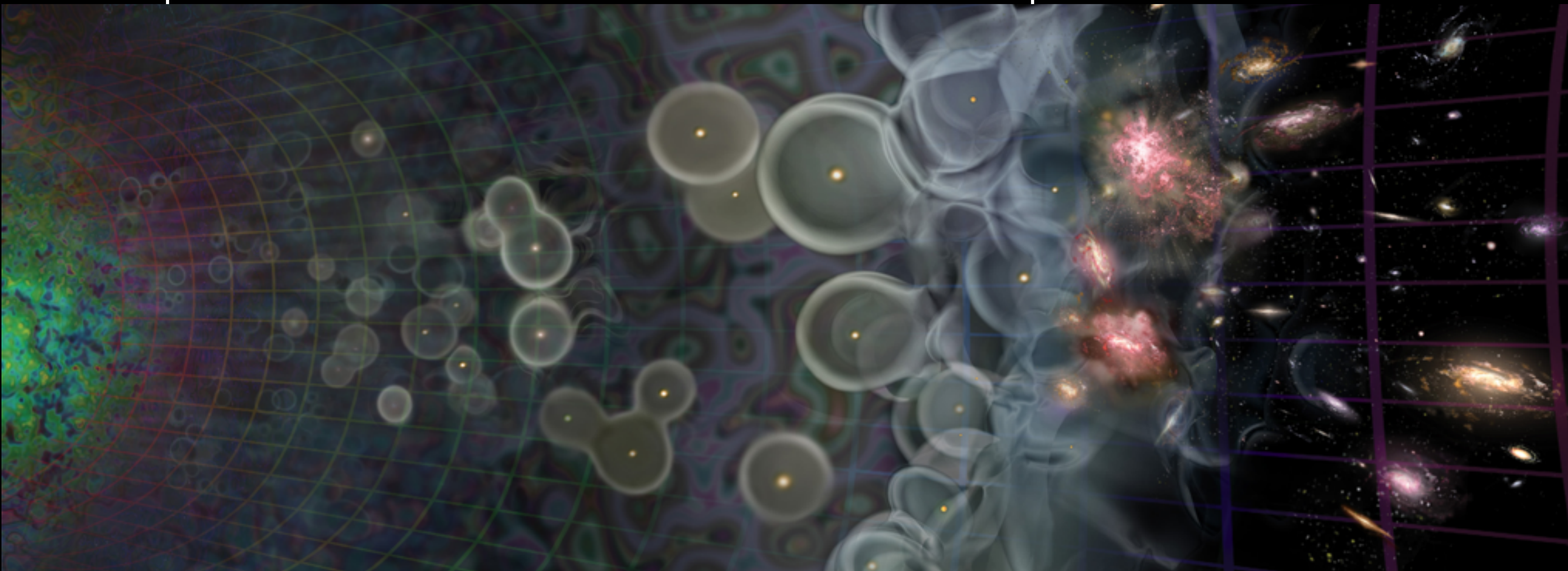
Galaxy formation and Evolution in the JWST Era

Hakim Atek

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

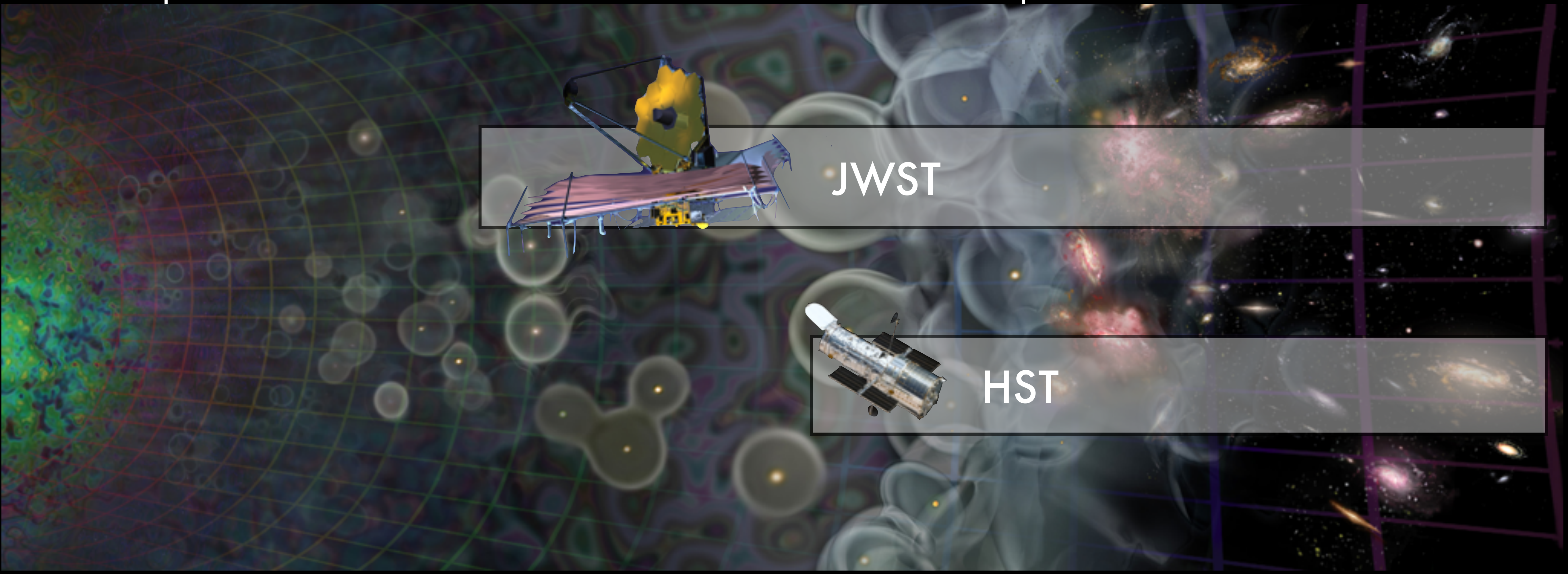
Ionized → | ← Neutral → | ← Ionized →



z=1100	z~30	z=10	z=6	z=2	z=0
Age = 0.3Myr	100 Myr	500 Myr	1 Gyr	5Gyr	13.7Gyr

CMB **Dark Ages** **Epoch of Reionization**

Ionized | Neutral | Ionized



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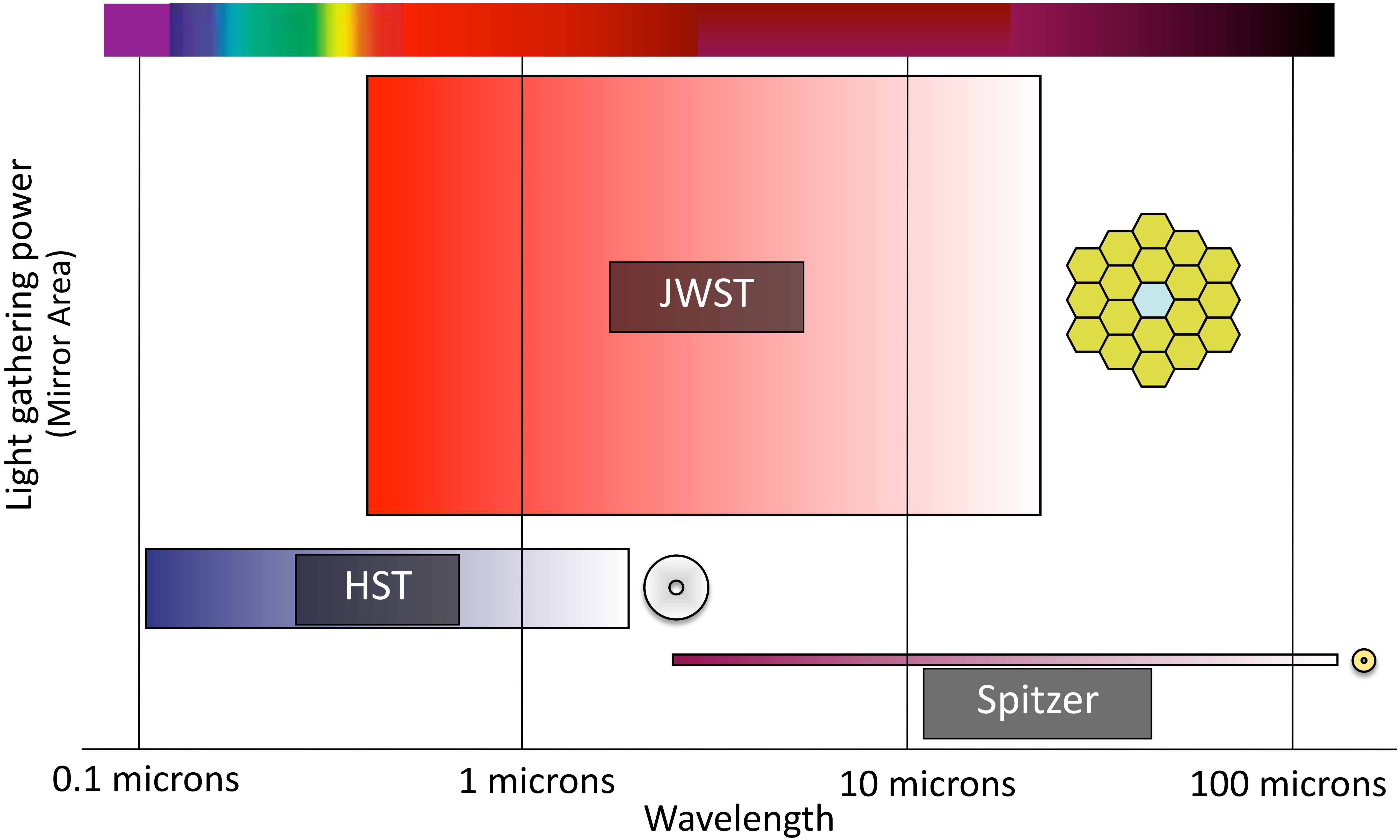
CMB **Dark Ages** **Epoch of Reionization**

