UCLA UCSB

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Sesto, 14 Jan 2016

Modelling Galaxy Luminosity Functions Before the Epoch of Reionization

with Michele Trenti (U. Melbourne) & Tommaso Treu (UCLA)
+ the BoRG and GLASS teams

GLASS

WFC3 BoRG SURVEY

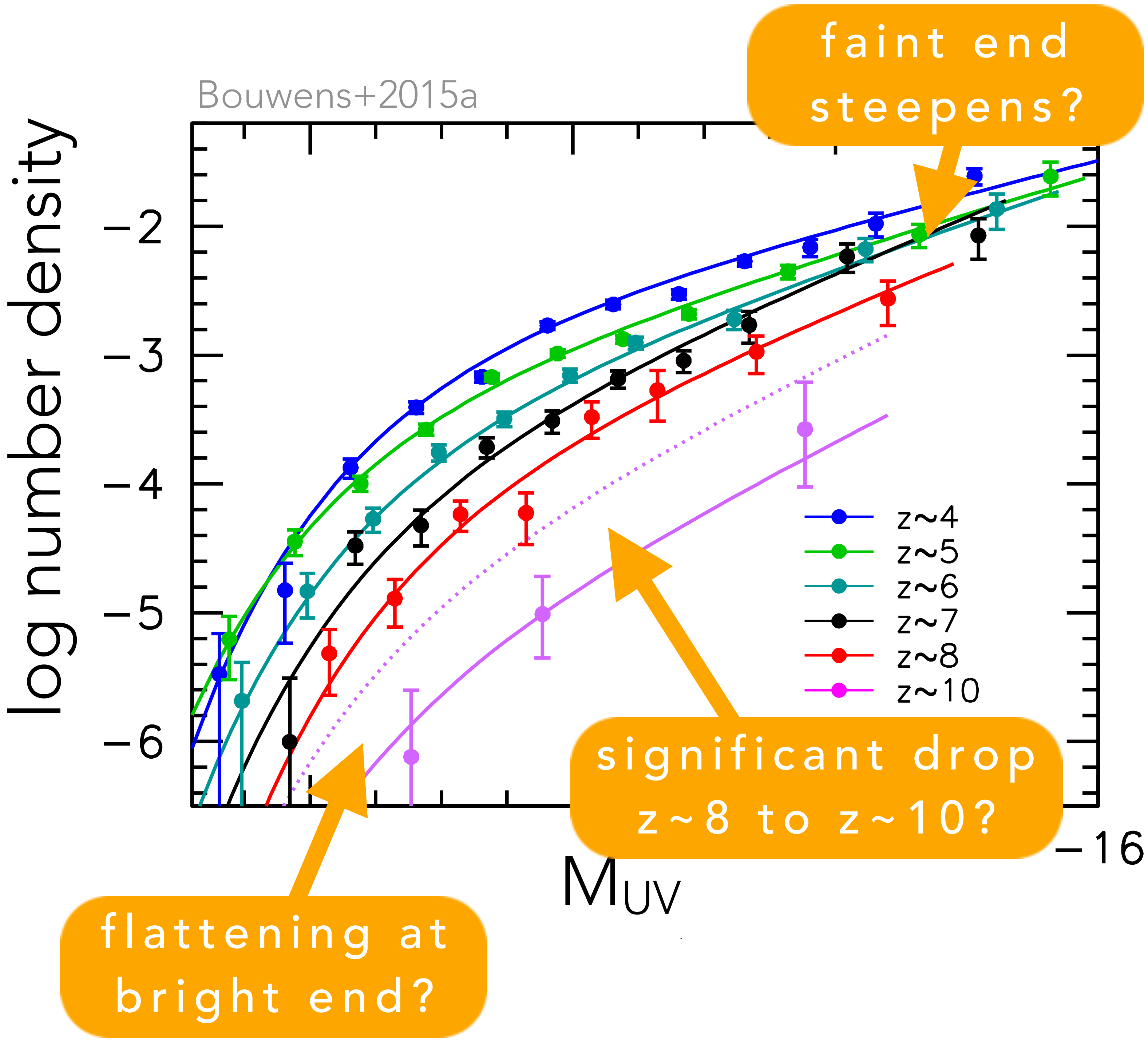
Malvarez (2009)

UV Luminosity functions are one of our best tools for studying high z galaxy populations and their evolution

Rest frame UV light traces **star forming galaxies**

Provides constraints on galaxy formation and evolution models

Can be **integrated to find the flux of ionizing photons** available to reionize the universe



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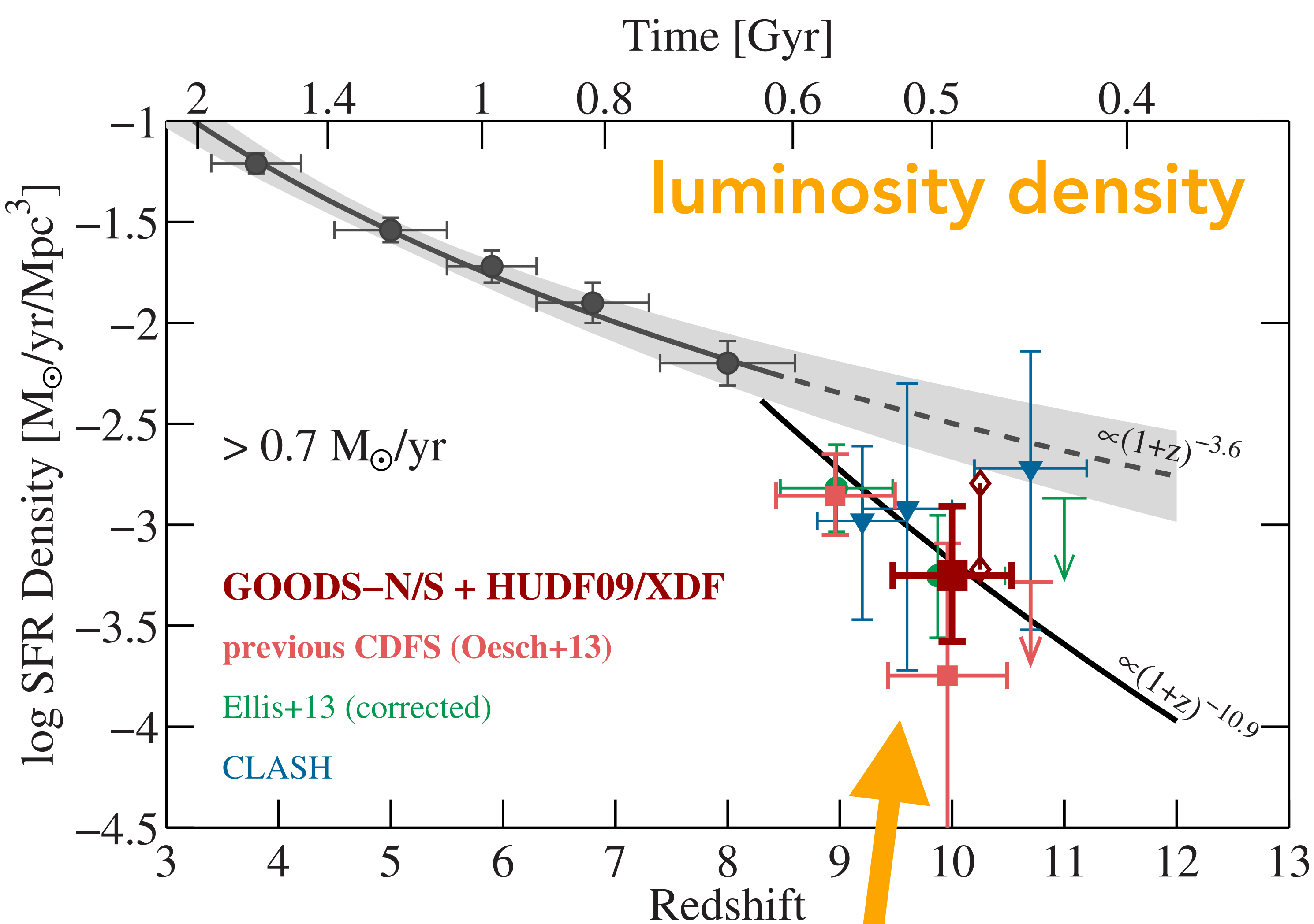
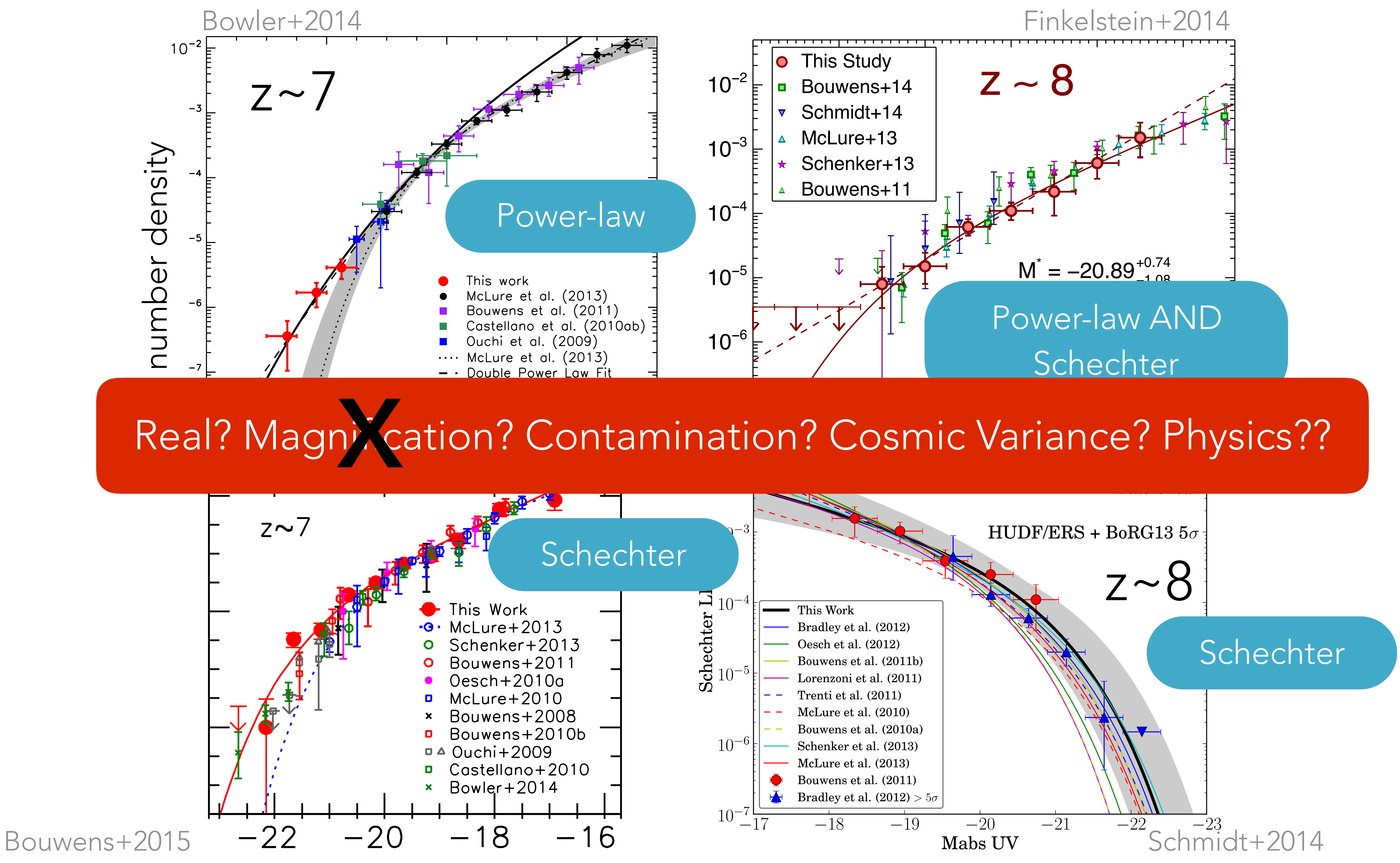


