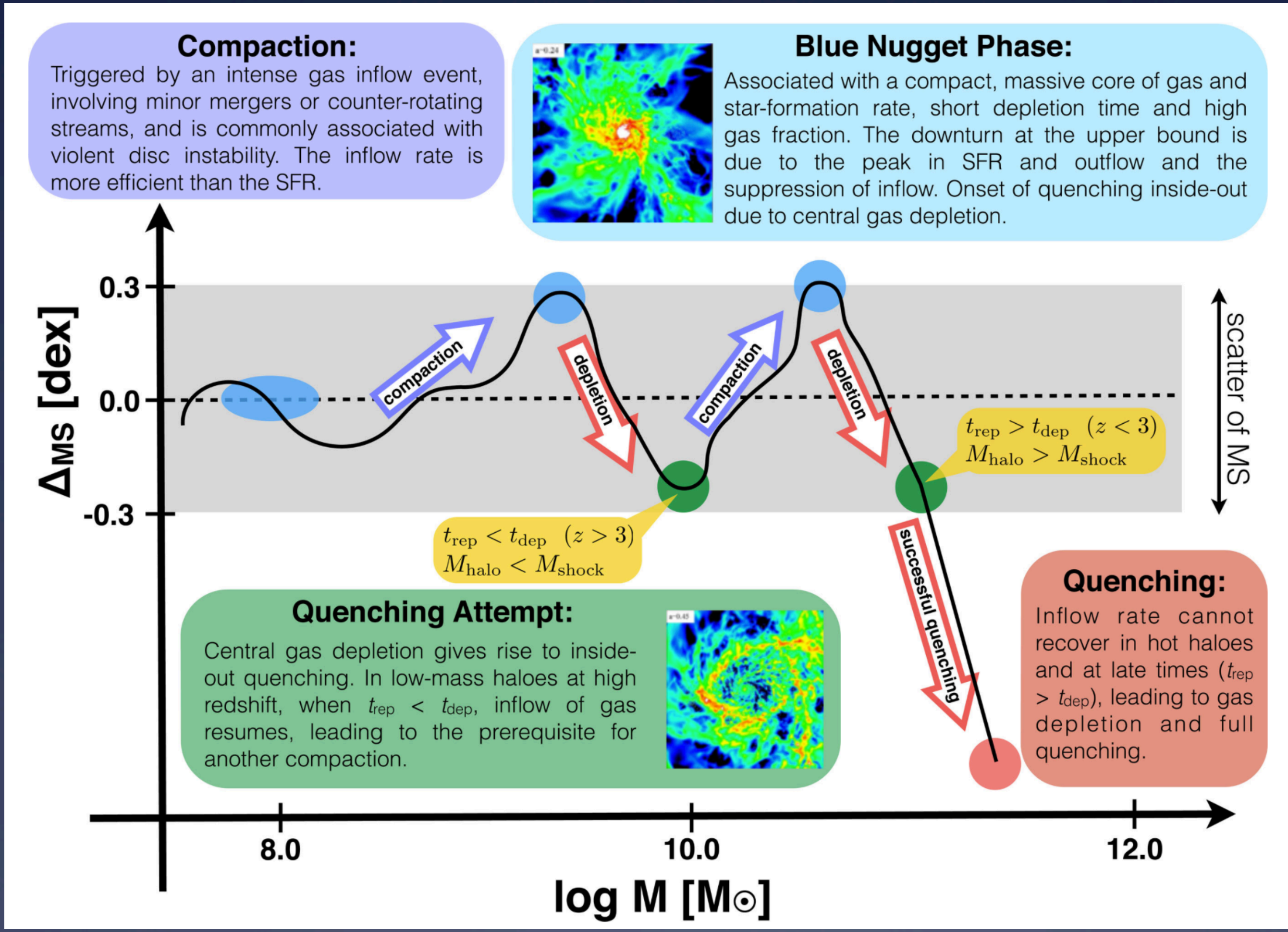
Davé+11, Lilly+13, Dekel+14, Birrer+14

Quenching:
Above some halo or stellar mass ($M^*\sim5\times10^{10}$), galaxies stop forming new stars

Mechanisms:
Mergers
AGN heating
Compaction
Ratio of t_{cool}/t_{ff}
Dust

Croton+06, Hopkins+08, Tacchella+16, Voit+15, Bekki 15

Compaction (earliest quenching mechanism?)



Tacchella+16

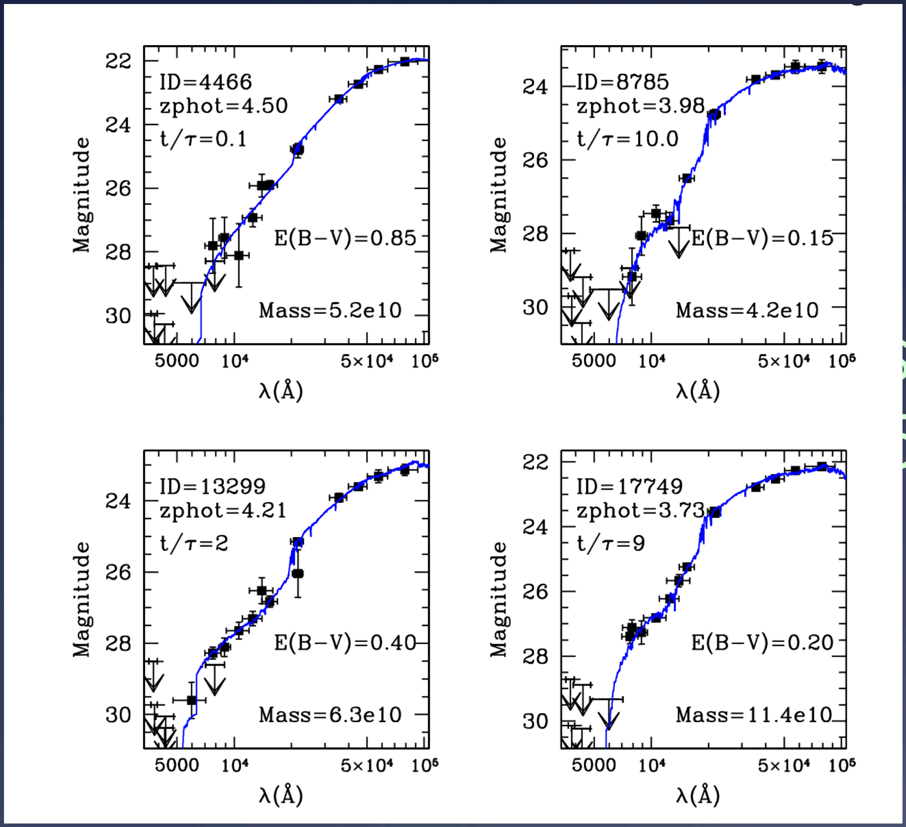
Are galaxies quenching at $z>>3$?