JWST: a major stride in discovery power

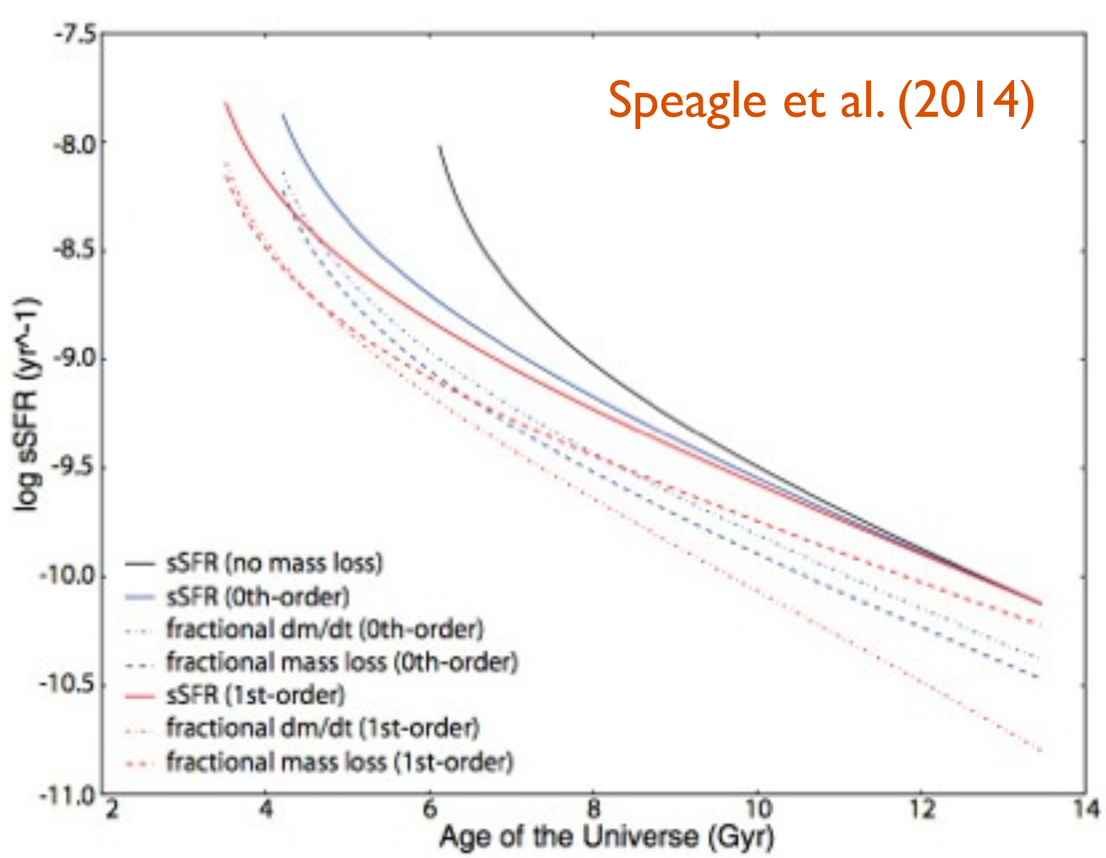


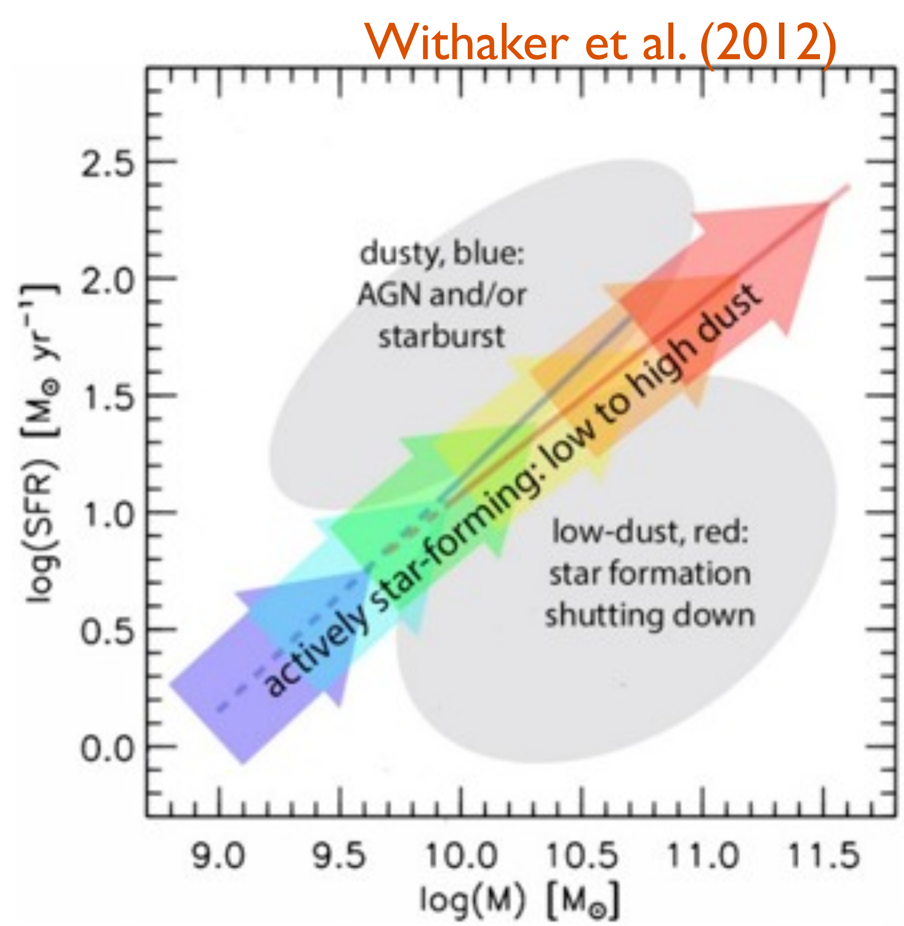
cf. instrument reviews

The Key Questions

- When did the first galaxies form ?
- How does the star formation activity evolve with time ?
- What is the contribution of different types of galaxies to the total star formation rate density o the Universe ?
- What is the contribution of different types of galaxies to the ionizing background ?
- Is there a galaxy “main sequence” ?
- What are the parameters regulating star formation ? star-forming to passive transition

The forgotten dwarf galaxies





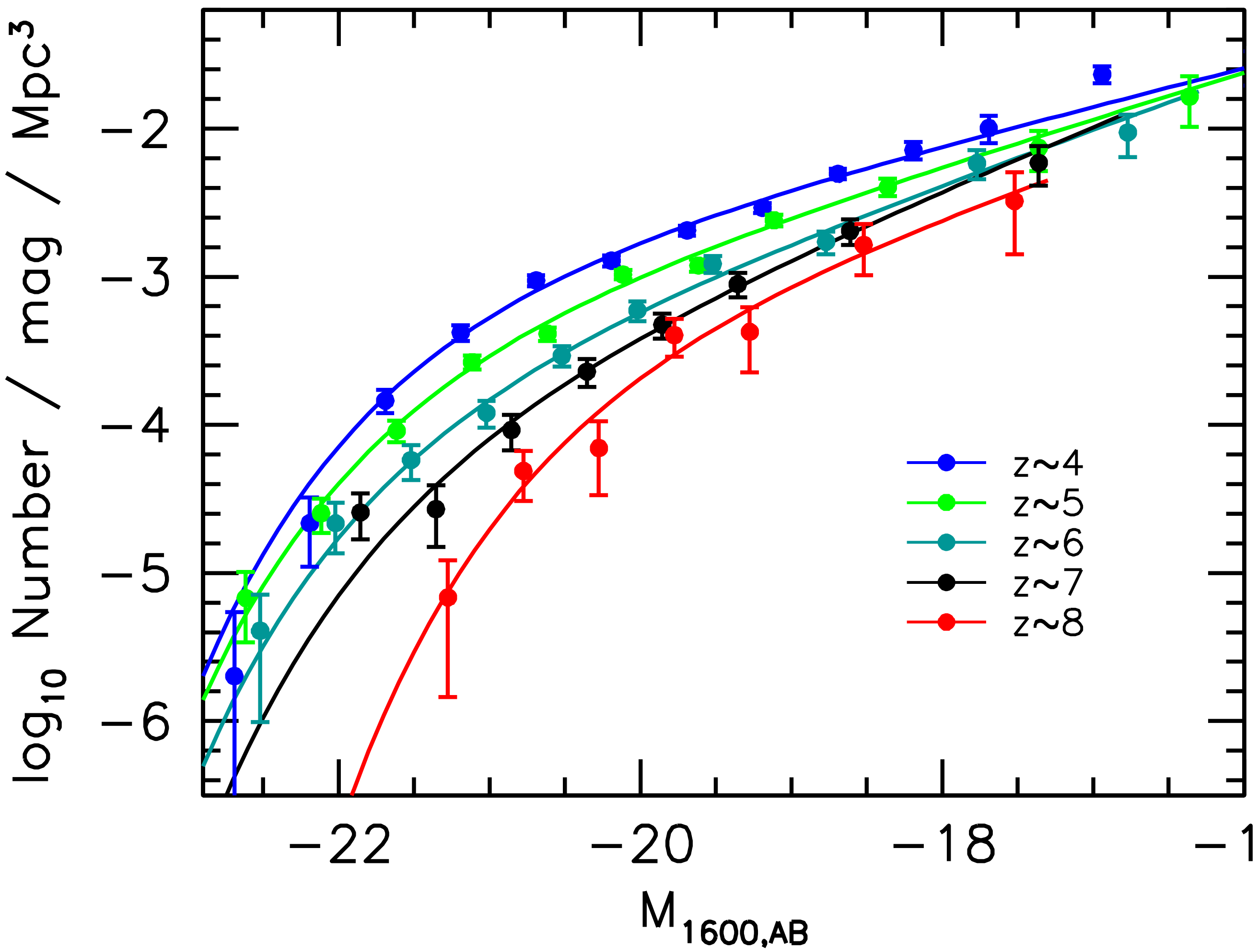
Constraints from Deep Blank Field Surveys