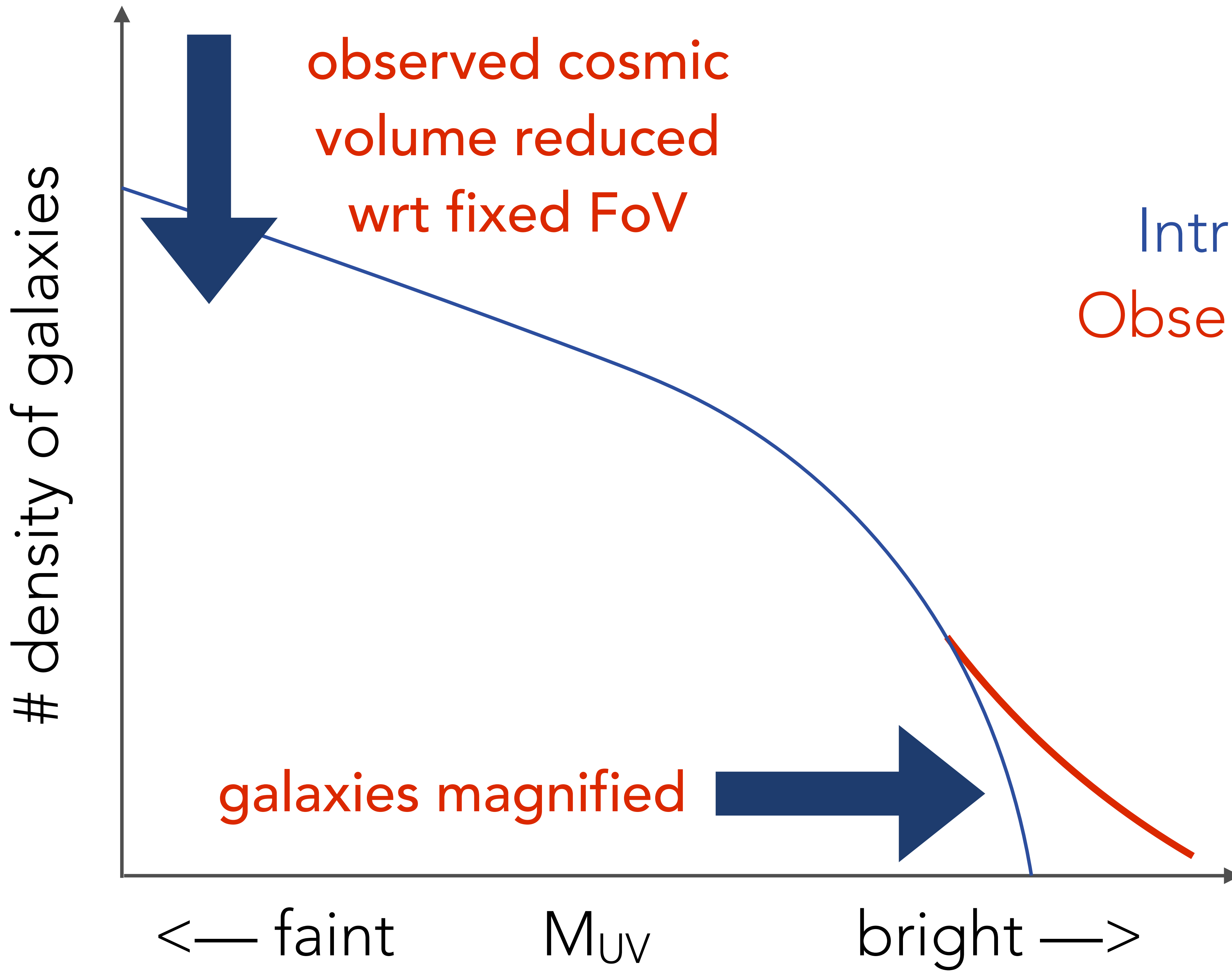
Oesch+2014

significant drop z~8 to z~10?

Are we observing hints that the LF changes form at high redshift?