Abundance-matched by SFR

Abudance-match log(SFR)>1.5 at z_0 to same number density at z_1. Take SFR*dt*(1-M_{lost}) + M_0 to predict M_1. Masses exceed observed masses at z_1.

z0	z1	M0	M1	SFR0	dt	Mass Ratio predicted/ observed
6	5	9.68	10.2	41	0.24	0.9
5	4	9.90	10.4	46	0.37	0.8
4	3	10.1	10.5	47	0.61	1.0

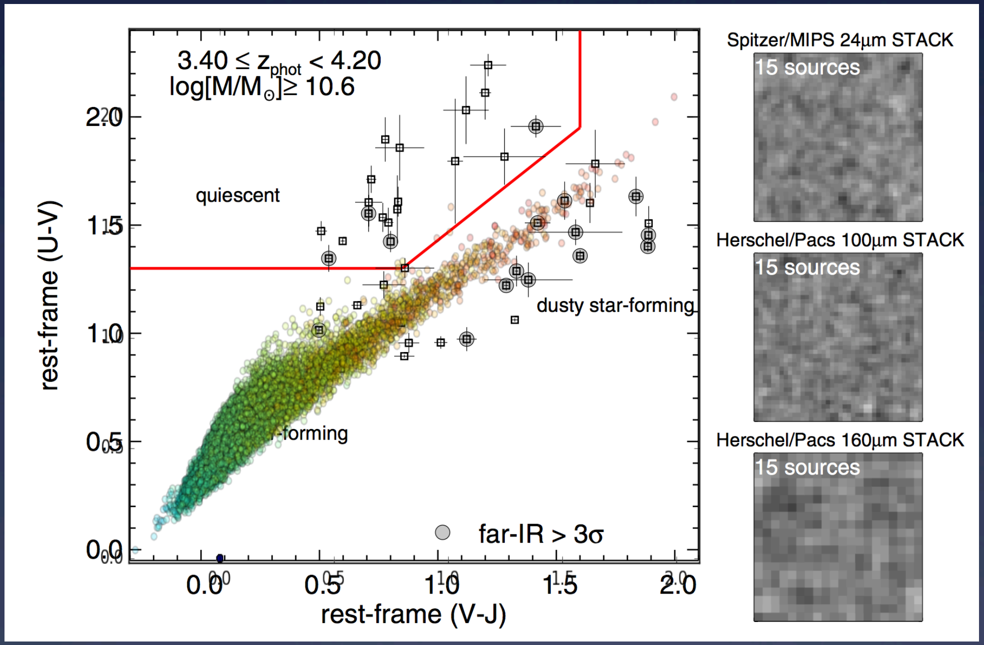
Somerville+12 simulation does not have this issue; massive galaxies not disappearing from SFR-selected samples at z>3 (perhaps because quenching in the models doesn't start until lower redshifts.)



Grazian+14
Examples of passive red galaxies at z~3-4 that would miss LBG detection.

s of red galaxies at
5

UVJ selection

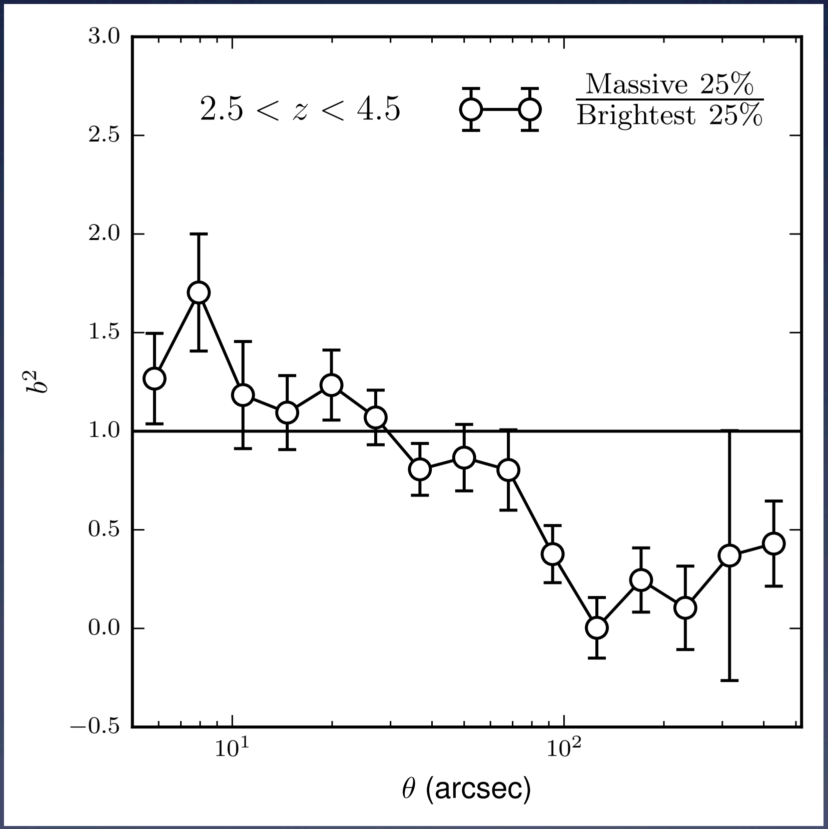


ZFOURGE: Straatman+14

Color: Somerville+11 SAM

ZFOURGE finds a substantial population of massive red galaxies at z~4, many of them passive

Massive halos quenching earlier?



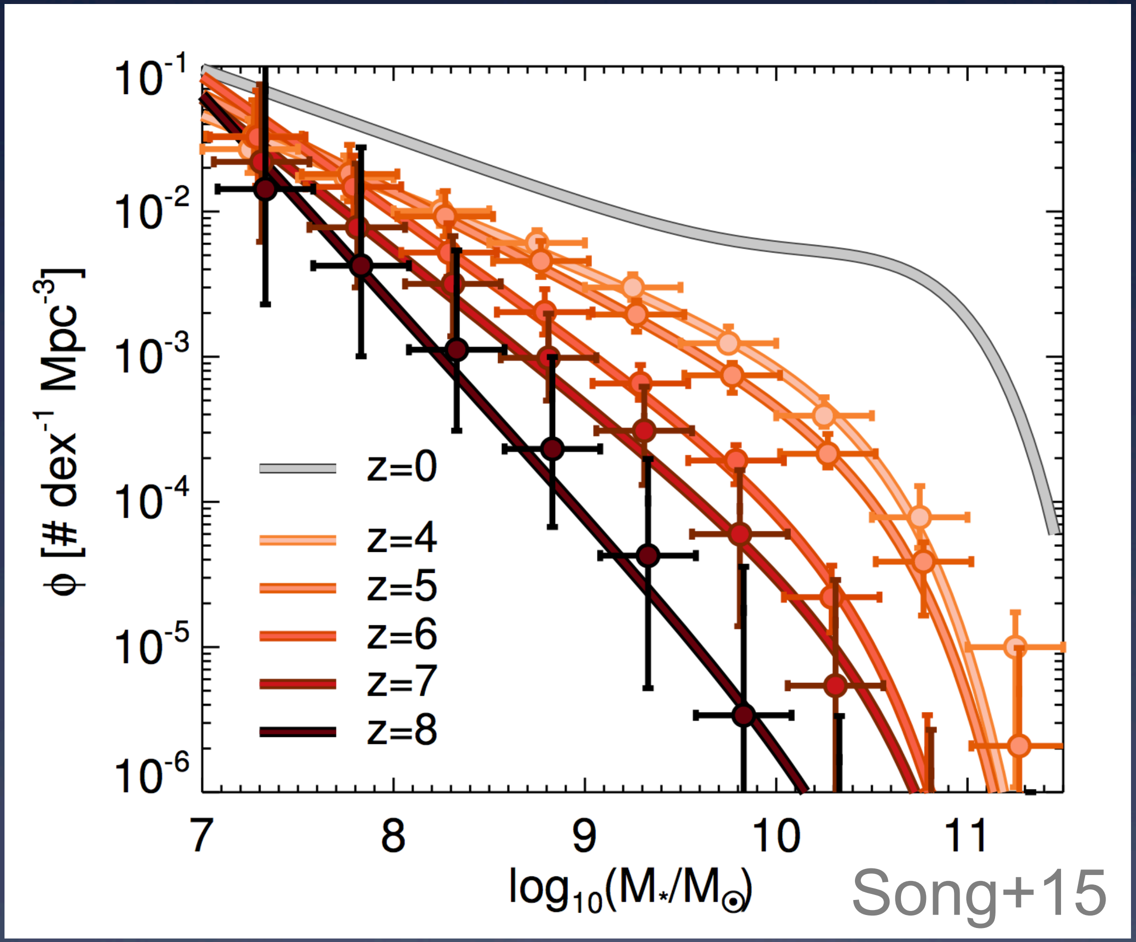
White+
In preparation

The most massive 25% of galaxies at z~3.5 are more strongly clustered than the brightest 25%.