more than 800 galaxies at z >7 from all HST legacy fields

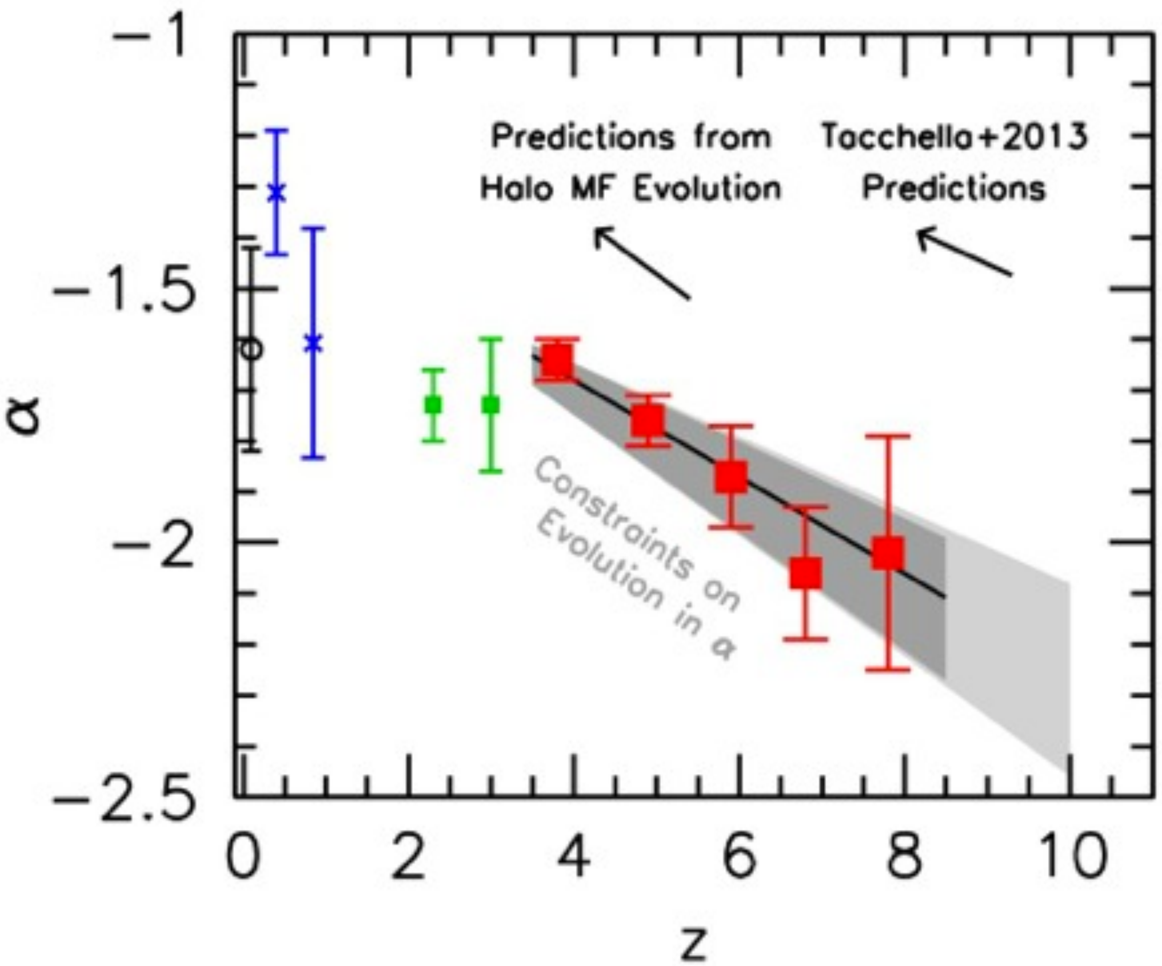
see also Bunker et al. (2010), Oesch et al. (2012) McLure et al. (2013), Schmidt et al. (2014), Finkelstein et al. (2014)

better constraints on the overall shape of the luminosity function.

Bouwens et al. (2014)



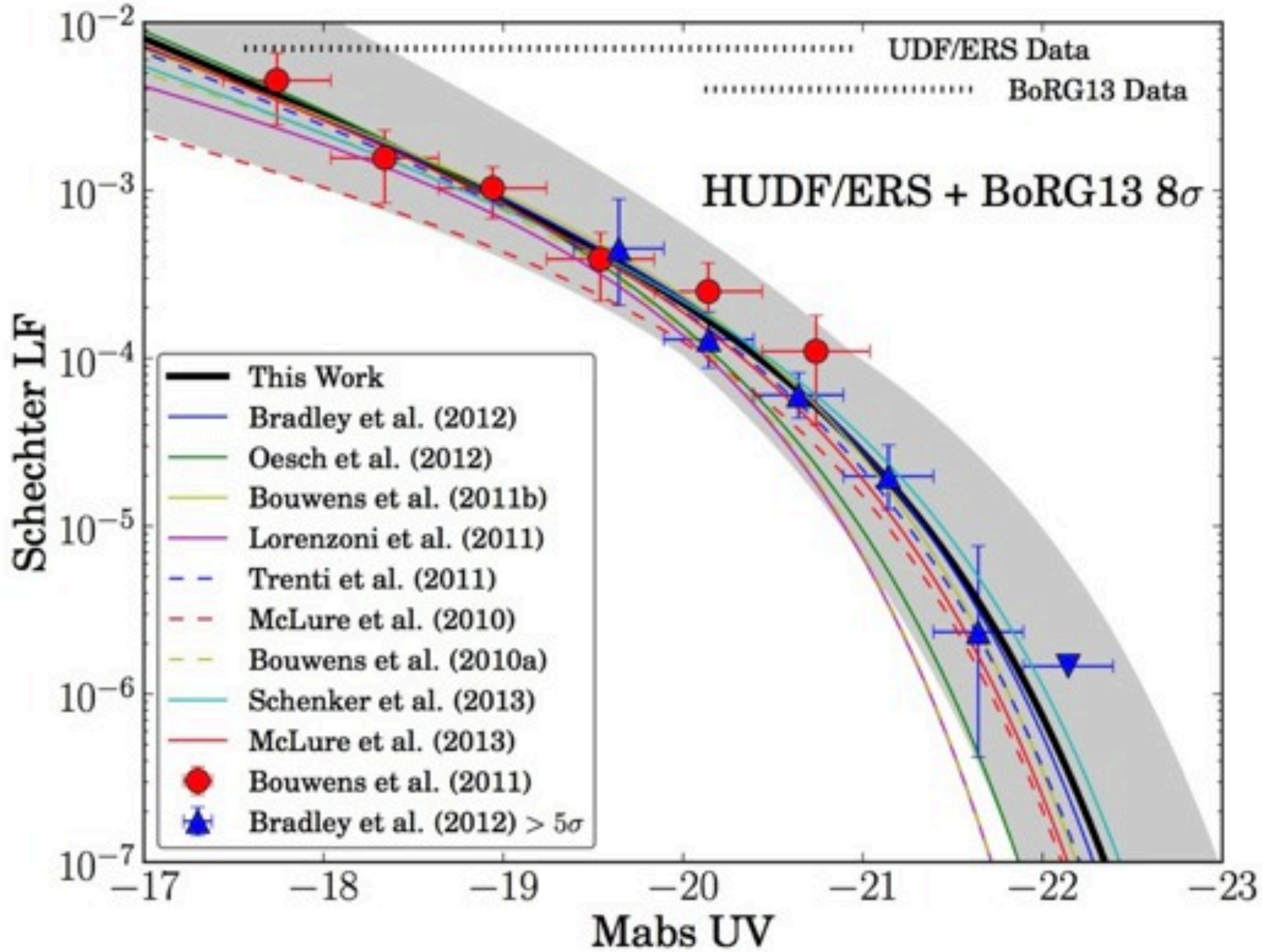
redshift evolution of the UV LF faint-end slope



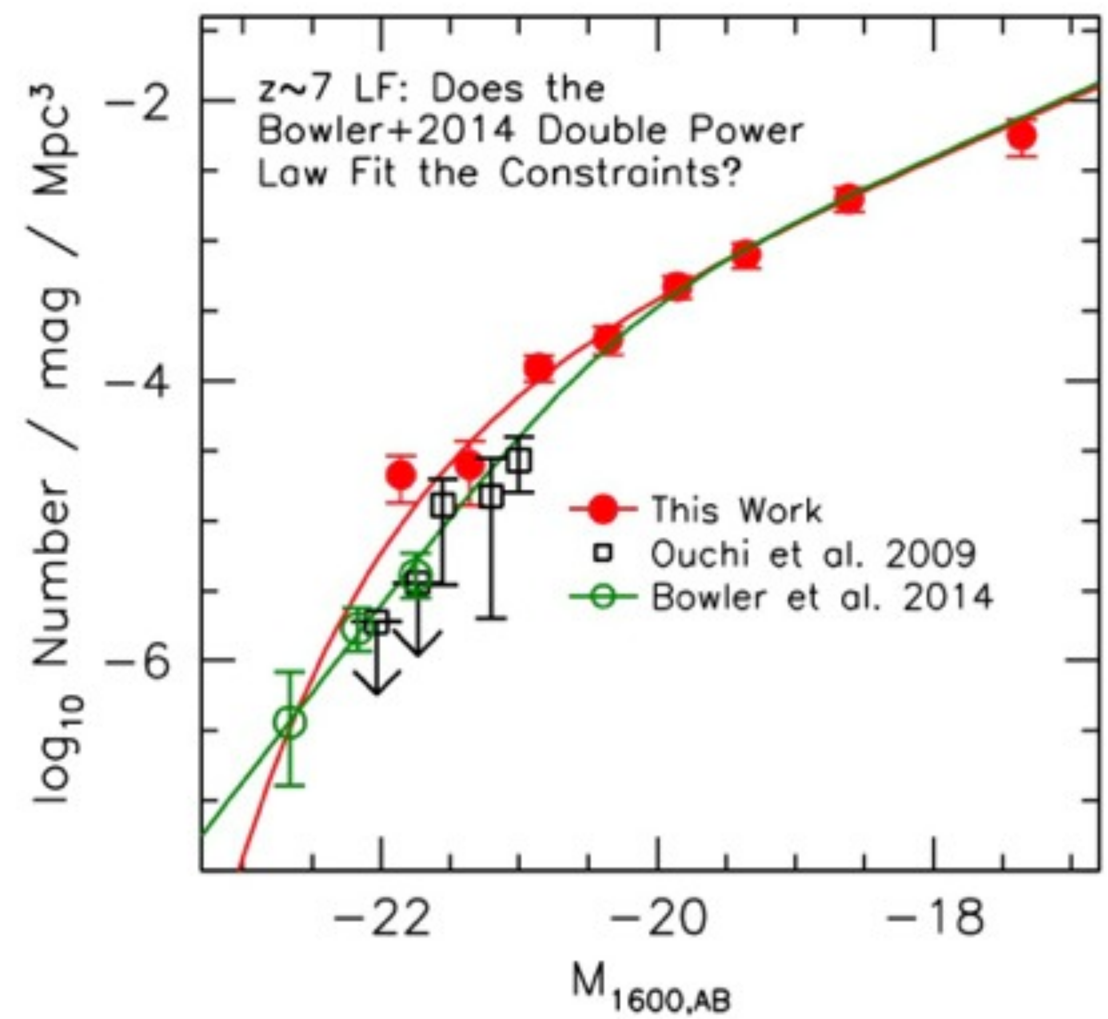
The Bright-end of the UV LF

- Wide Field surveys probe the brightest of the luminosity function at z>7
- Large uncertainties still affect the slope (shape ?) of the bright end.