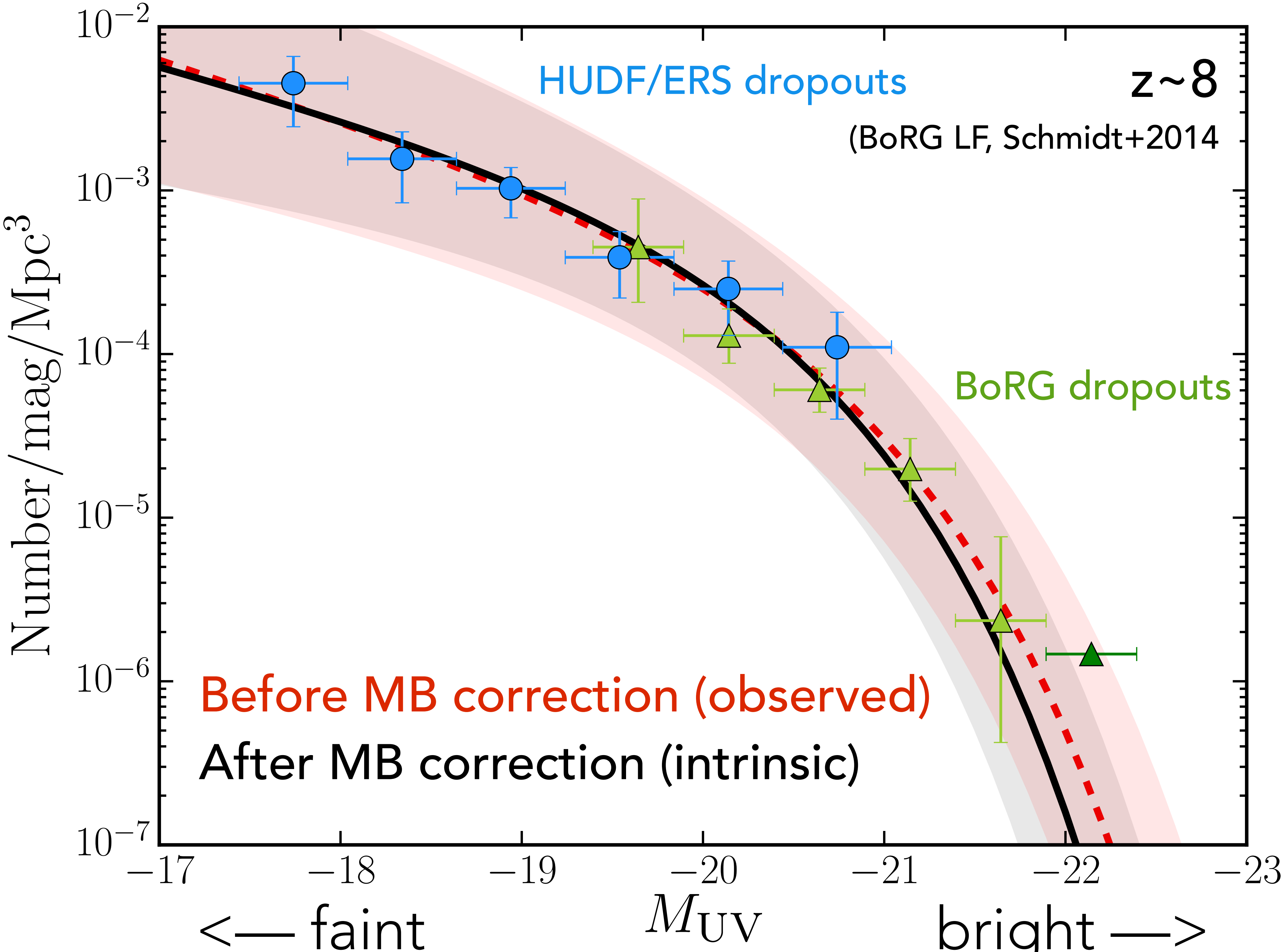


Gravitational lensing in blank fields (*magnification bias*) distorts the bright end of the luminosity function in flux-limited surveys



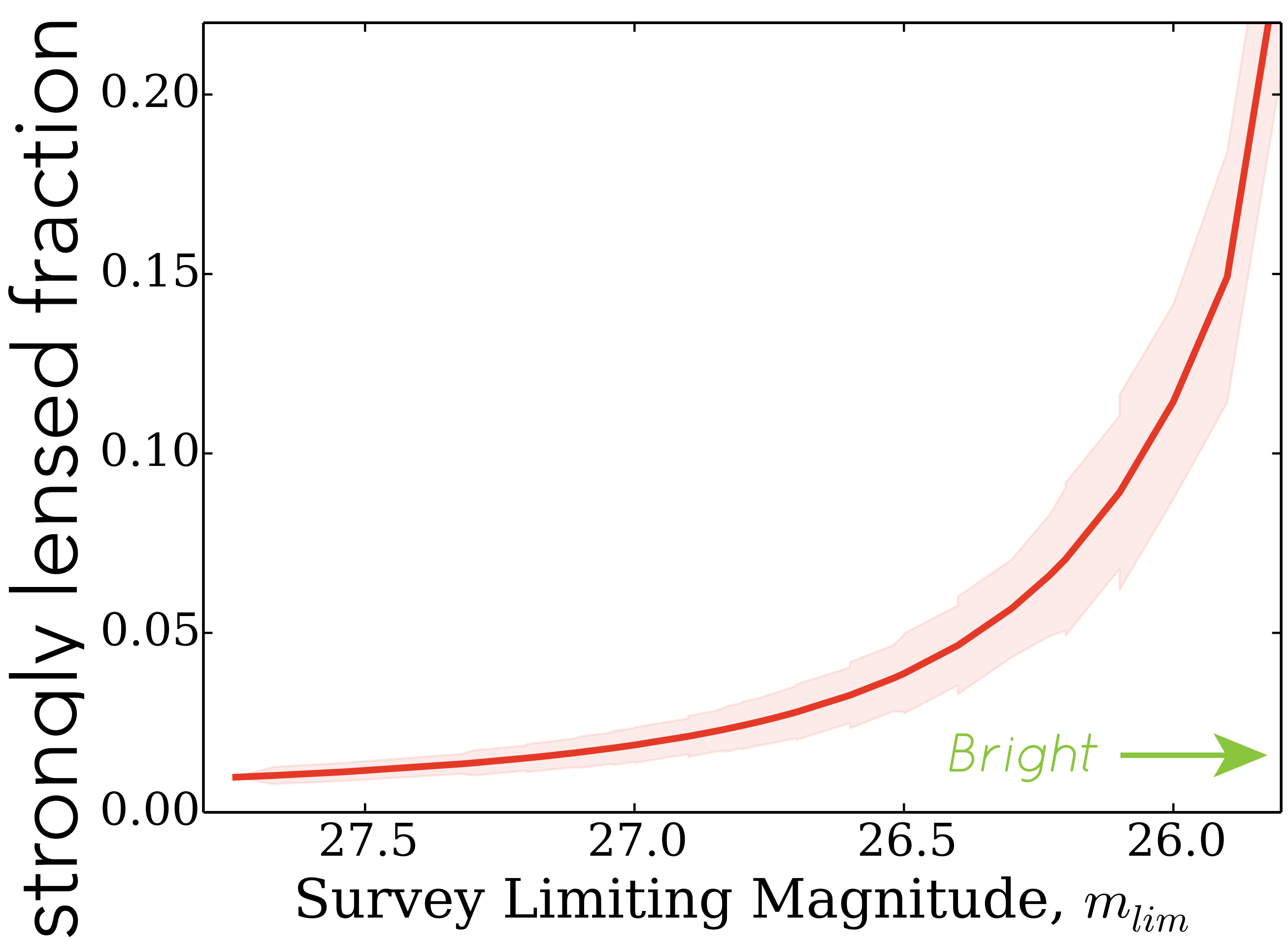
Turner+1984, Wyithe+2001,2011

Bayesian approach to account for magnification bias
- it is not significant for current estimations of the LF

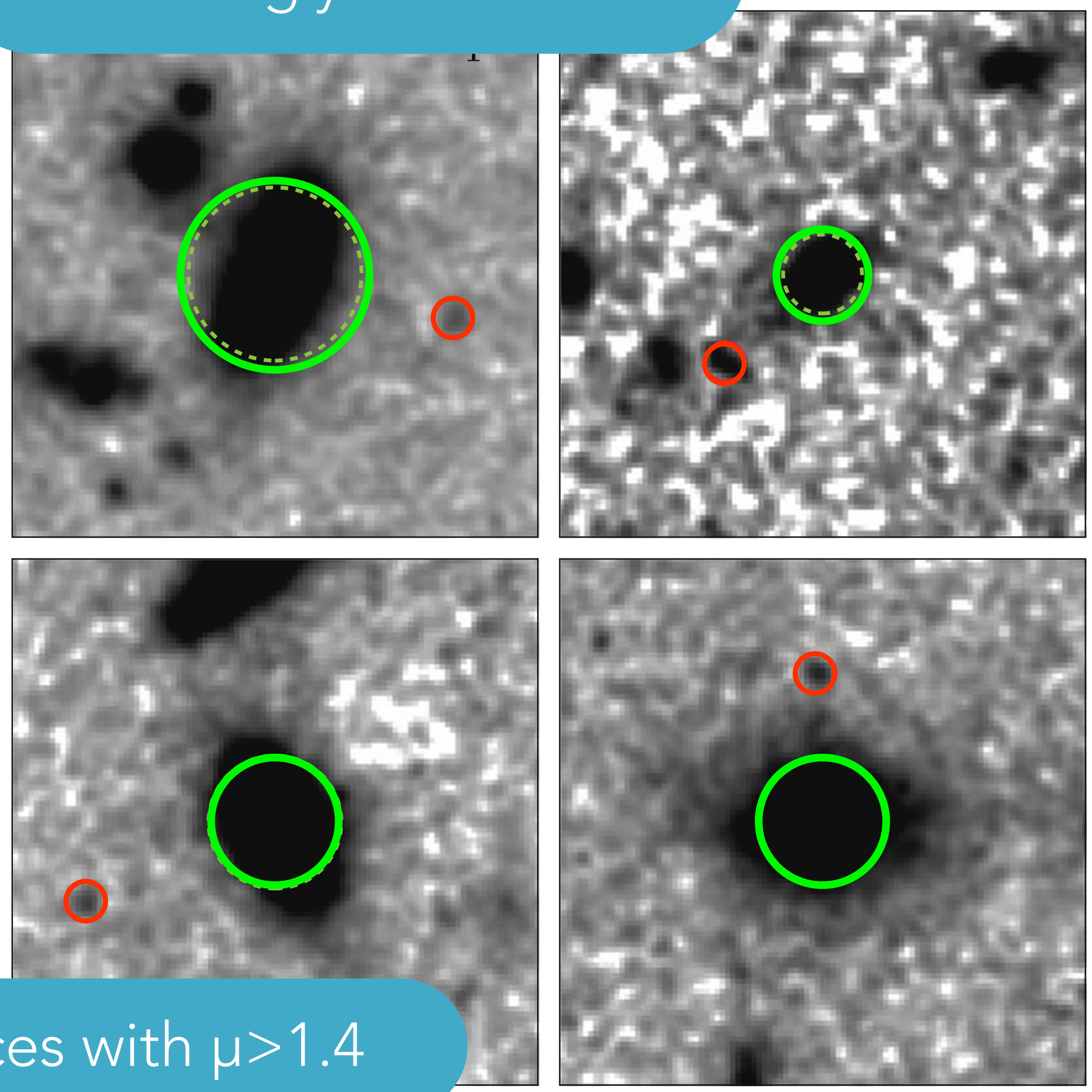


Mason+2015a

But >20% of galaxies in shallow surveys could be strongly lensed
- this will dominate wide-area surveys (Euclid, WFIRST)



2/38 BoRG z~8 sources strongly lensed?