High-z luminosity- and mass-function predictions

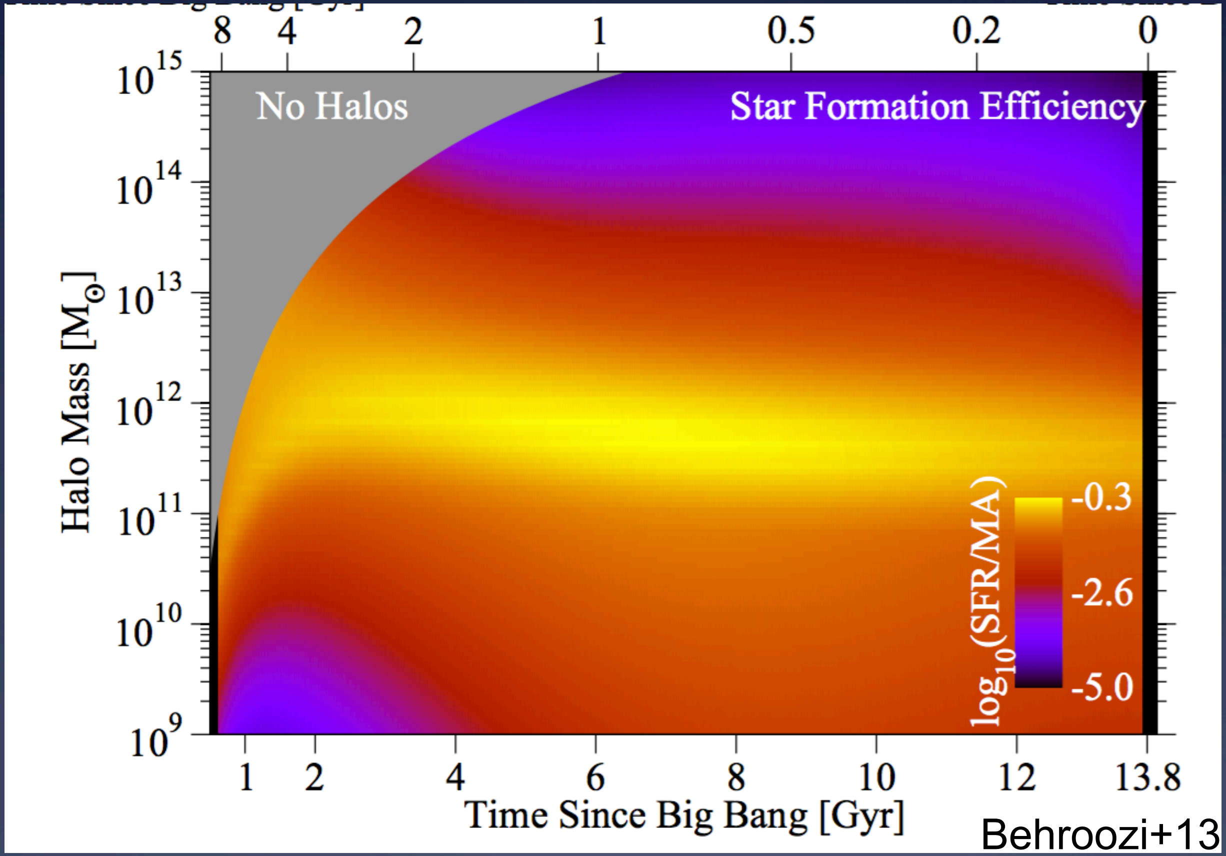
- Phenomenological models
- Semi-analytical models
- N-body + hydrodynamical models

Mass-function evolution



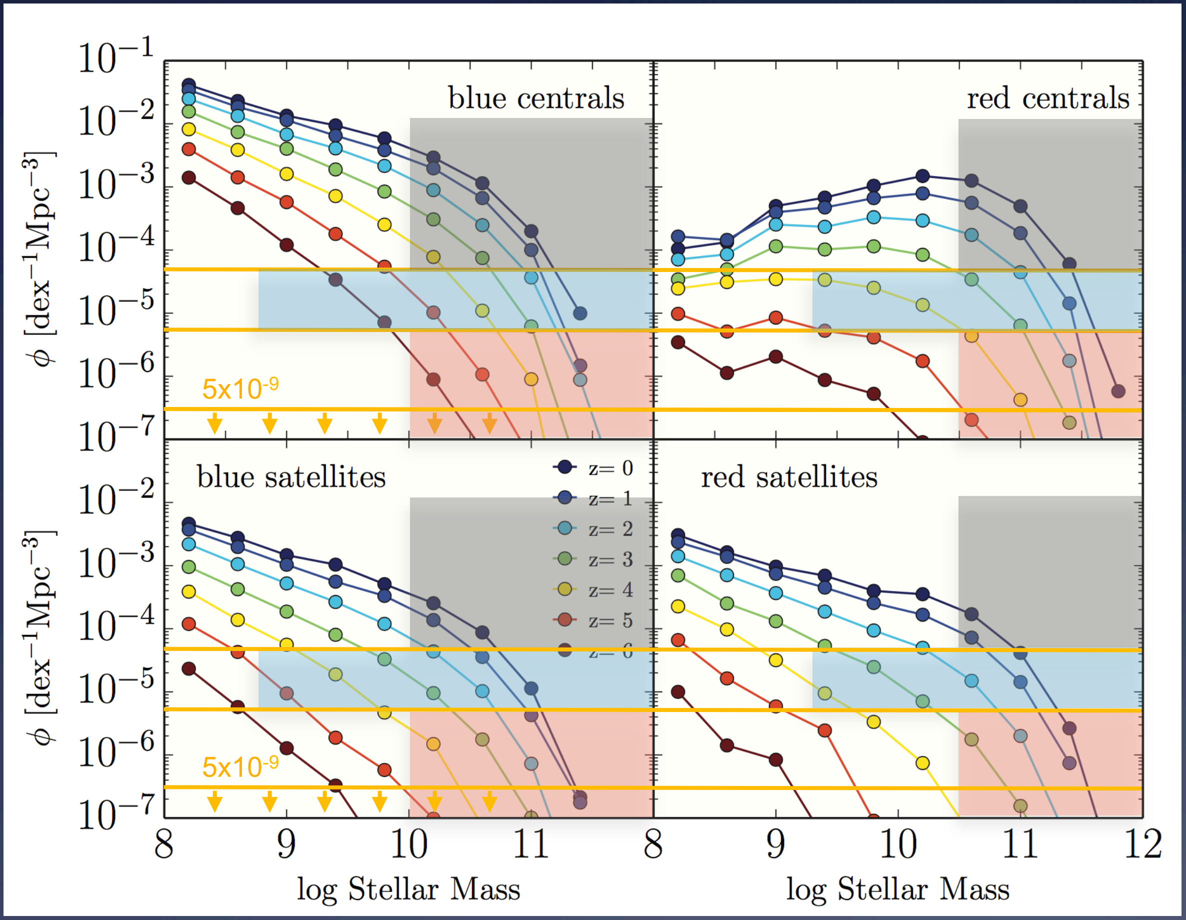
Mass function shows strong evolution, but shape of the bright end is poorly constrained at z>3

At z<3 peak efficiency at M_{halo}~10^{12}



M_{halo} of peak efficiency shifts at z>3?