Schmidt et al. (2014)



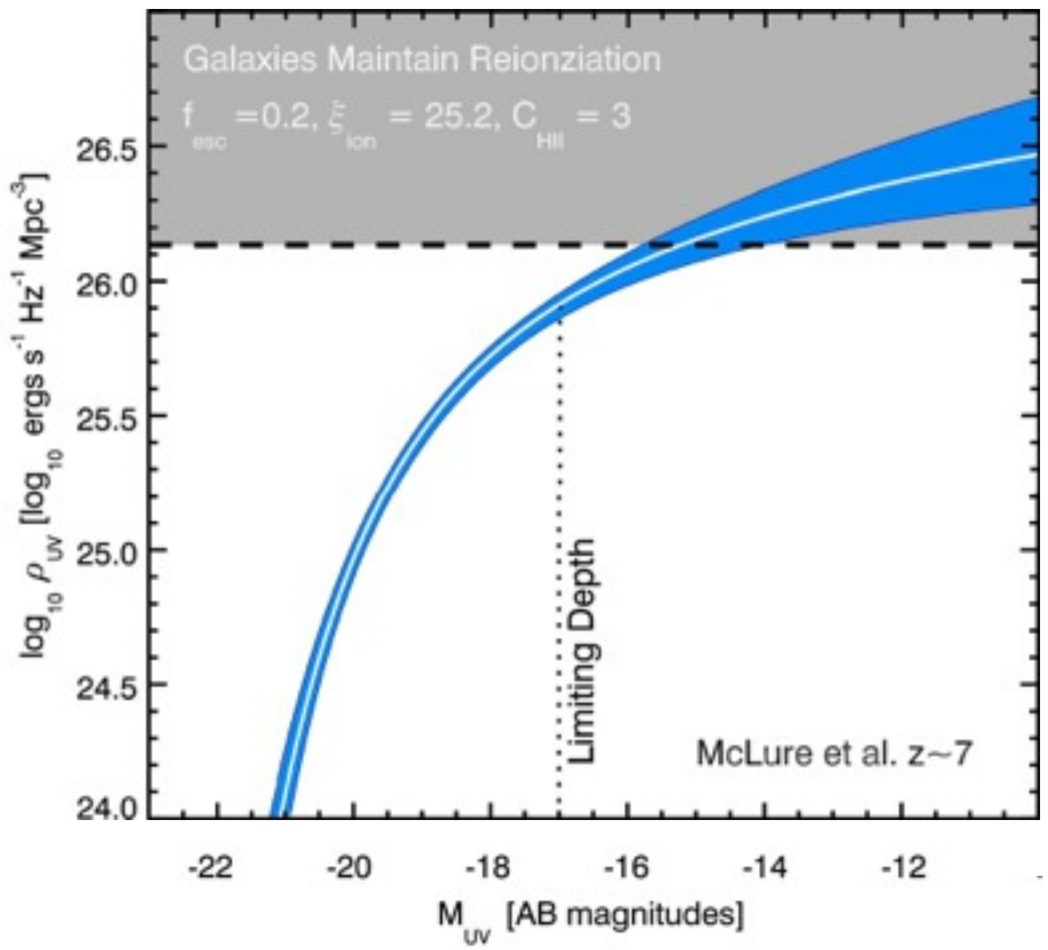
Bouwens al. (2014)



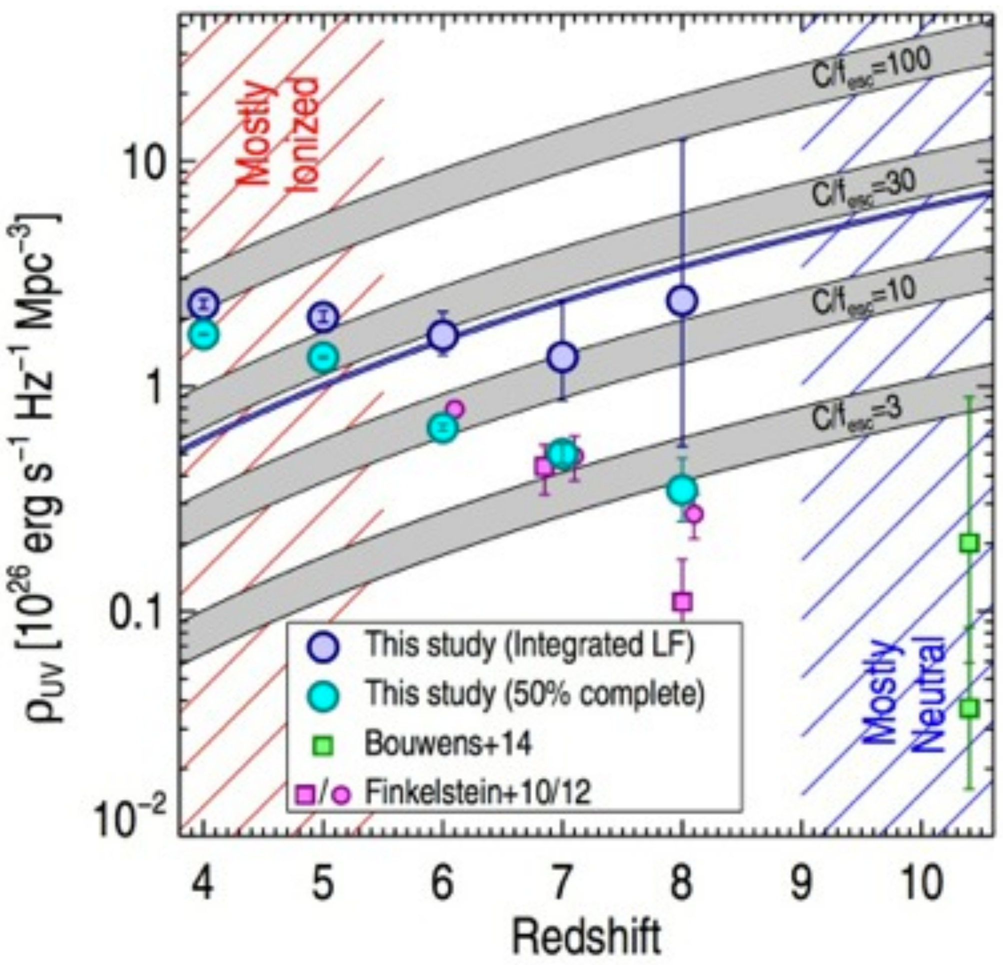
Star-forming Galaxies and Cosmic Reionization

Contribution of star-forming galaxies to the ionizing background
Universe mostly (90%) ionized at z~6

Robertson et al. (2013)

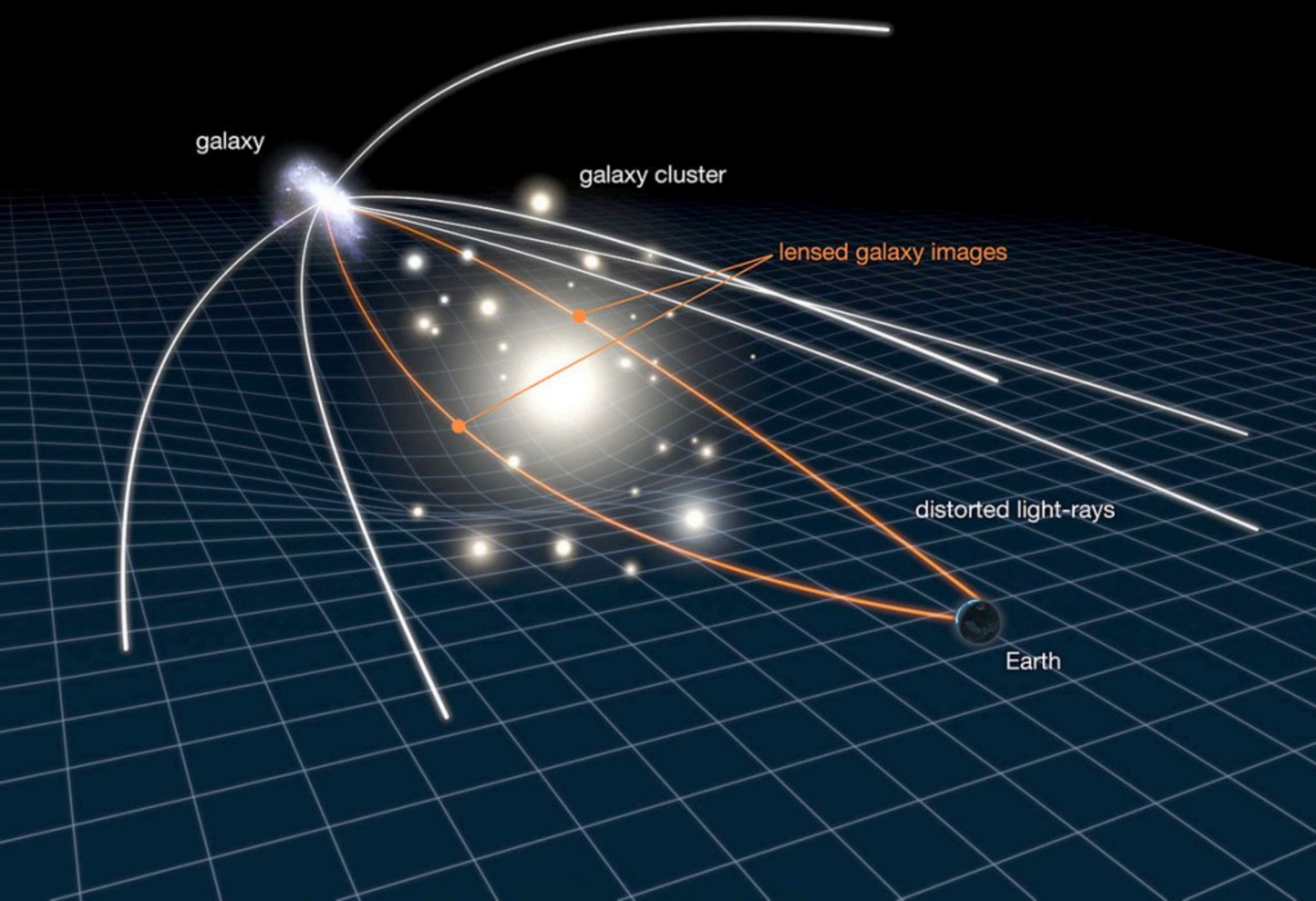


Finkelstein et al. (2014)