+3 sources with μ>1.4

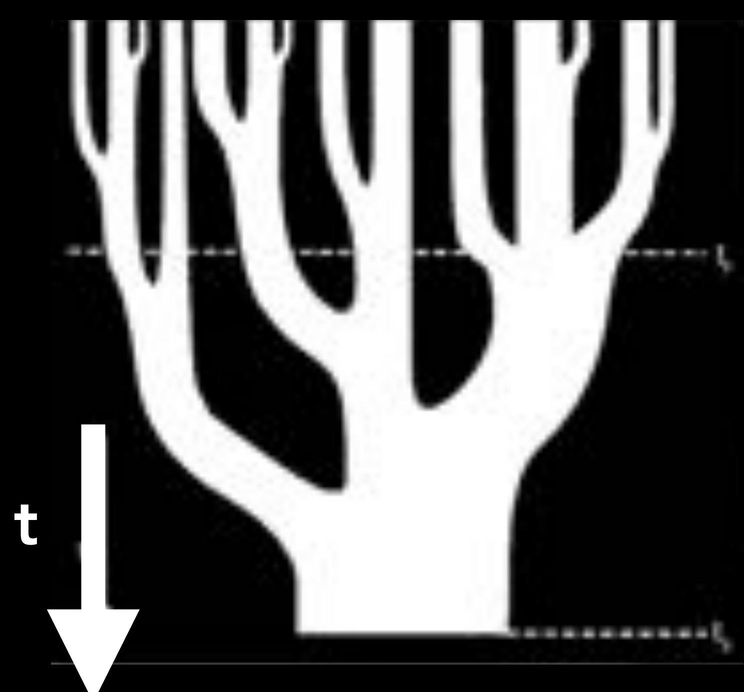
Mason+2015a, Barone-Nugent+2015

Lots of questions...

- What is driving the evolution of the LF?
- Why does the luminosity density drop at $z>8$?
- What's happening at the bright end of the LF?
- Are there enough faint galaxies at $z>6$ to reionize the universe?
- Can we make reasonable predictions for LFs
  at high z when growth is rapid?
- What will JWST see?

What drives evolution in the LF?

halo mass function + star formation + physical conditions (feedback/ dust)?



What is the simplest theoretical model to connect halo growth to star formation?

- minimal degrees of freedom
- self-consistency over redshift

$$\mathrm{SFR}(M_h, z) \sim M_h \times \boldsymbol{\varepsilon}(M_h) \times \text{gas accretion rate}$$

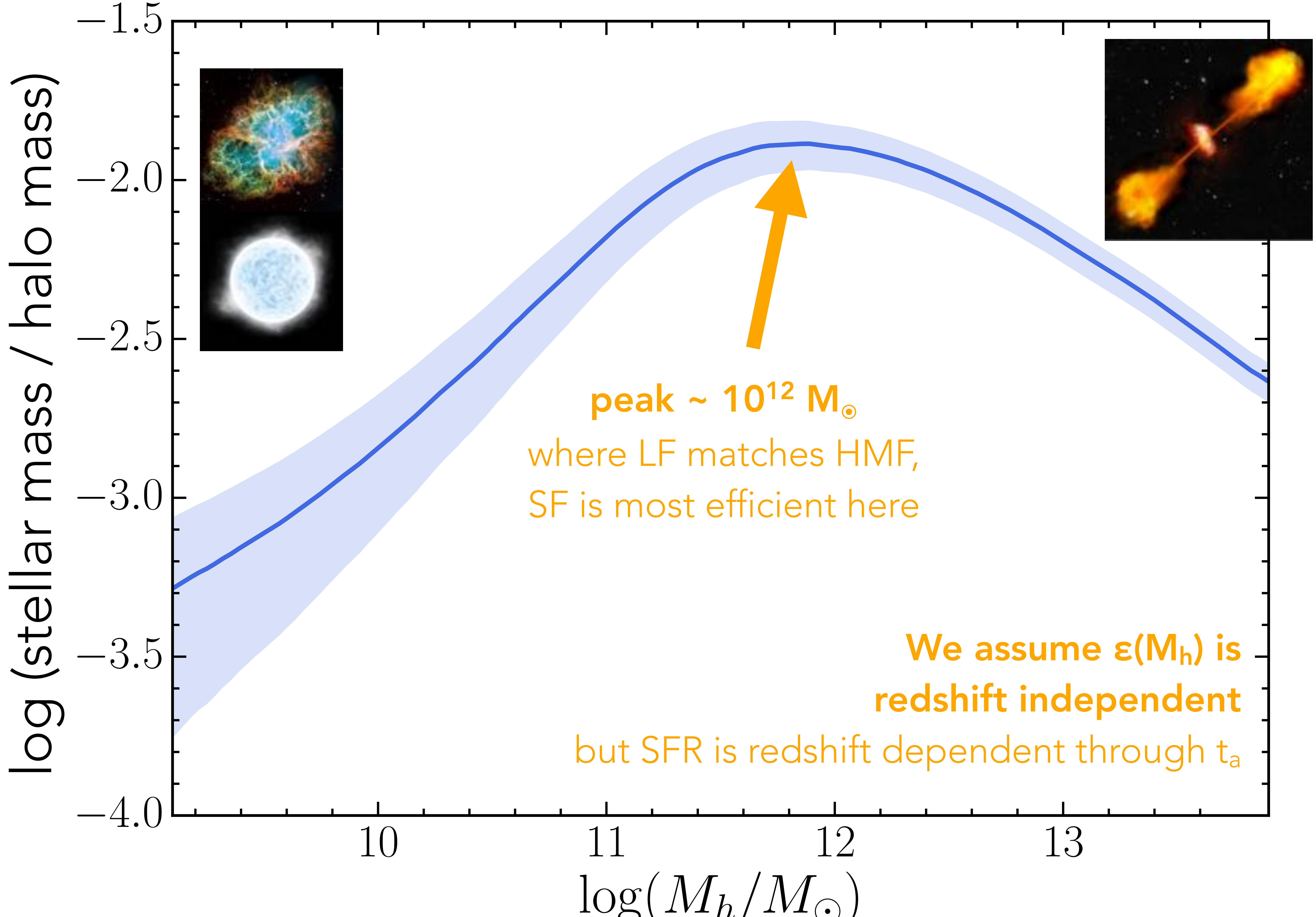
halo mass
from cosmology

SF efficiency ~ $M_\star/M_h$
fixed from calibration
at one redshift
very weakly evolving
(Behroozi+2013)

assume gas follows DM
~1 / halo assembly timescale
from cosmology
(Planck ΛCDM + ellipsoidal collapse,
Sheth+2001 Lacey & Cole 1993)