Differential evolution of quenched and star-forming sequences

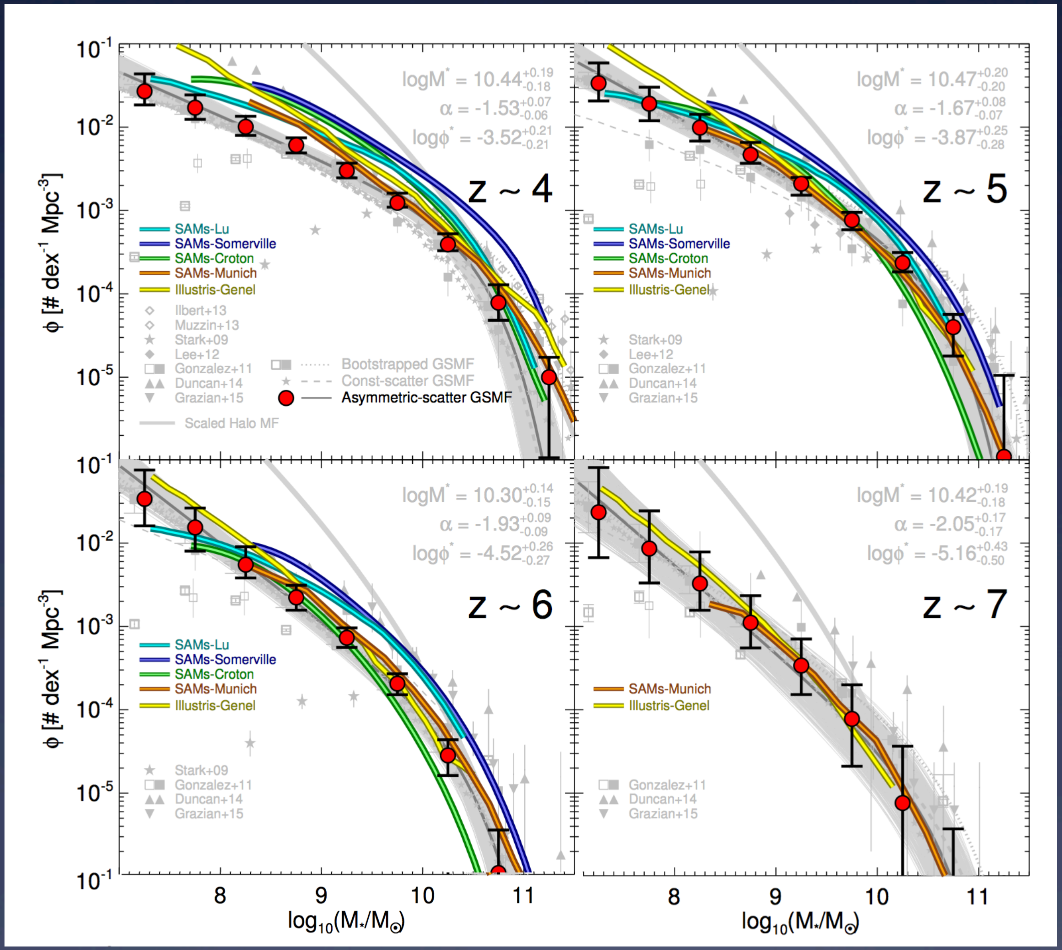


Boxes:
Bottoms n=100
Left: limiting mass

CANDELS
SN Deep
HLS

Birrer+15

CANDELS Mass functions



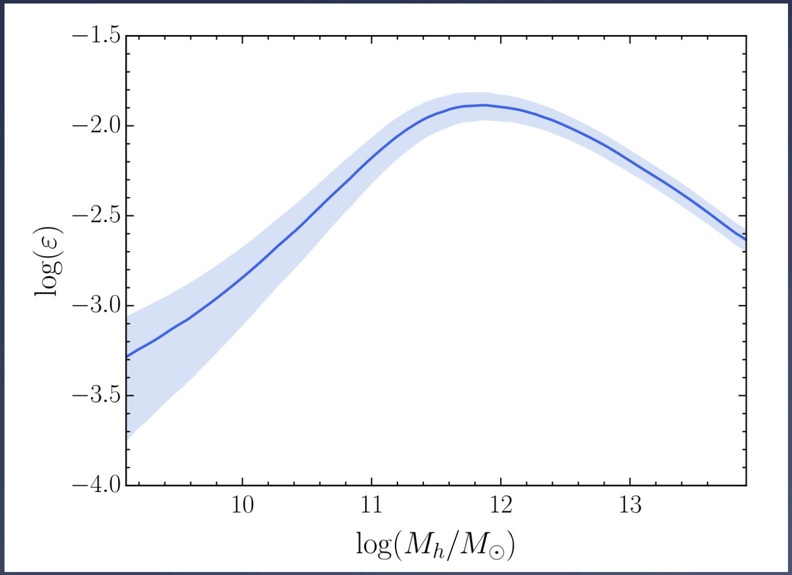
Song+15

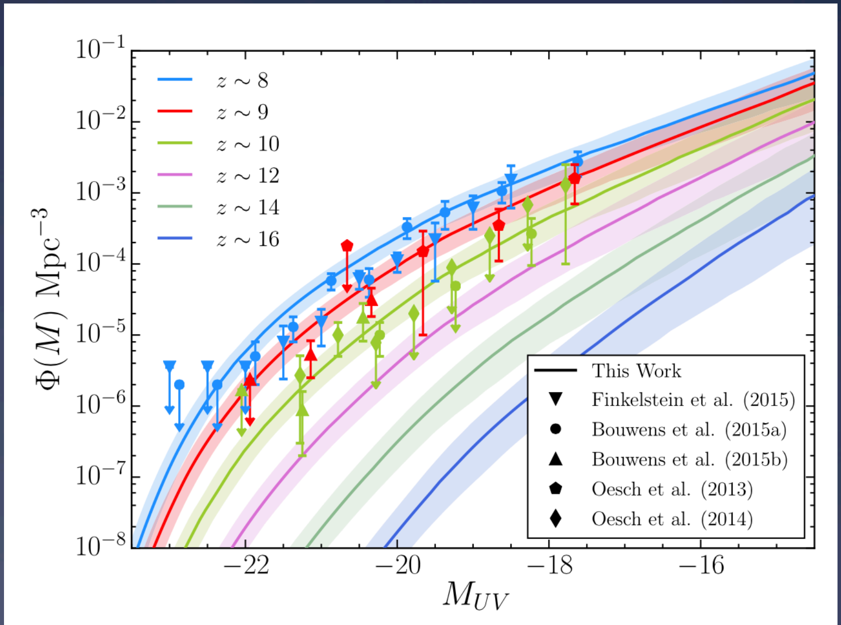
At the high-mass end, matches halo mass function scaled down to 20% of baryon mass (light grey)