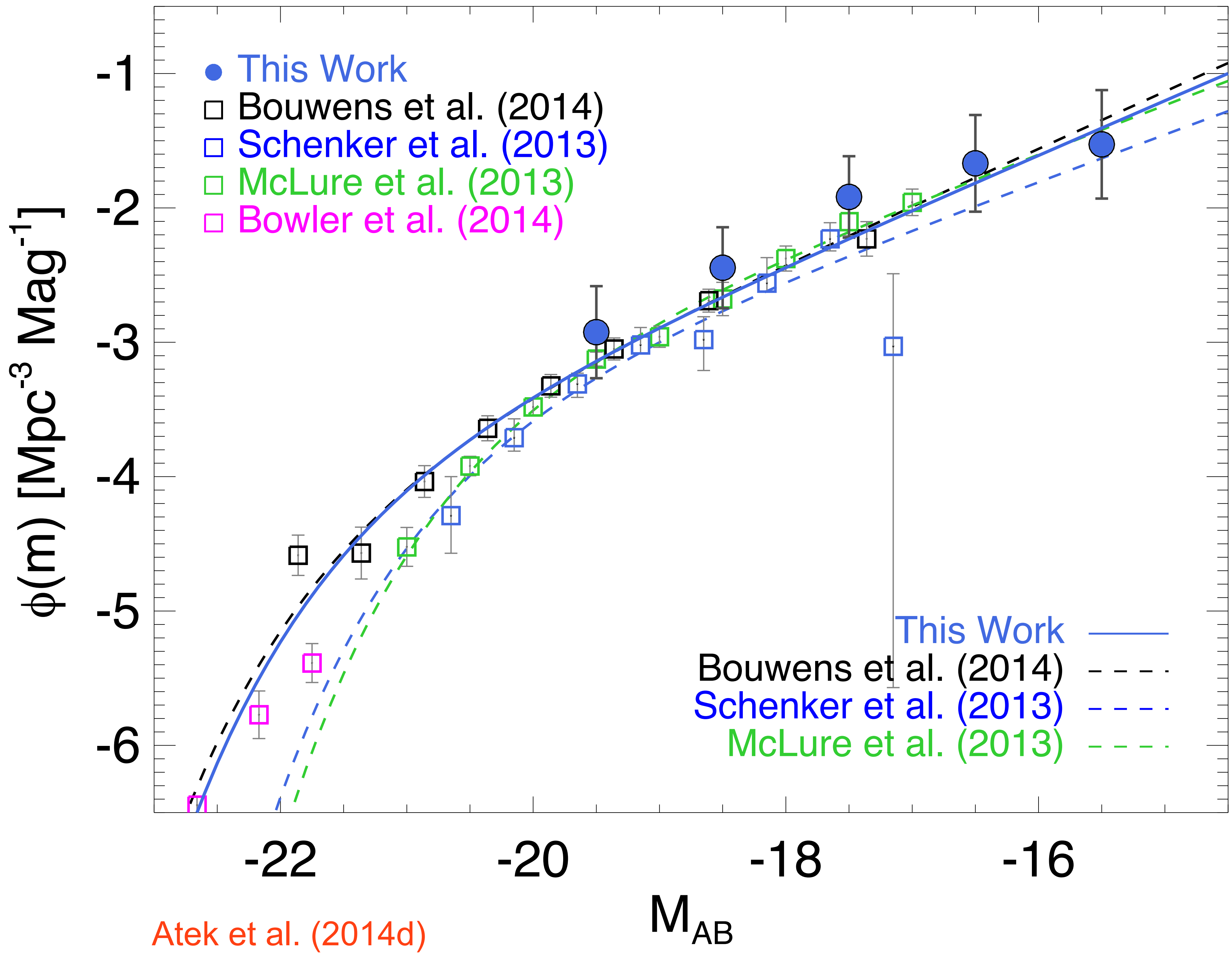


cf. talks by Chevallard & Trebisch

With a Little Help From Gravitational Lensing



The UV LF at z>6 Through Cosmic Telescopes



Atek et al. (2014d)

see also Ishigaki et al. (2015), Oesch et al. (2015)

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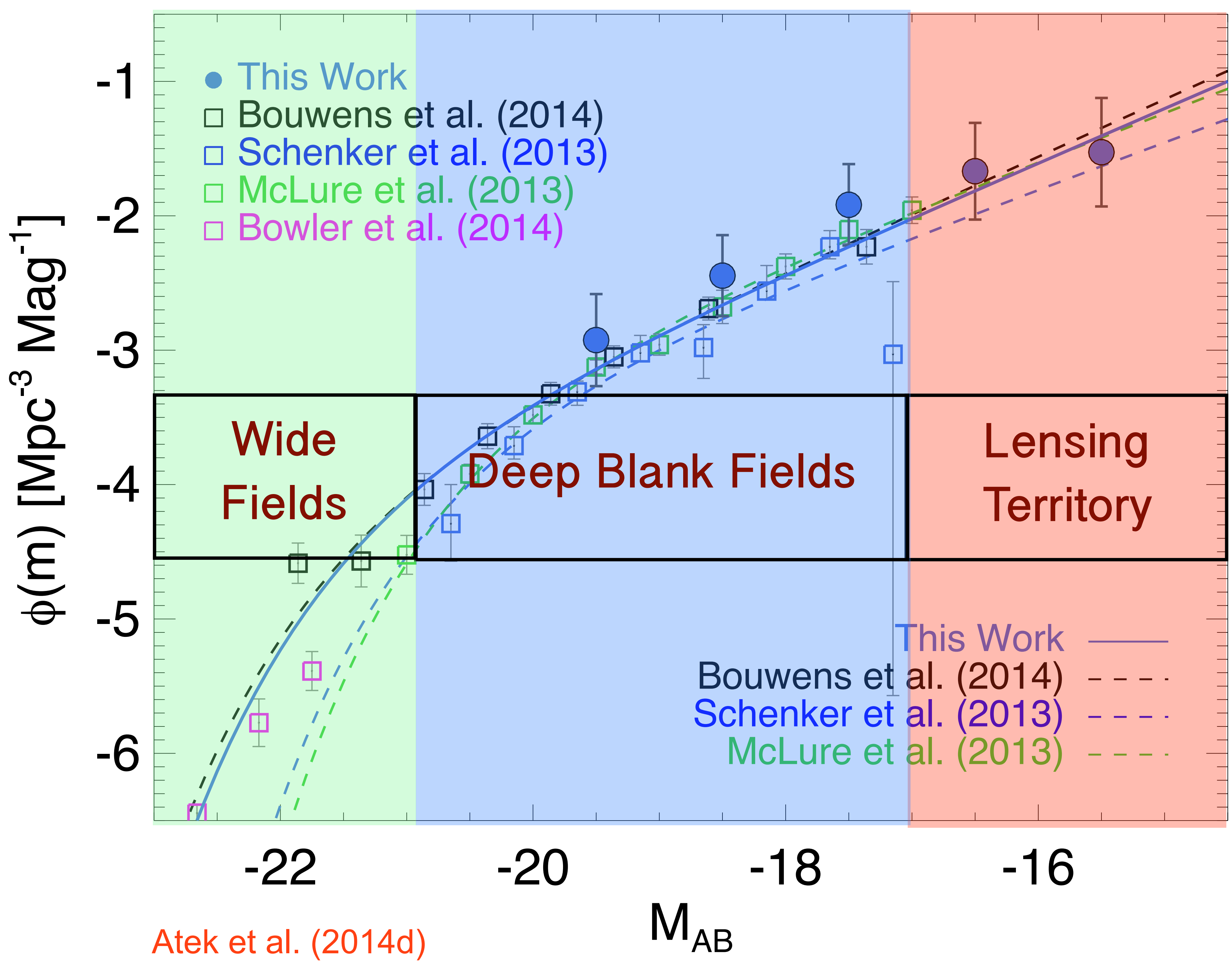

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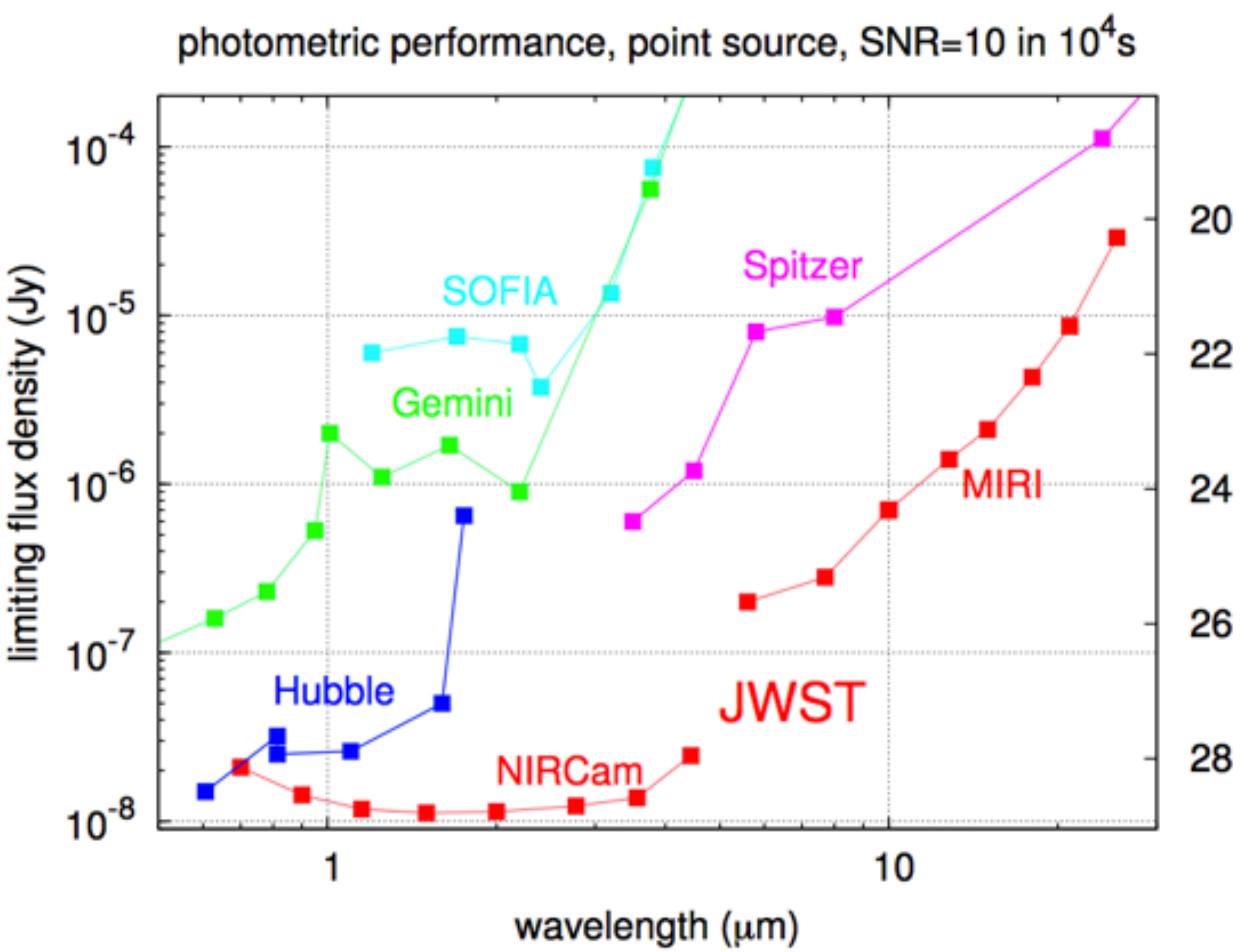
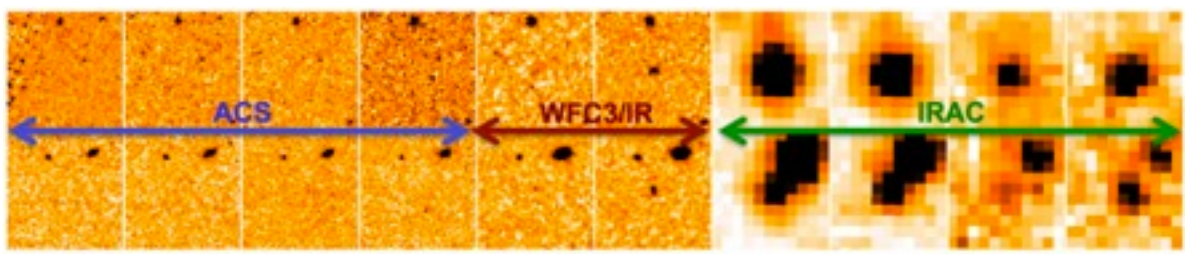
HST/WFC3 & ACS reaching AB=28-29.0 mag (5-σ) at 0.06–0.13” FWHM from 0.2–1.7 µm