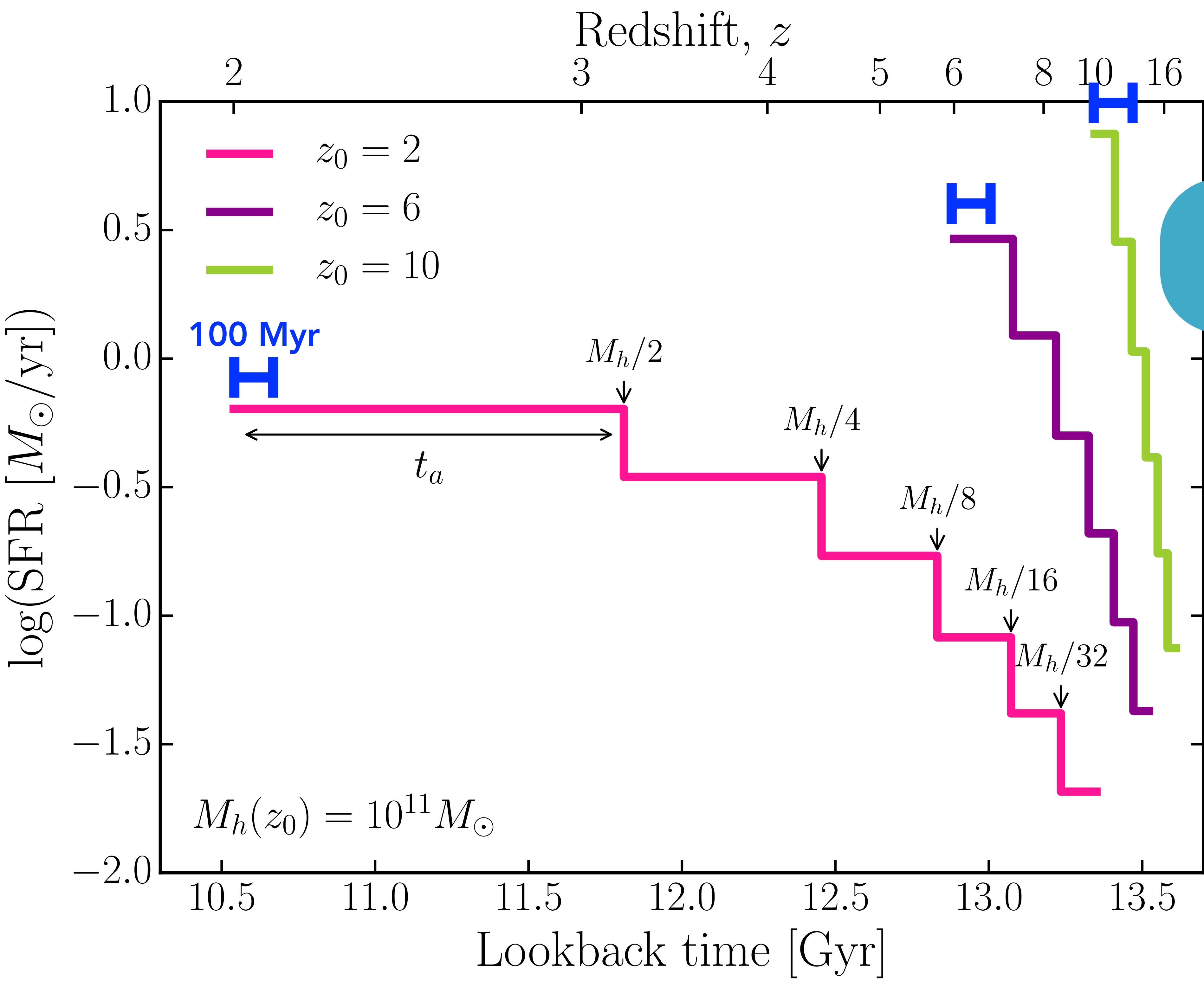
Trenti+2010, Tacchella+2013, Mason+2015b

Calibrate once at z~5 to find SF efficiency ε(M_h),
by abundance matching observed LF to theoretical HMF



Mason+2015b

We model star formation histories as a series of epochs of constant SFR as halos grows in mass



Star formation is rapid at high z

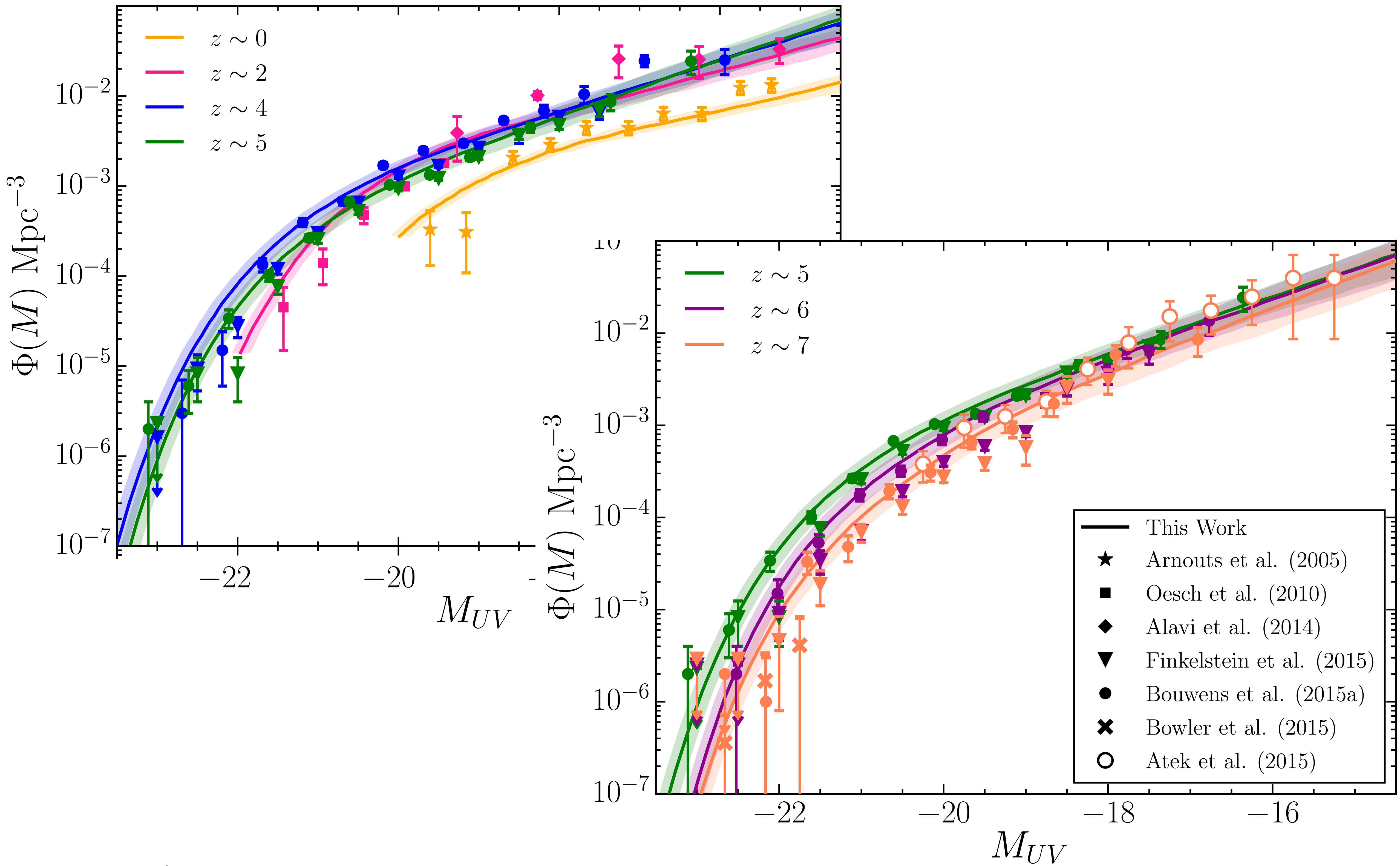
Smoothly rising SFHs (Finlator+2011, Papovich+2011; Behroozi+2013b; Lee+2014)

Mason+2015b

Luminosity functions are generated through simple assumptions

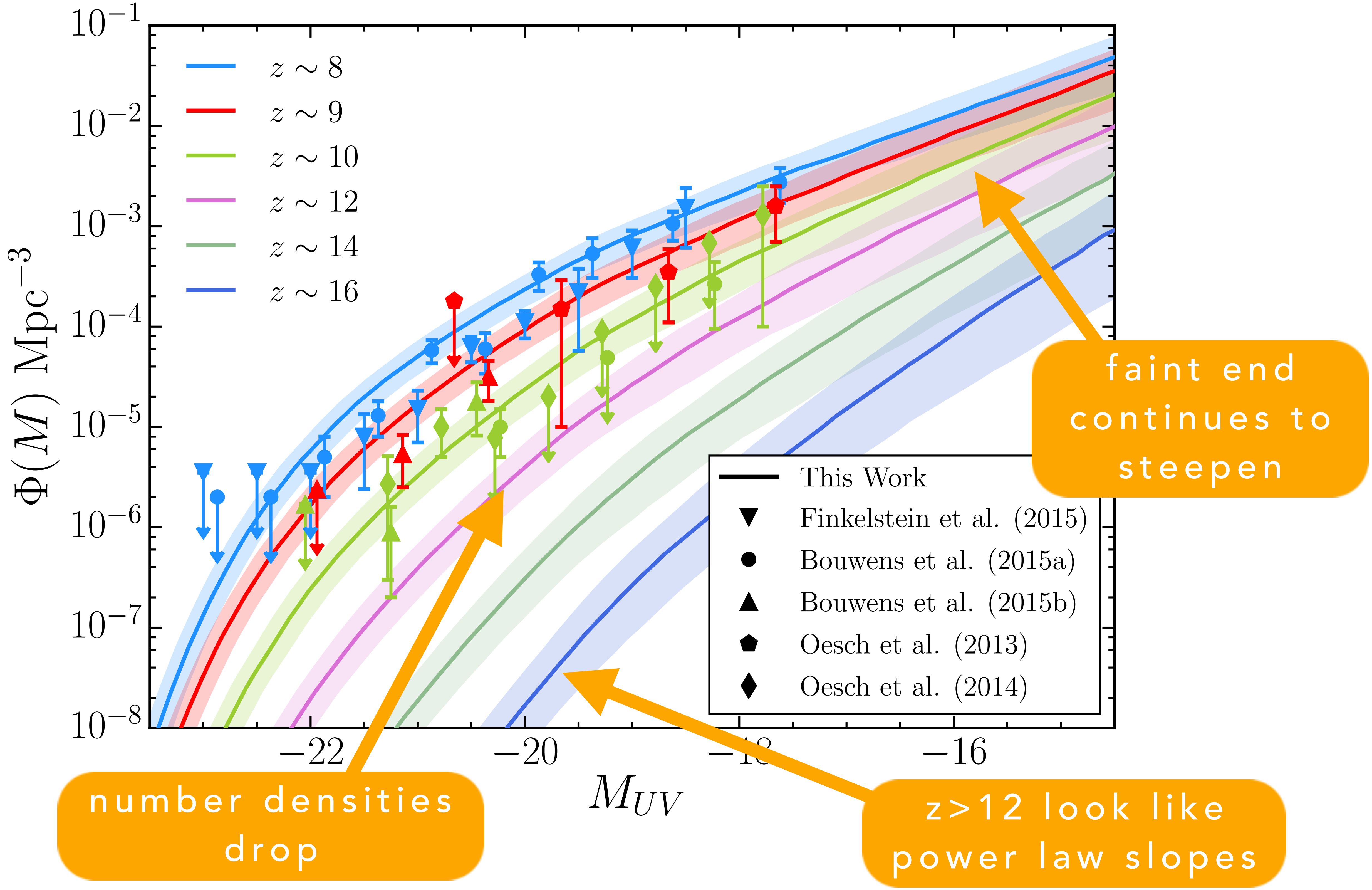
- Integrate SFR with Bruzual & Charlot (2003) SSP over their ages
  - Salpeter IMF 0.1 - 100 $M_\odot$
  - $Z = 0.02\ Z_\odot$
- Dust included by Meurer+1999 extinction correction from observed UV β
  - Fit Bouwens+2009,2014 β
    - extrapolate and interpolate over z
    - assume a Gaussian distribution of β at each M_{UV}