Phenomenological approach

Assume redshift independent (but mass-dependent) efficiency; calibrate at z~5

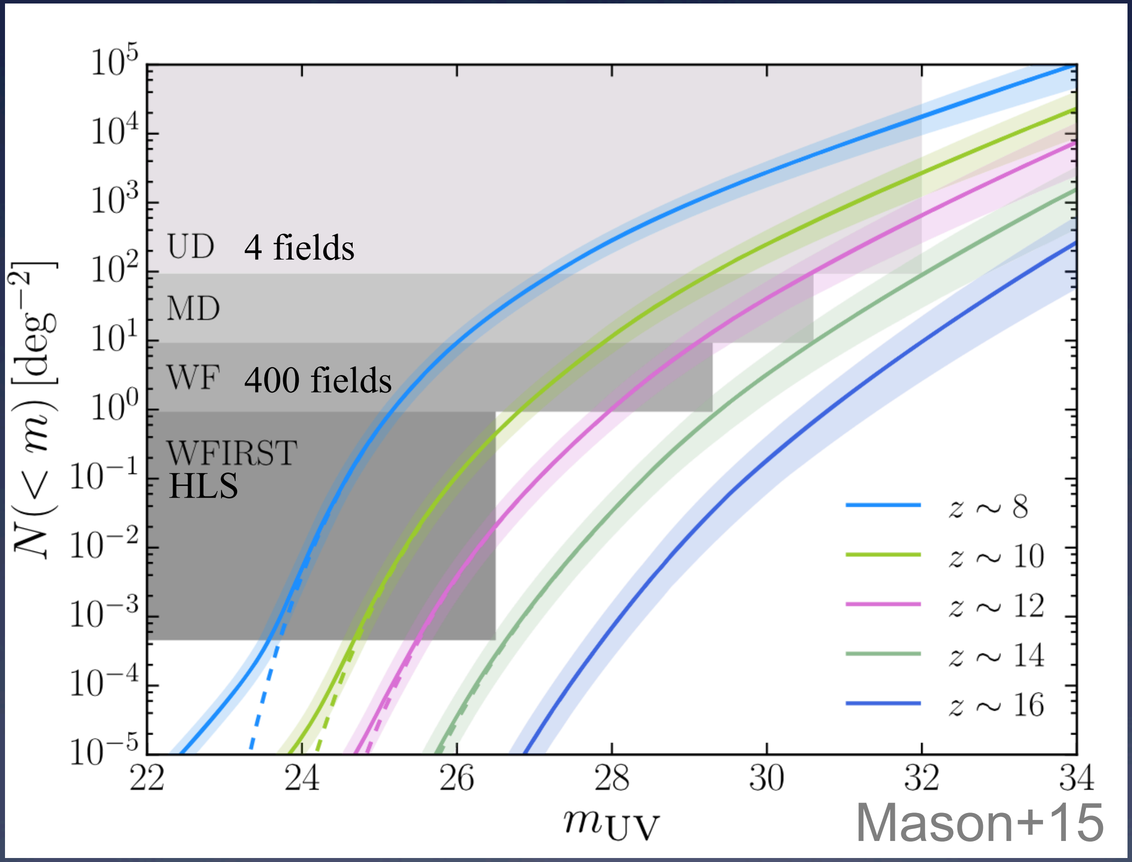
Predict LF with empirically-calibrated redshift-dependent dust law





Trenti+11, Mason+15, Behroozi & Silk 15

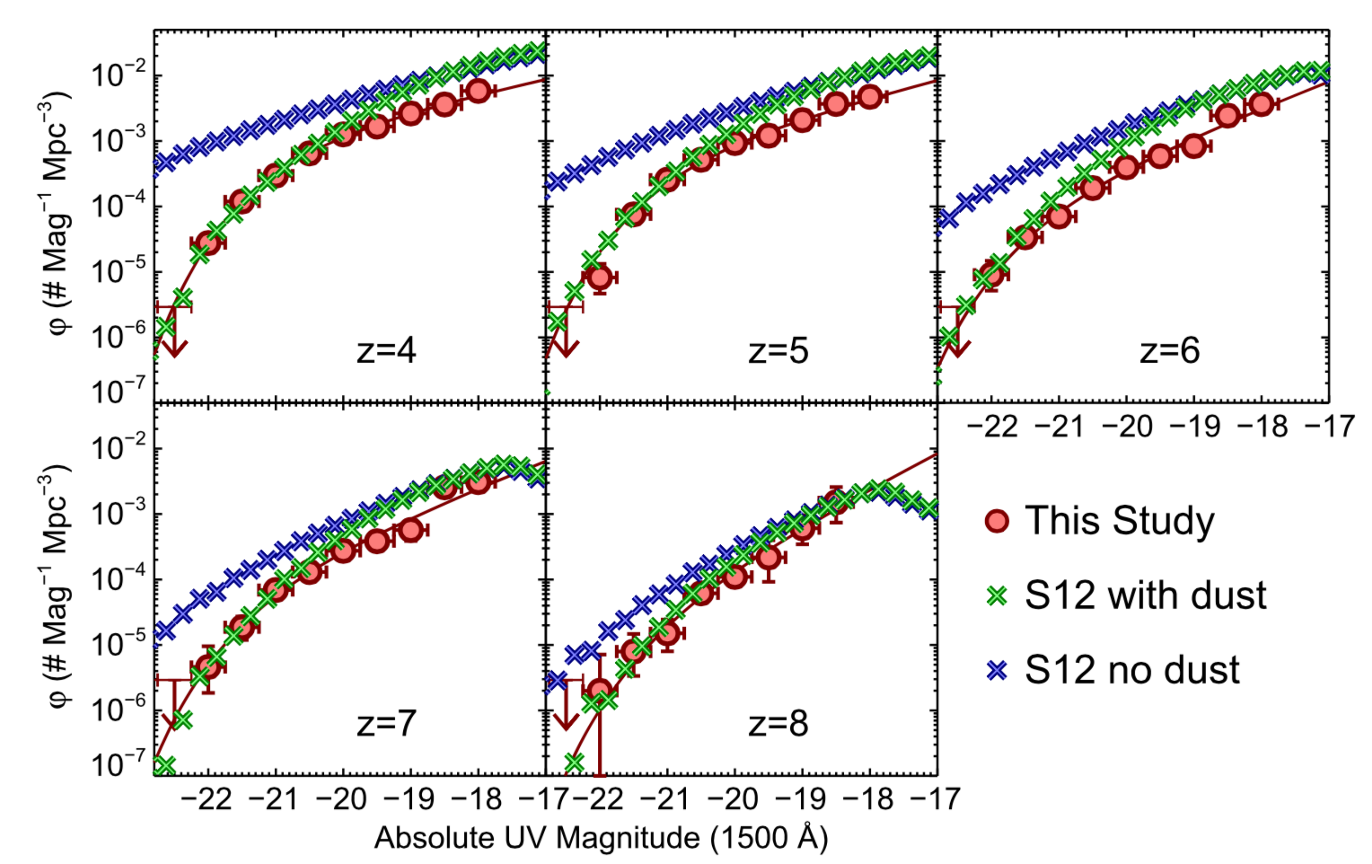
Numbers compared to plausible surveys with JWST & WFIRST



WFIRST is capable of exploring the bright end of the LF to redshifts z~13

Dust

The effect of dust?