JWST adds 0.03–0.2” FWHM imaging to AB=31.5 mag (1 nJy) at 1–5 µm, and 0.07–1.2” FWHM at 5–29 µm



Oesch et al. (2014)

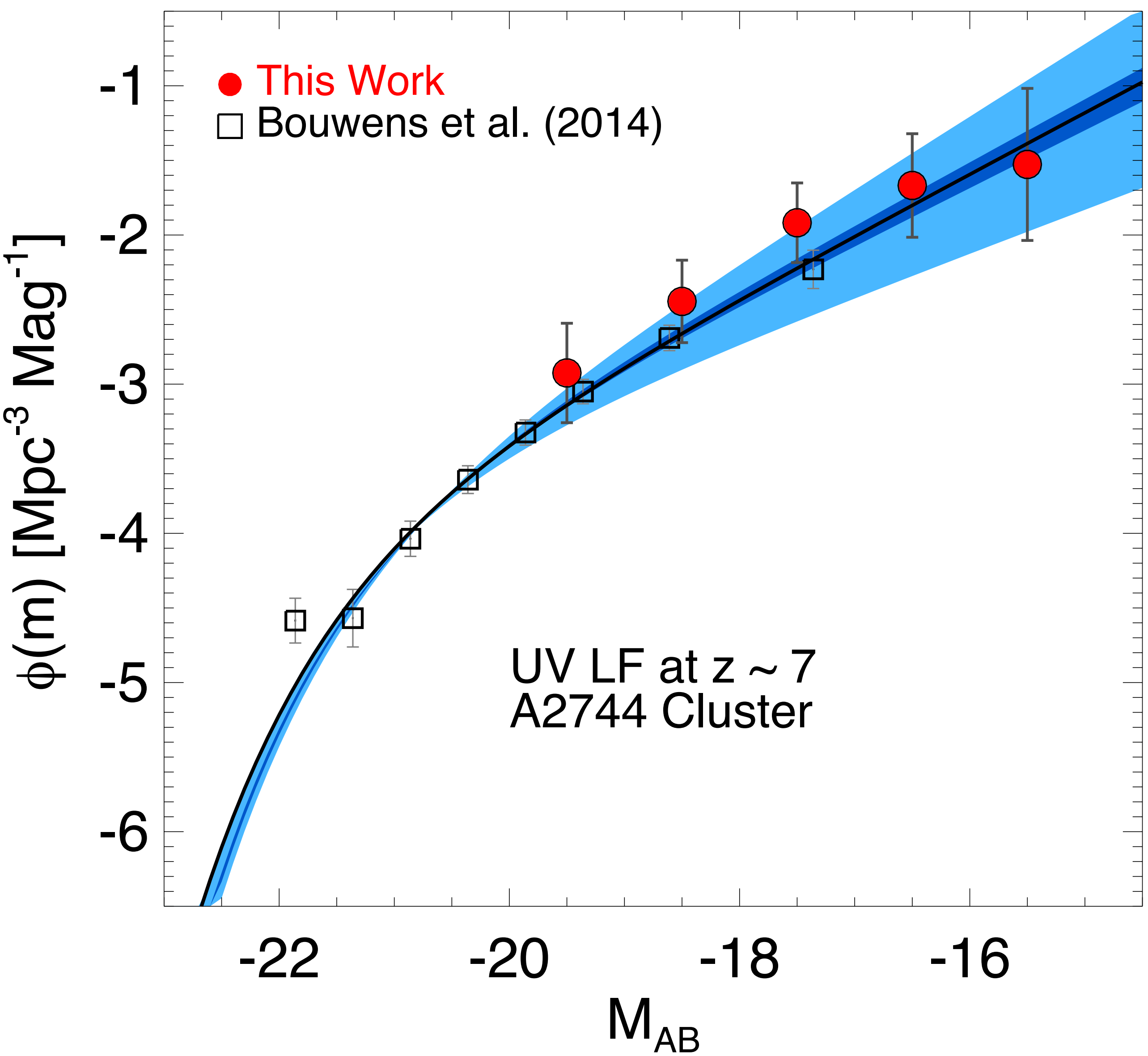


JWST Imaging: Wide wavelength coverage and very reliable photometry requirement for accurate photometric redshifts and SED fitting to access the formation of early galaxies z>20

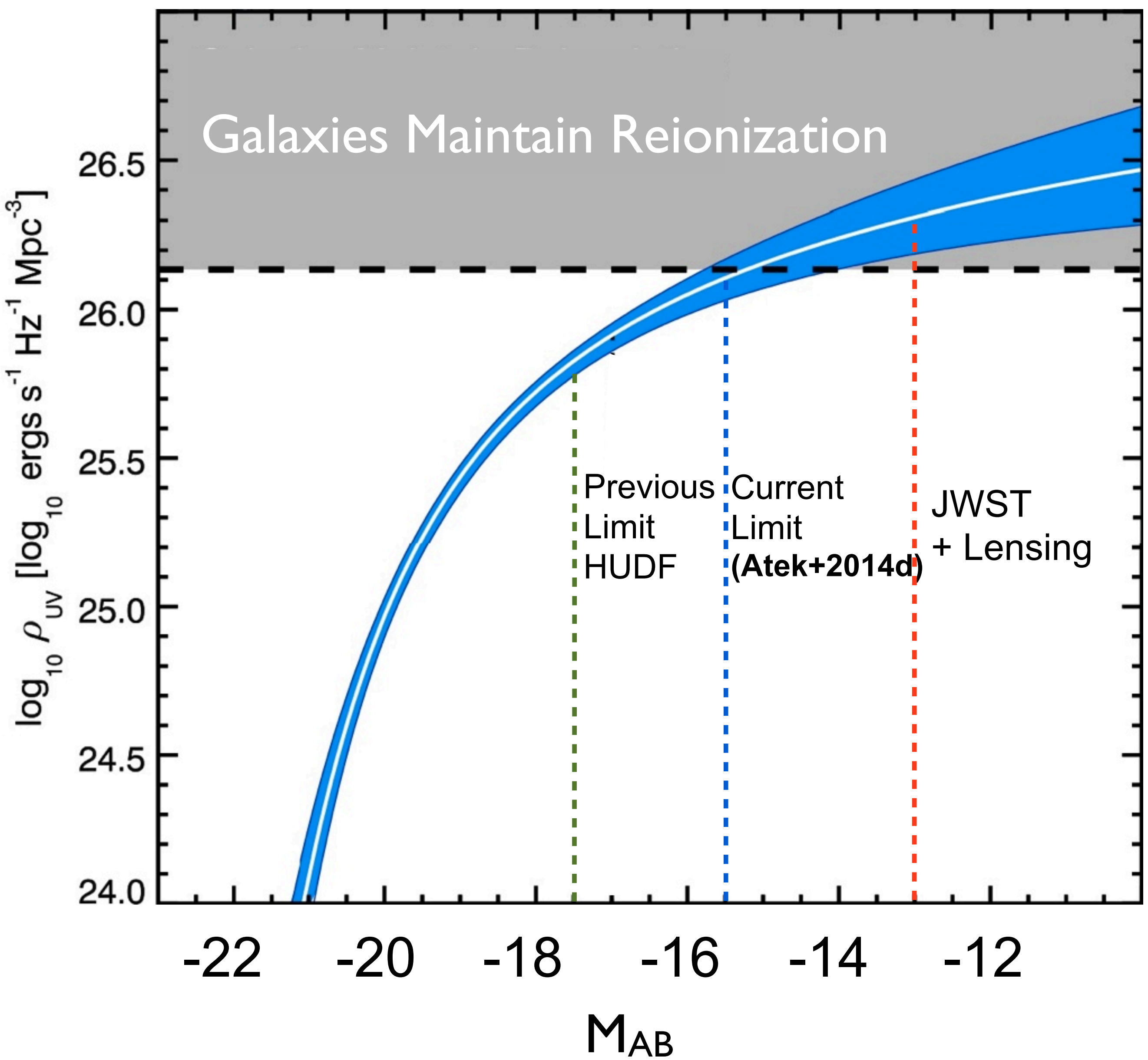
Crucial for the Stellar mass estimate Dominguez et al. (2014), Mobasher et al. (2015)

UV Luminosity density and Reionization

- z~7 UV LF projection for 6 Frontier Fields
- down to 0.05 precision on faint-end slope
- 30% uncertainty on the UV luminosity density



Robertson et al. (2013)