Our simple model is remarkably **consistent with observed luminosity functions over 13 Gyr of cosmic time!**



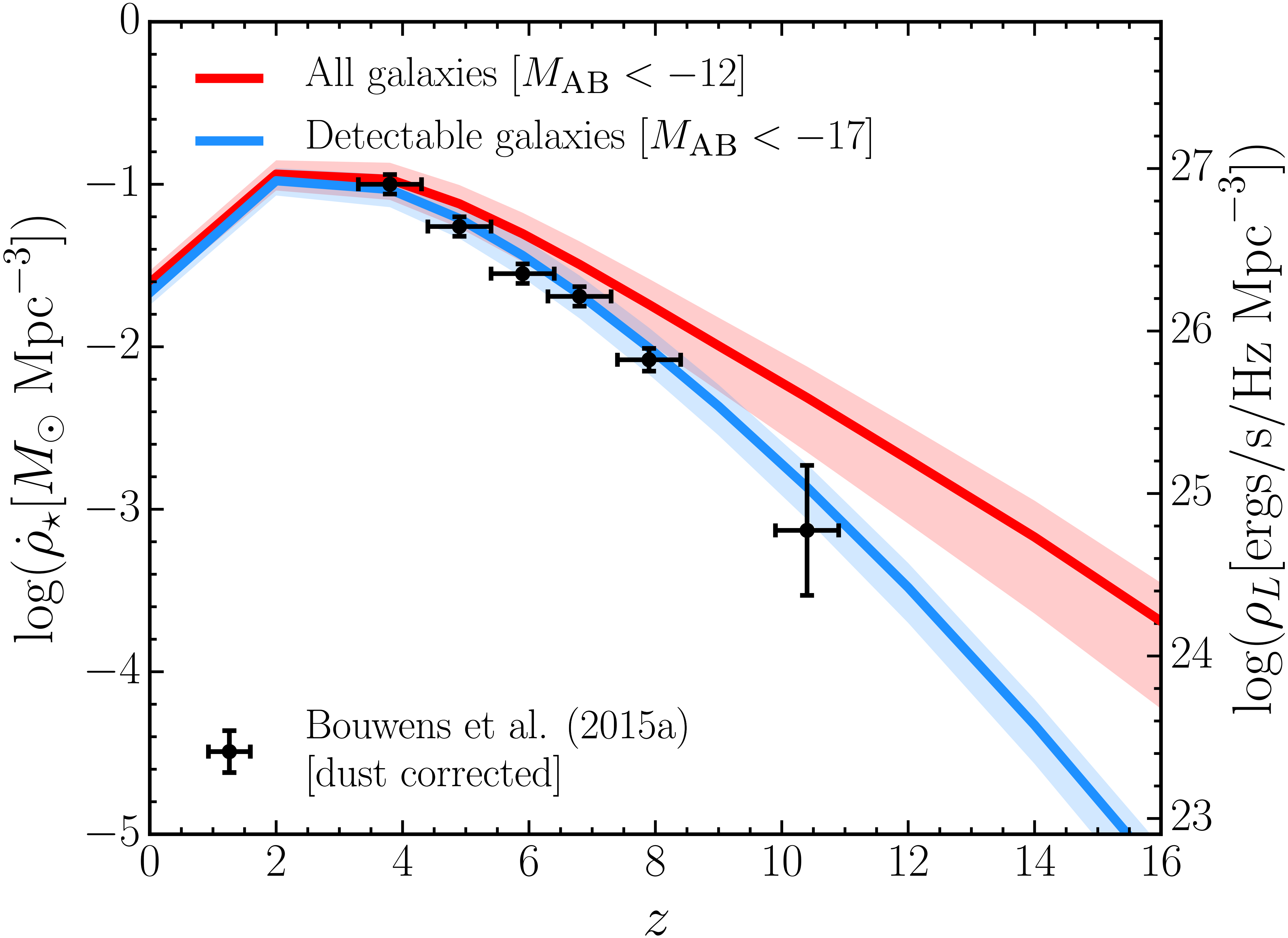
Mason+2015b

During and before Reionization the LF continues to evolve **without requiring any evolution in physical conditions**



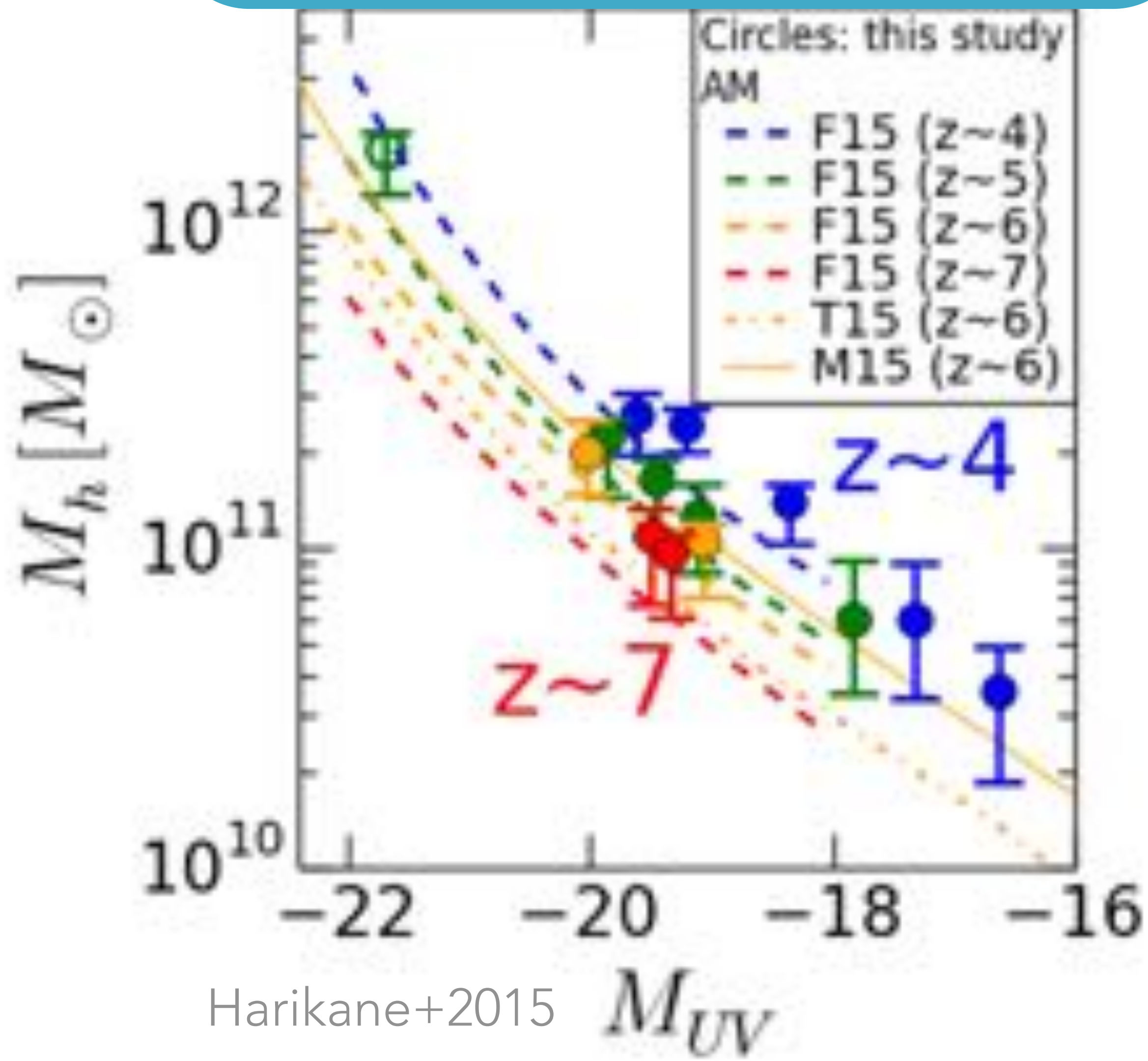
Mason+2015b

Drop in luminosity density explained by steepening of LF —
shift of star formation towards less massive galaxies