Finkelstein+15

Somerville+12 models with and without dust attenuation.
Empirical evolution: $\tau_{dust} \sim e^{-0.5z}$

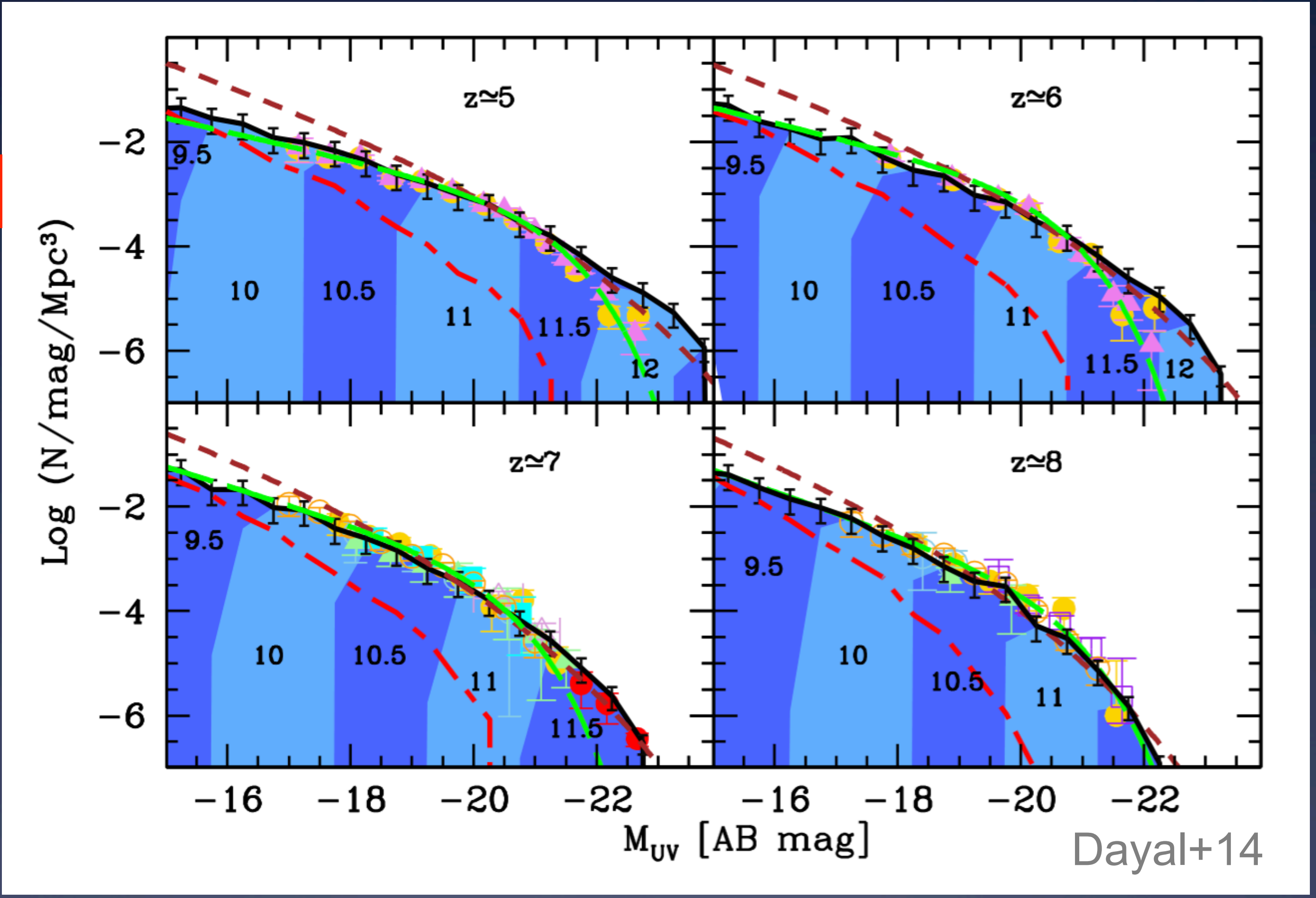
The effect of mergers (no dust)