cf. Jauzac's talk

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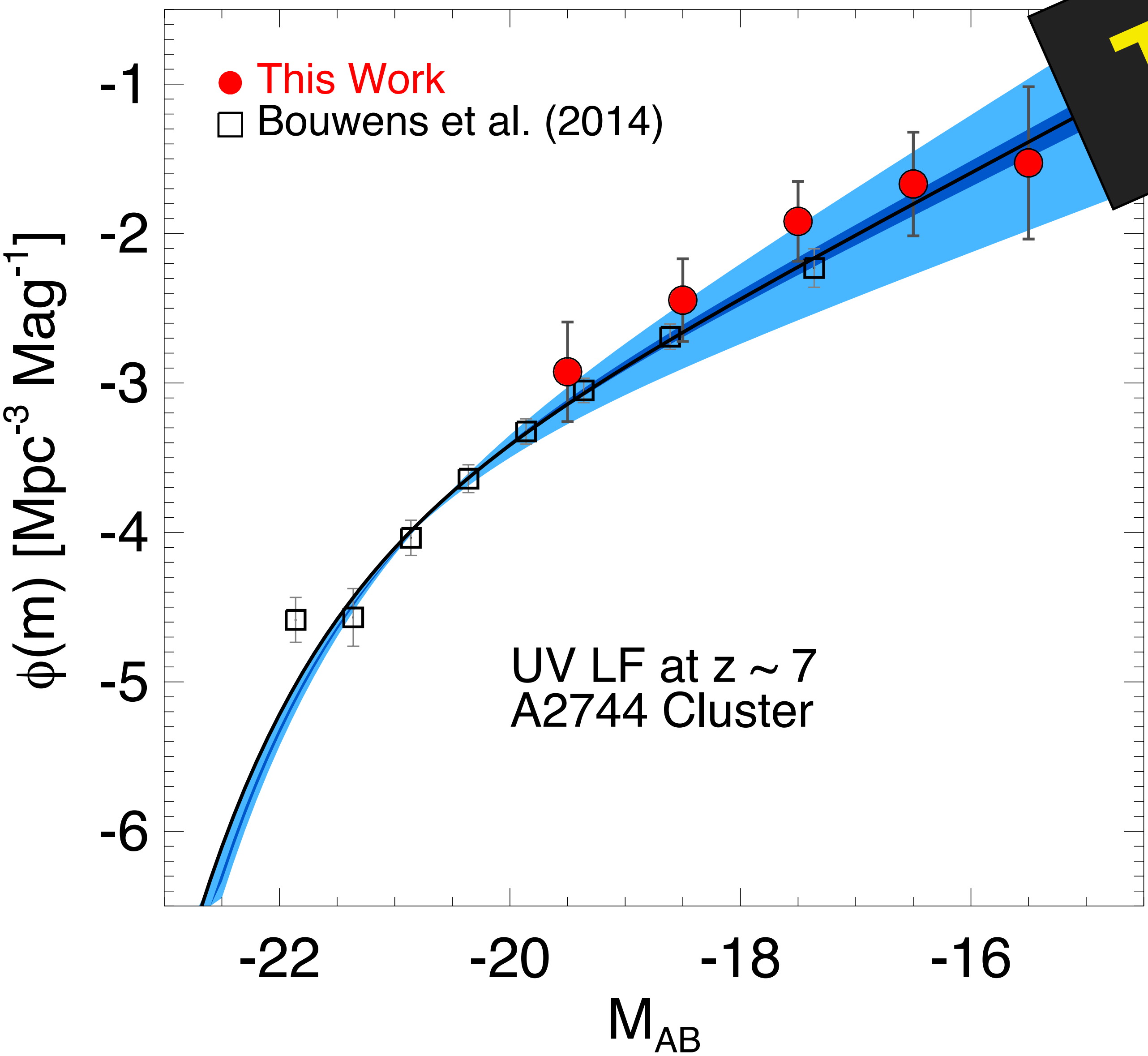
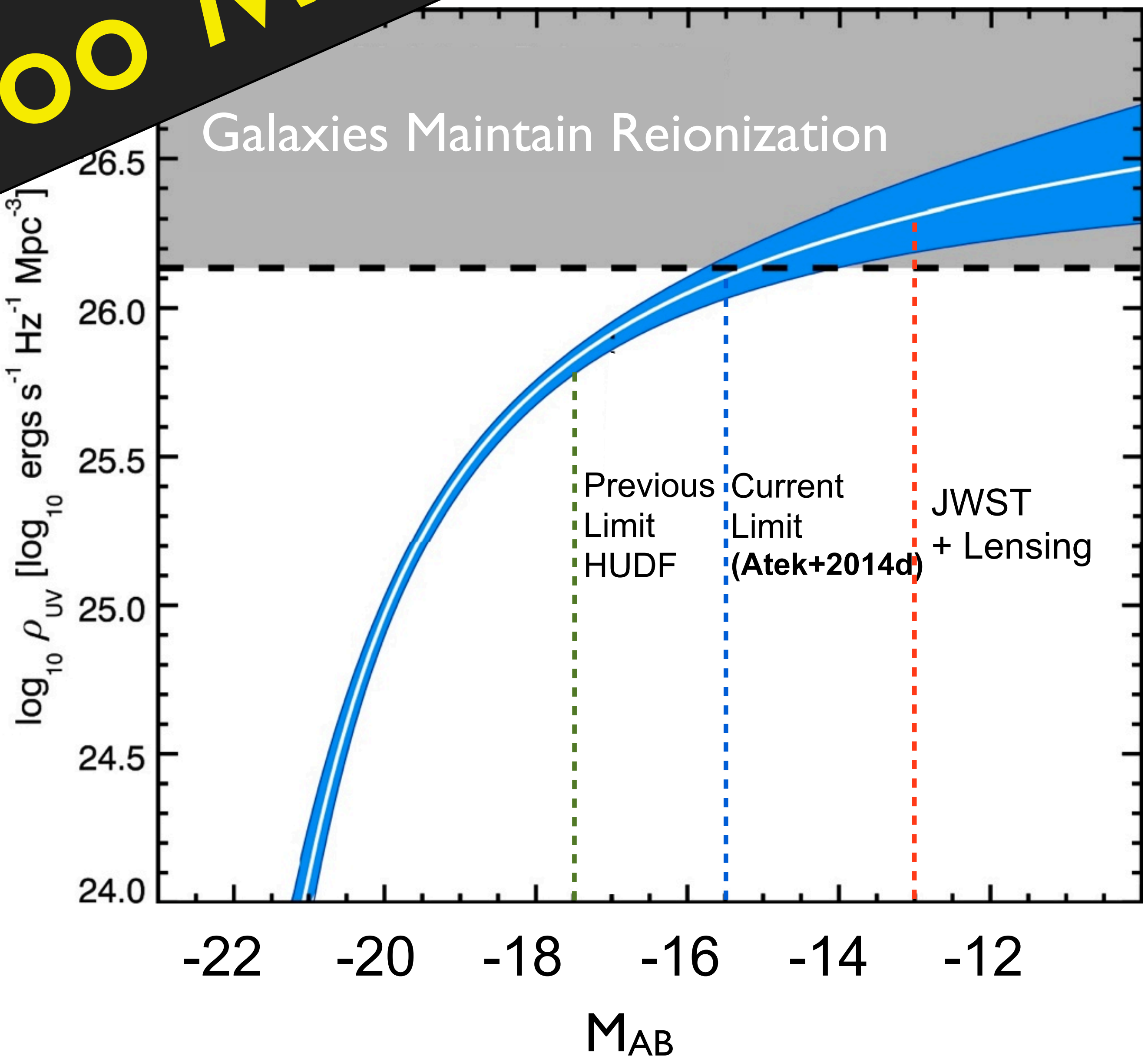
Too Many to Fail ?



Robertson et al. (2013)



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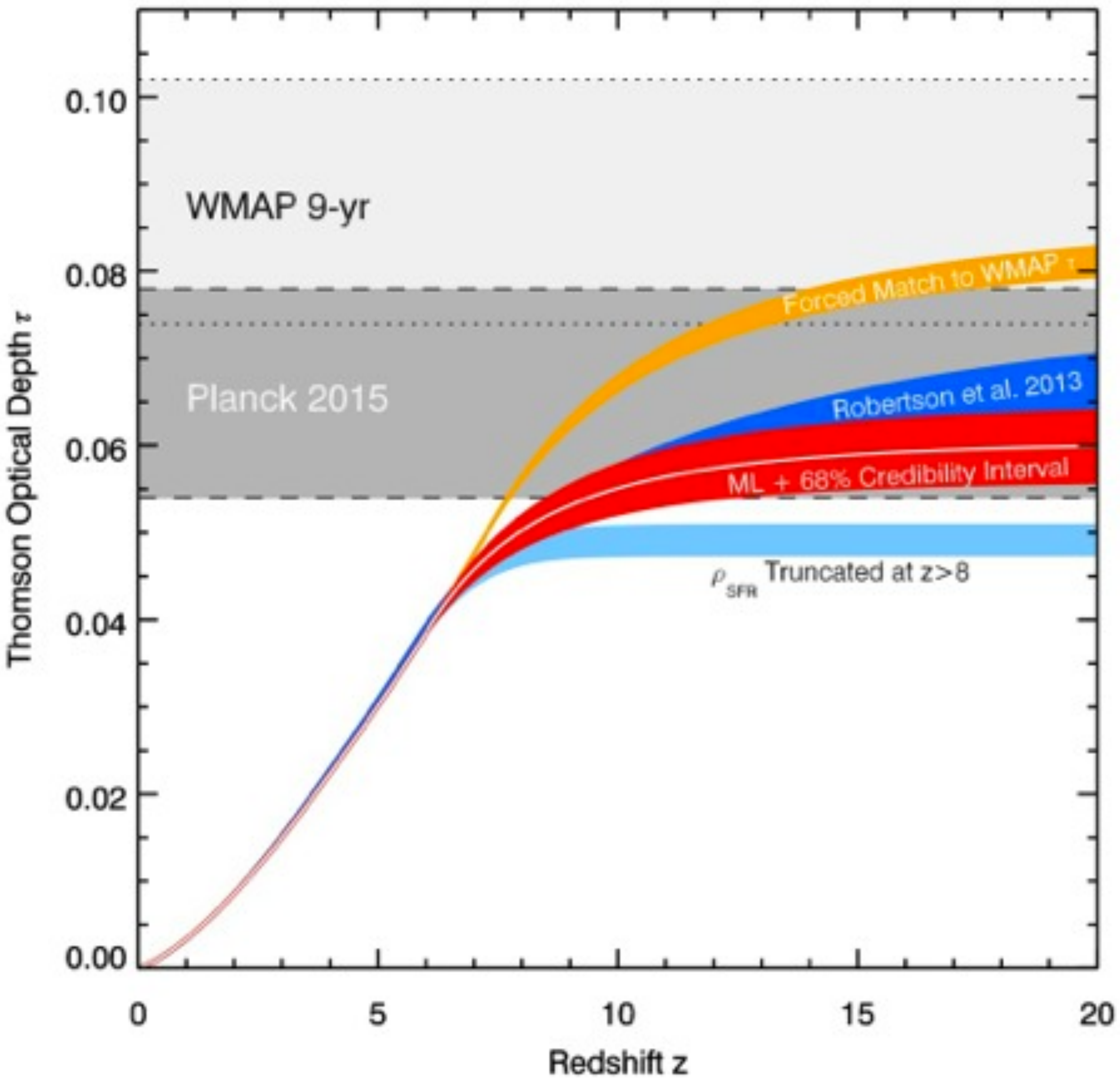
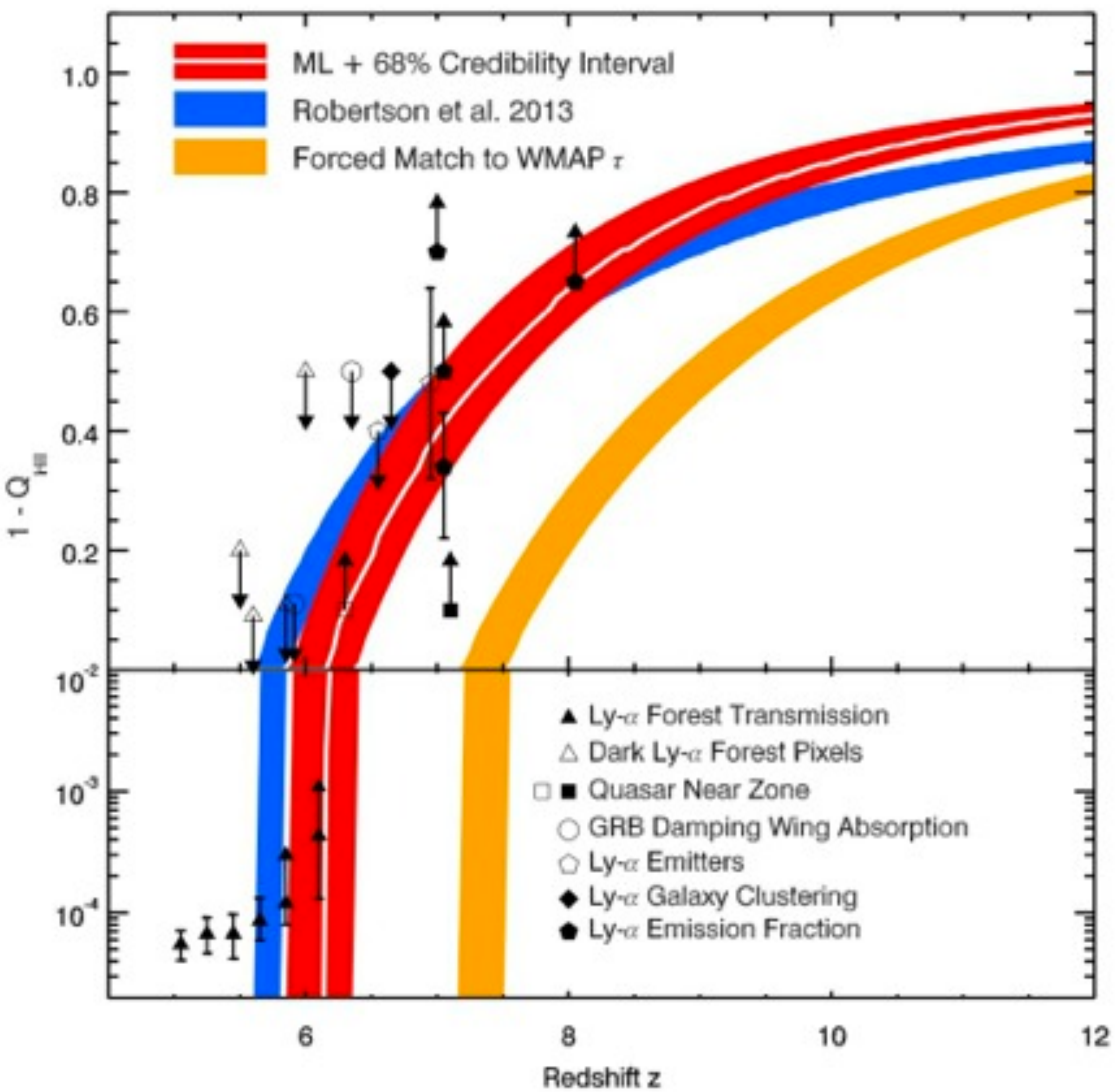
UV Luminosity density and Reionization