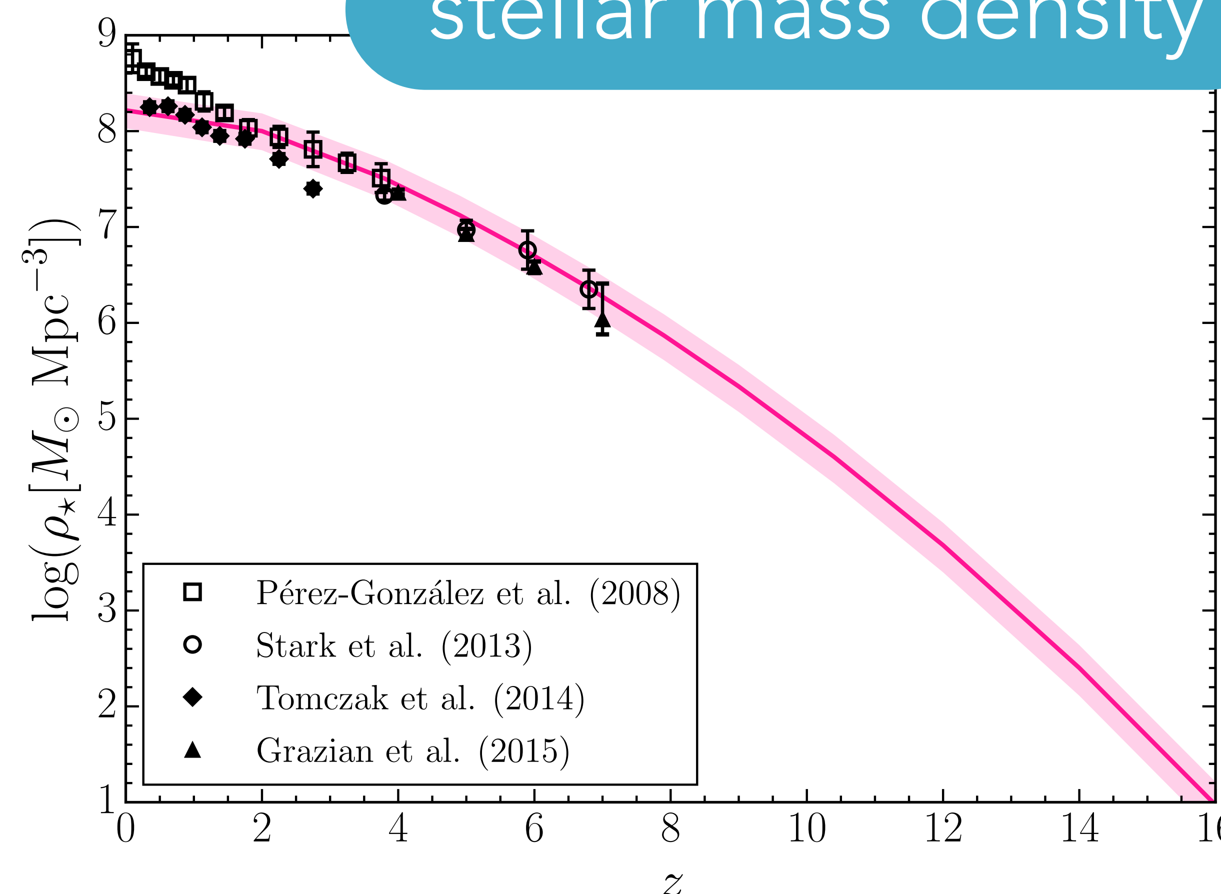
Other global galaxy properties we predict are consistent with observations