Without mergers

With mergers

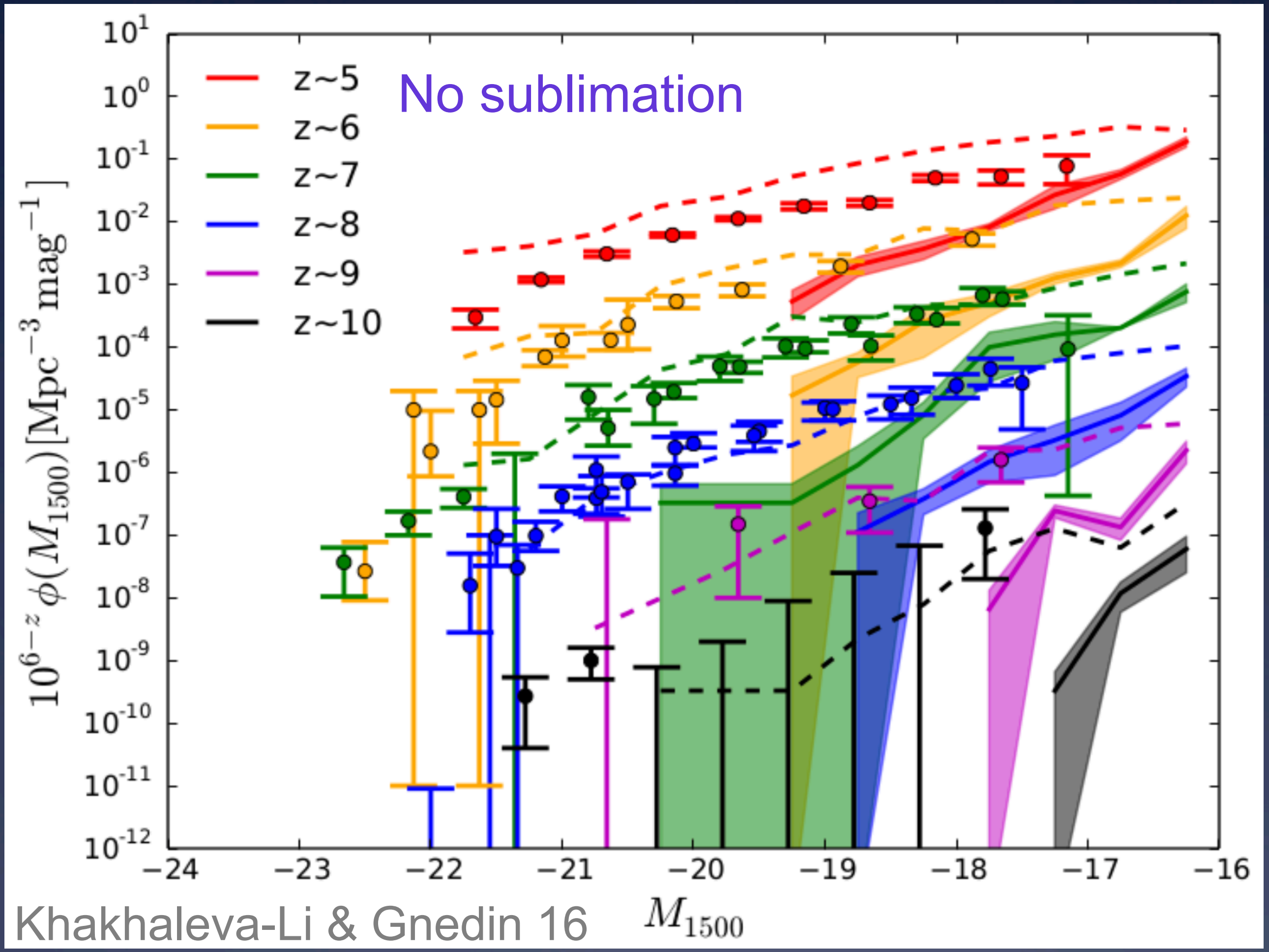
Constant SFE

Observed fit



SAM Regulated by gas accretion, mergers and SN feedback

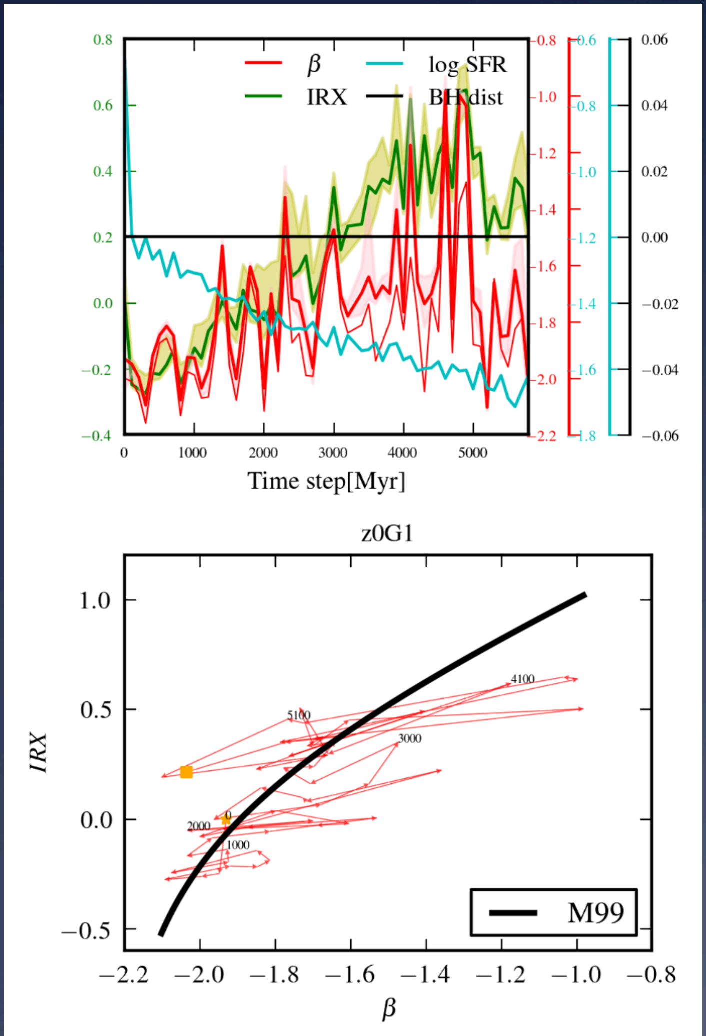
UVLF & Dust: second opinion



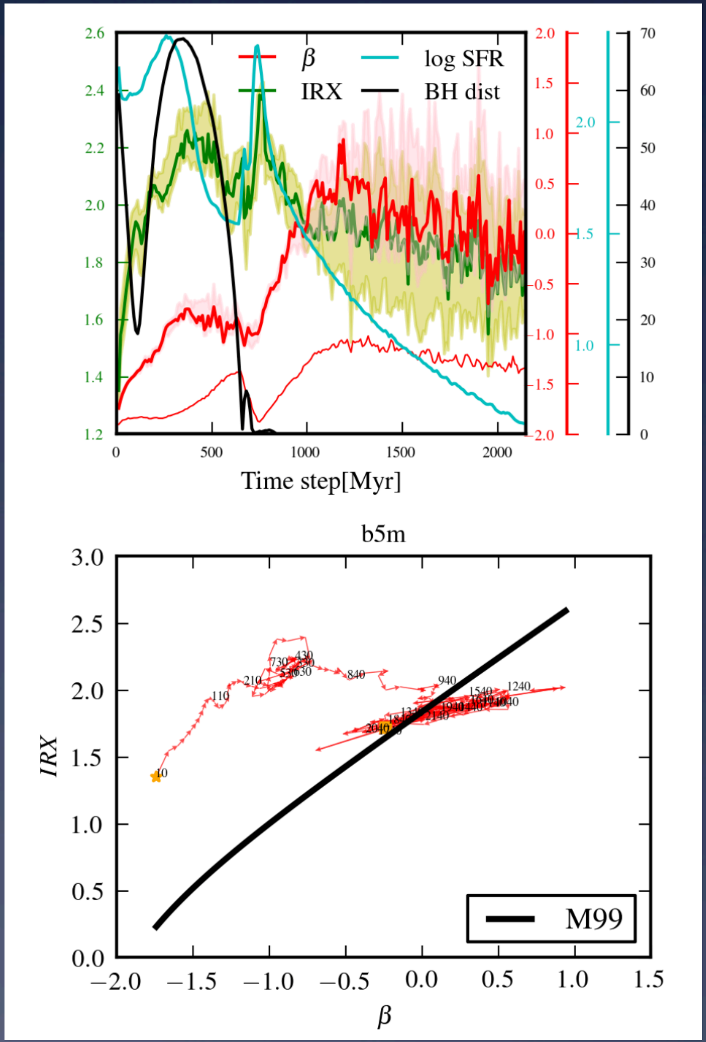
Dusty Radiative transfer
Dust creation & destruction