L(Mh,z) - from clustering



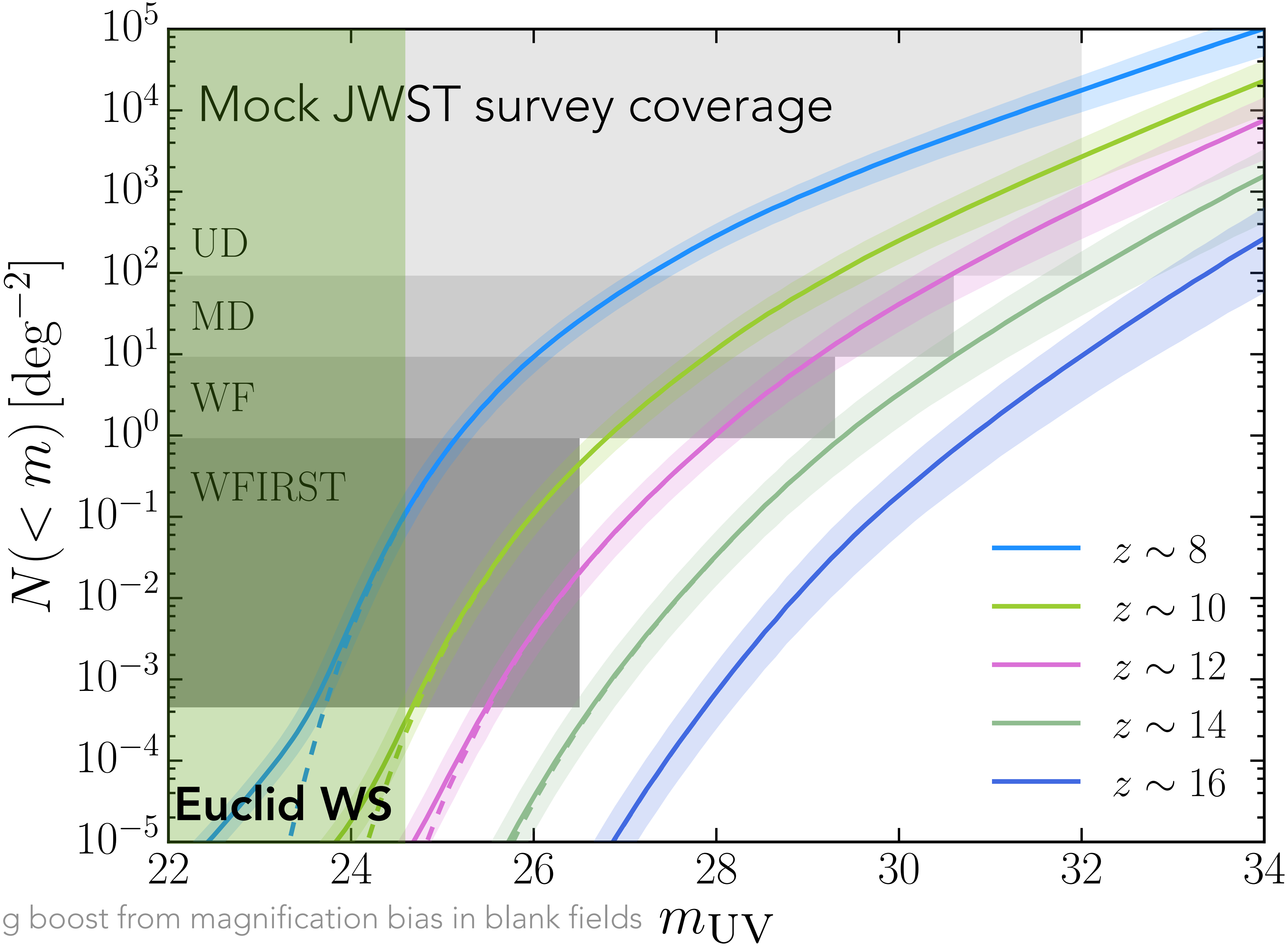
Harikane+2015

stellar mass density



Mason+2015b

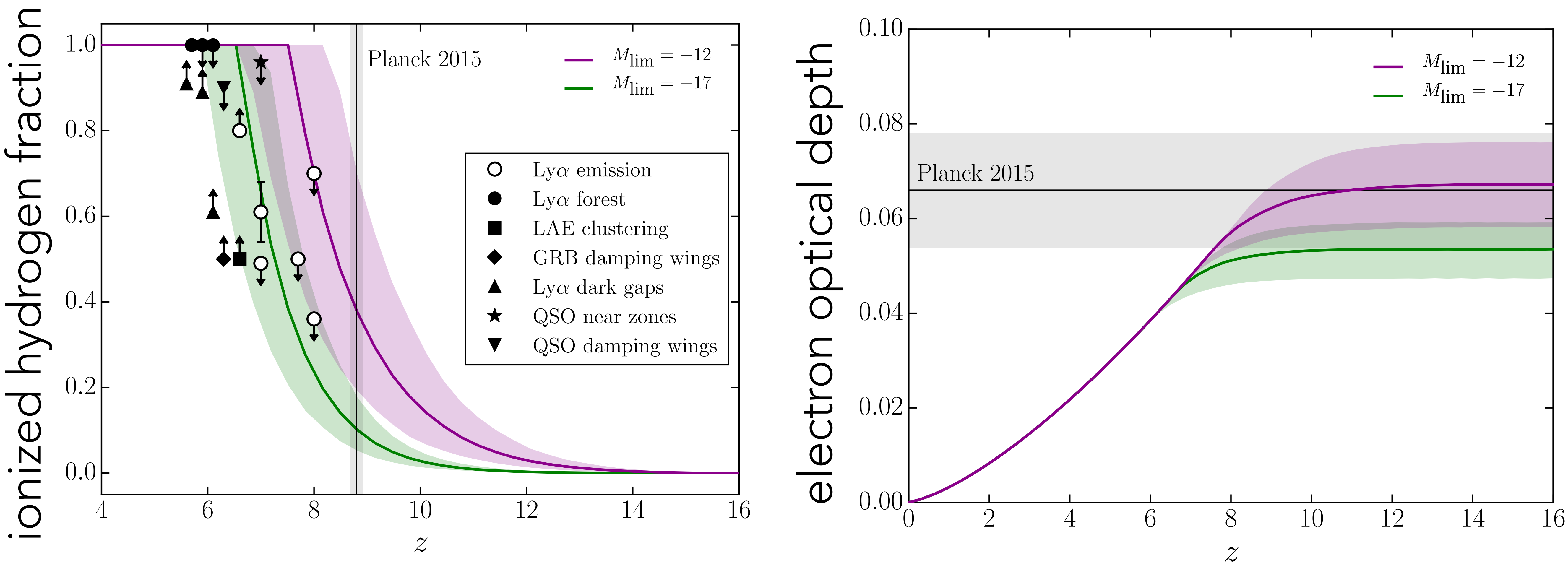
JWST + WFIRST will detect galaxies at z<~14,
impossible without strong lensing (clusters) at z>~15



Including boost from magnification bias in blank fields
(Wyithe+2011; Mason+2015a)

Faint galaxies are probably needed to reionize the universe

all galaxies
detectable galaxies



Mason+2015b

f_{esc} = 0.1 - 0.3

C = 1 - 6

log ξ_{ion} ~ 25.2

We are expanding the search for Lyα emission at z>7 by exploiting the power of cluster lenses

GLASS

(PI Treu) Extensive follow-up ongoing:

Keck DEIMOS and MOSFIRE (PI Bradač)

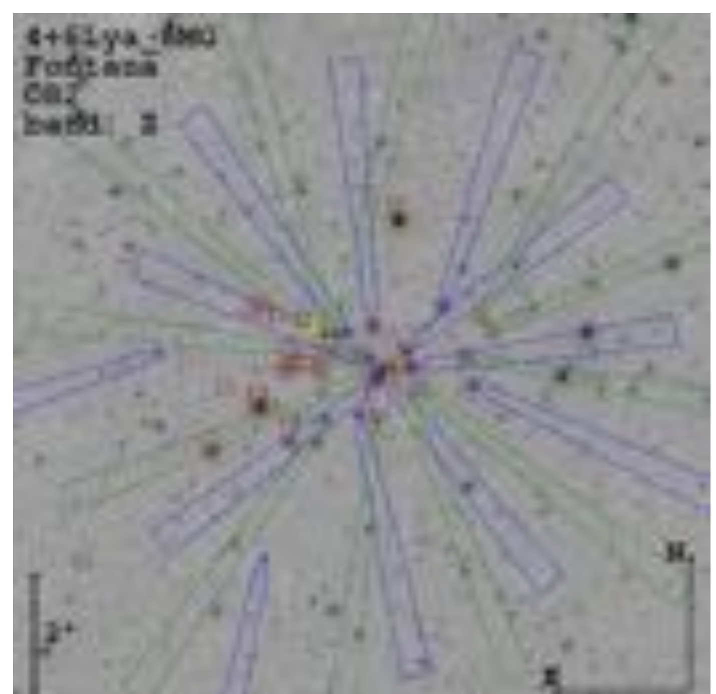
KMOS

VLT KMOS large program (PI Fontana)

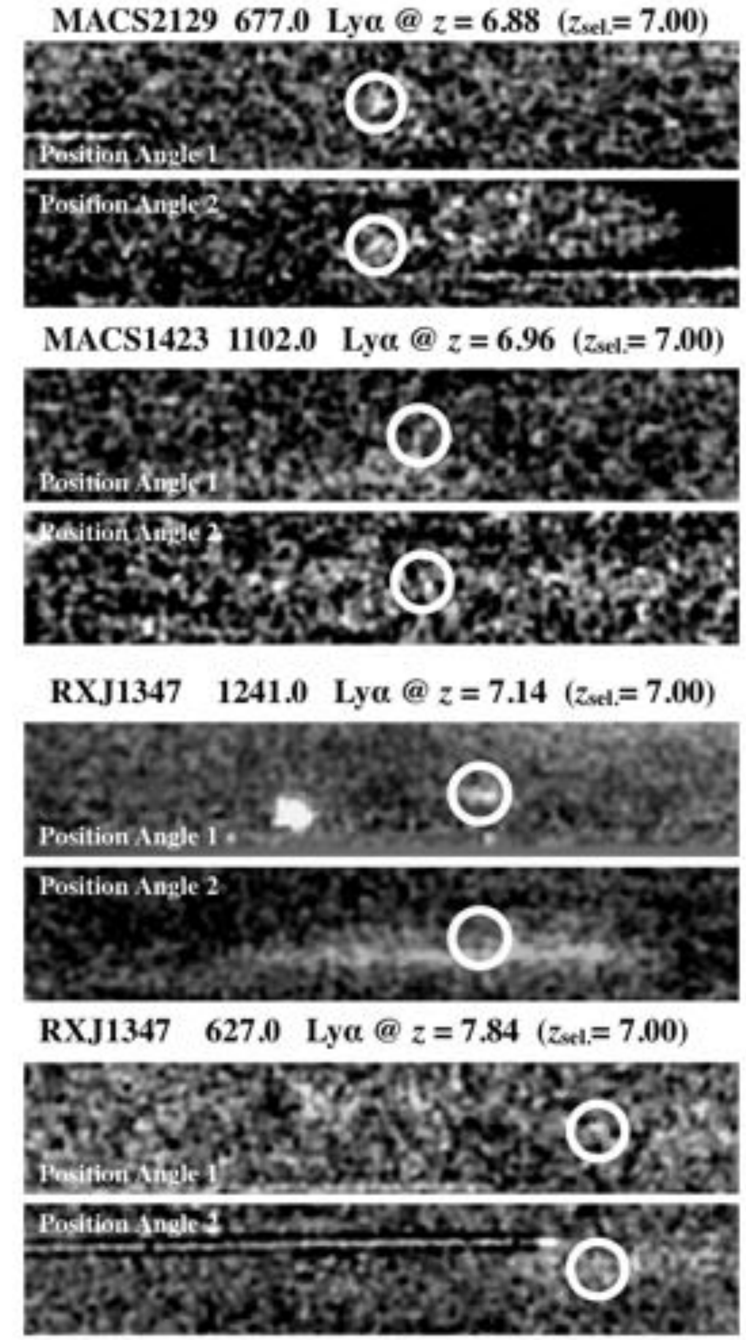
7 clusters - 20 hrs per cluster

~70 z>7 candidates
~25 with candidate emission lines

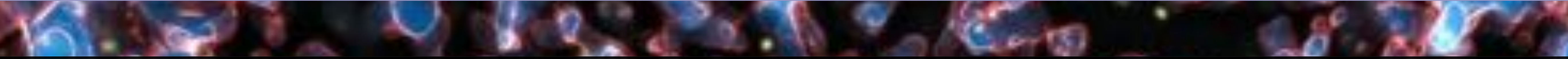
first results in the Spring…



High z Lya candidates



Schmidt+2015



Conclusions

Magnification bias distorts the brightest end of the LF

Watch out in shallow wide-area surveys!

UV LF and other global galaxy properties at $0 \lesssim z \lesssim 10$ can be easily modelled by assuming **halo growth is the dominant driver of galaxy growth**

No evolution of physical conditions/feedback is needed!

Drop in luminosity density of currently detectable galaxies $z > 8$ explained by **shift of star formation toward less massive, fainter galaxies**
— which will be hard for JWST to see at $z > 12$

Faint galaxies can reionize the universe
given current estimates of escape fraction and clumping factor

More Lyα emission constraints on reionization to come…