Time-dependent dust effects

z=0 isolated disk



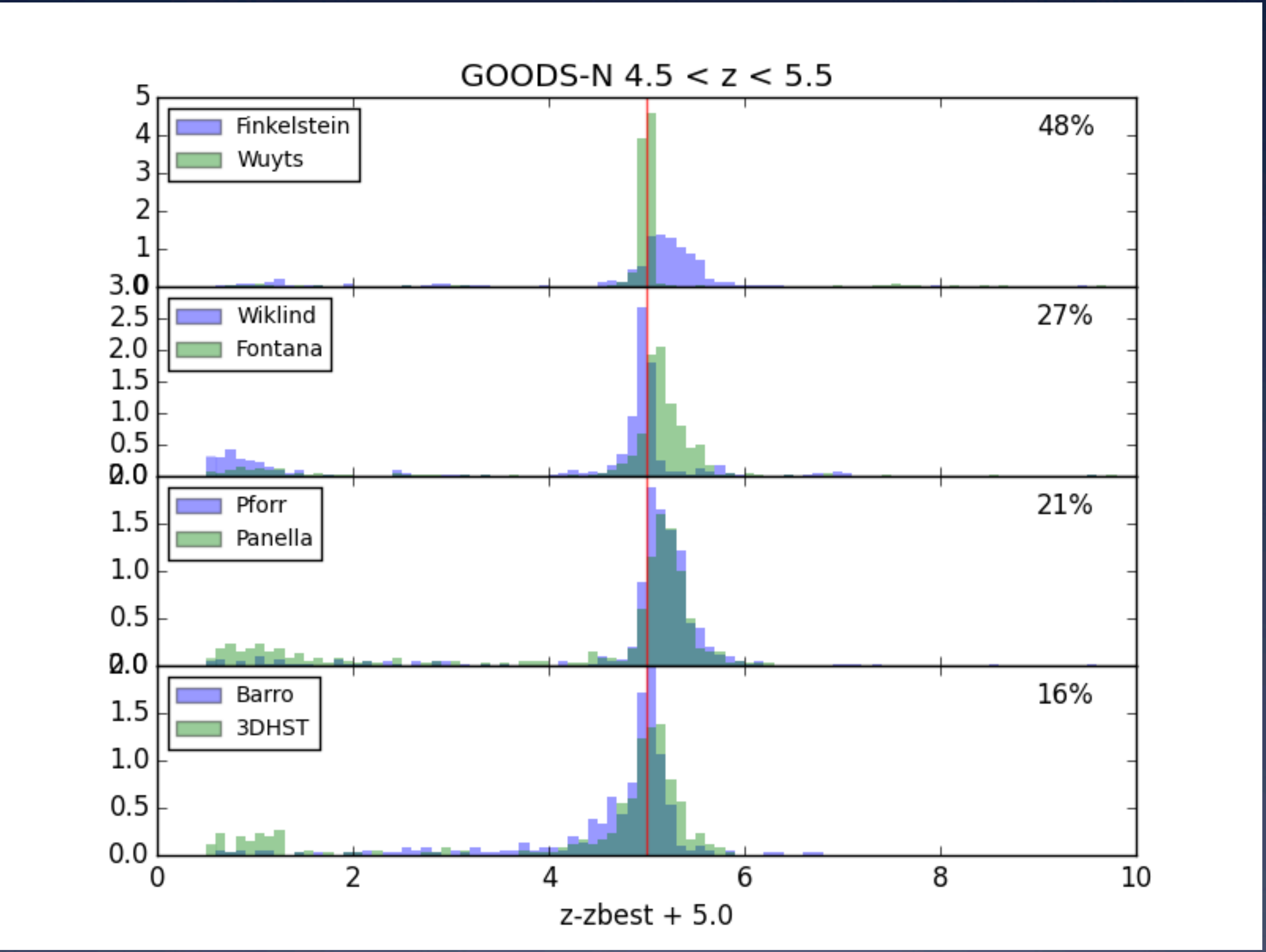
z=3 merger



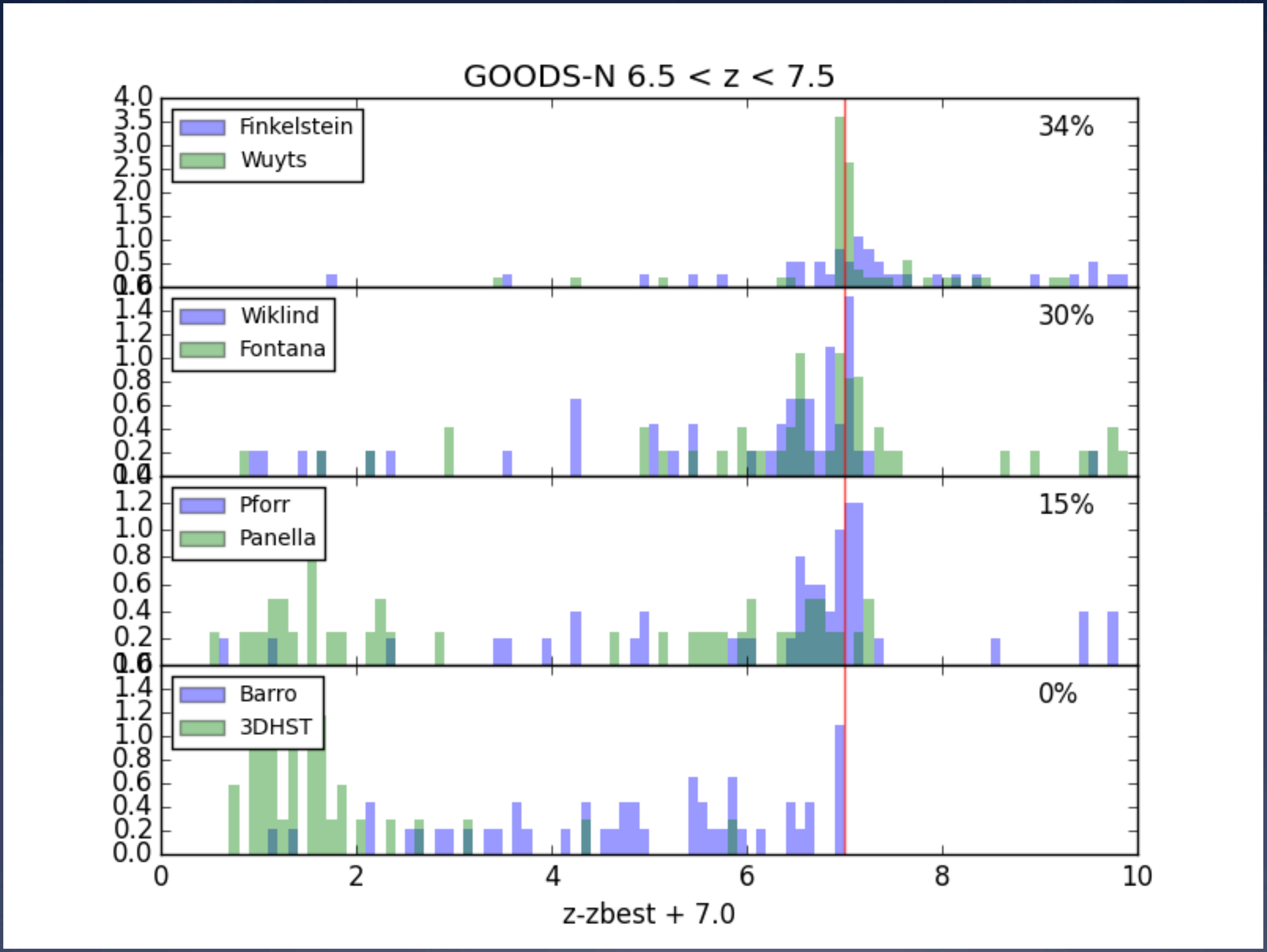
Safarzadeh+16 in prep

Photometric Redshifts

Comparison of photz estimates



Comparison of photz estimates



High-z photometric redshifts need to improve

- WFIRST offers
  - Wide-field grism
    - Hα, [OII], [OIII] $0.7<z<4$ (longer λ 👍)
    - Lyα $8<z<14$ (shorter λ 👍)
  - Ability to calibrate via clustering vs JWST spectroscopic samples
  - Longer wavelengths than HST
  - Synergy with LSST for shorter wavelength photometry

Considerations for WFIRST

- Investigation of quenching at early times requires large-area near-IR surveys.
- Ideally in time for followup with JWST
  - Longer-wavelength observations important for constraining dust
- This topic favors extending to longer λ
  - Better constraints on Balmer break
- Need to improve photo-z estimation at high redshift
- Magnification bias likely to be important