Joint constraints of Planck and HFF UV Luminosity density

Robertson et al. (2013)





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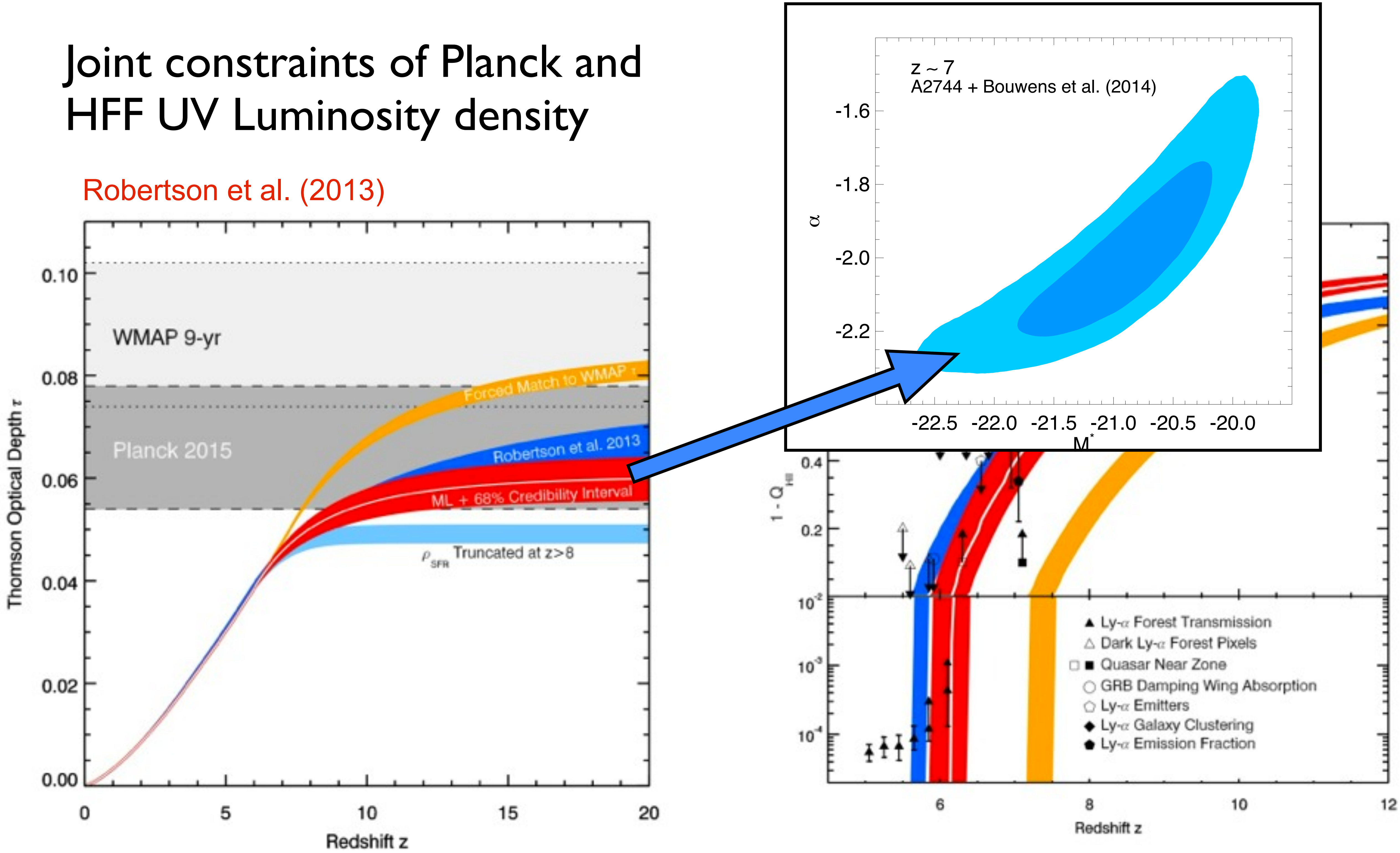
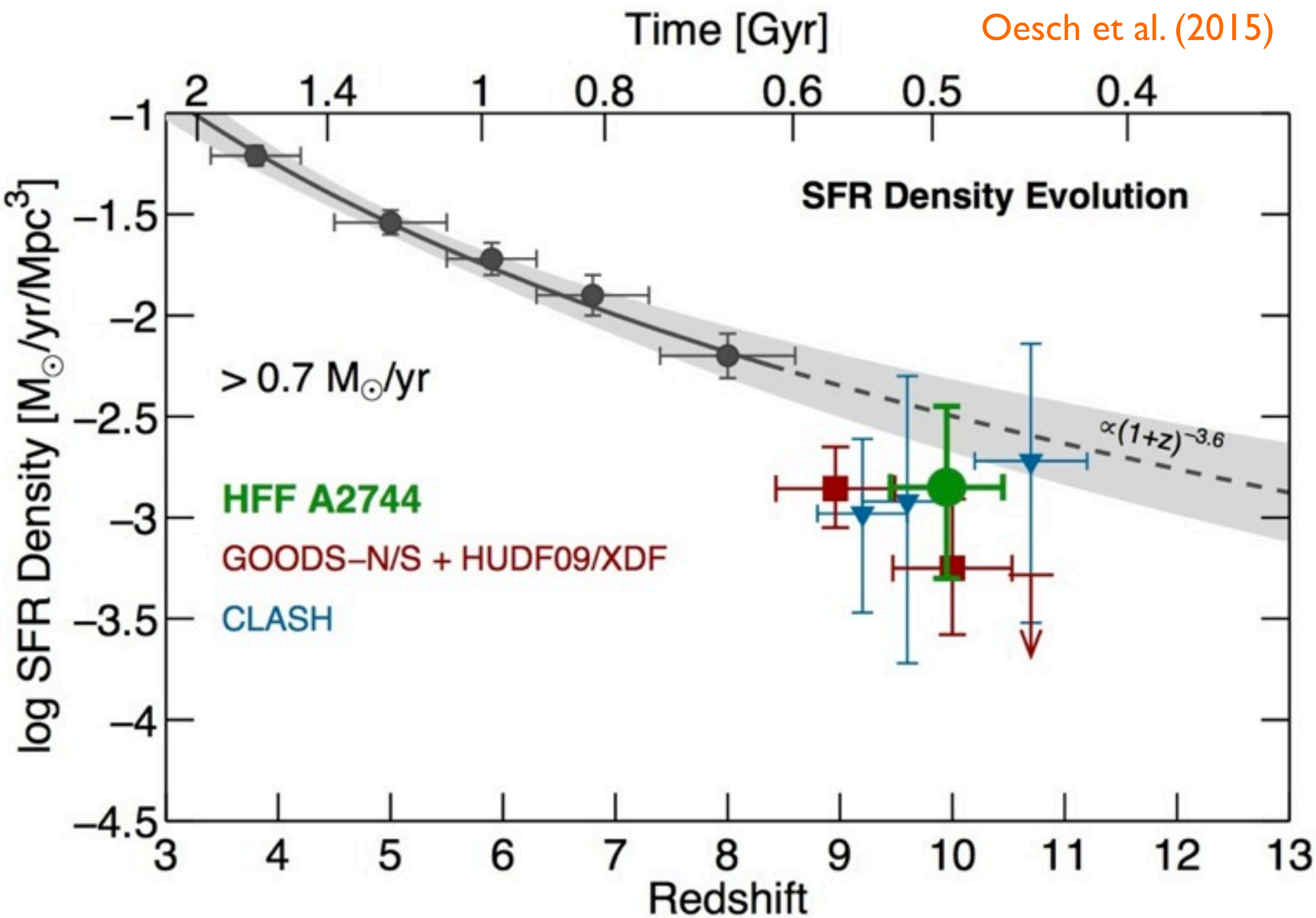


Evolution of the SFR Density at z>8

Oesch et al. (2015)



see also Zheng et al (2012), McLure et al. (2013), Coe et al. (2013), Bouwens et al. (2015), Ishigaki et al. (2015)

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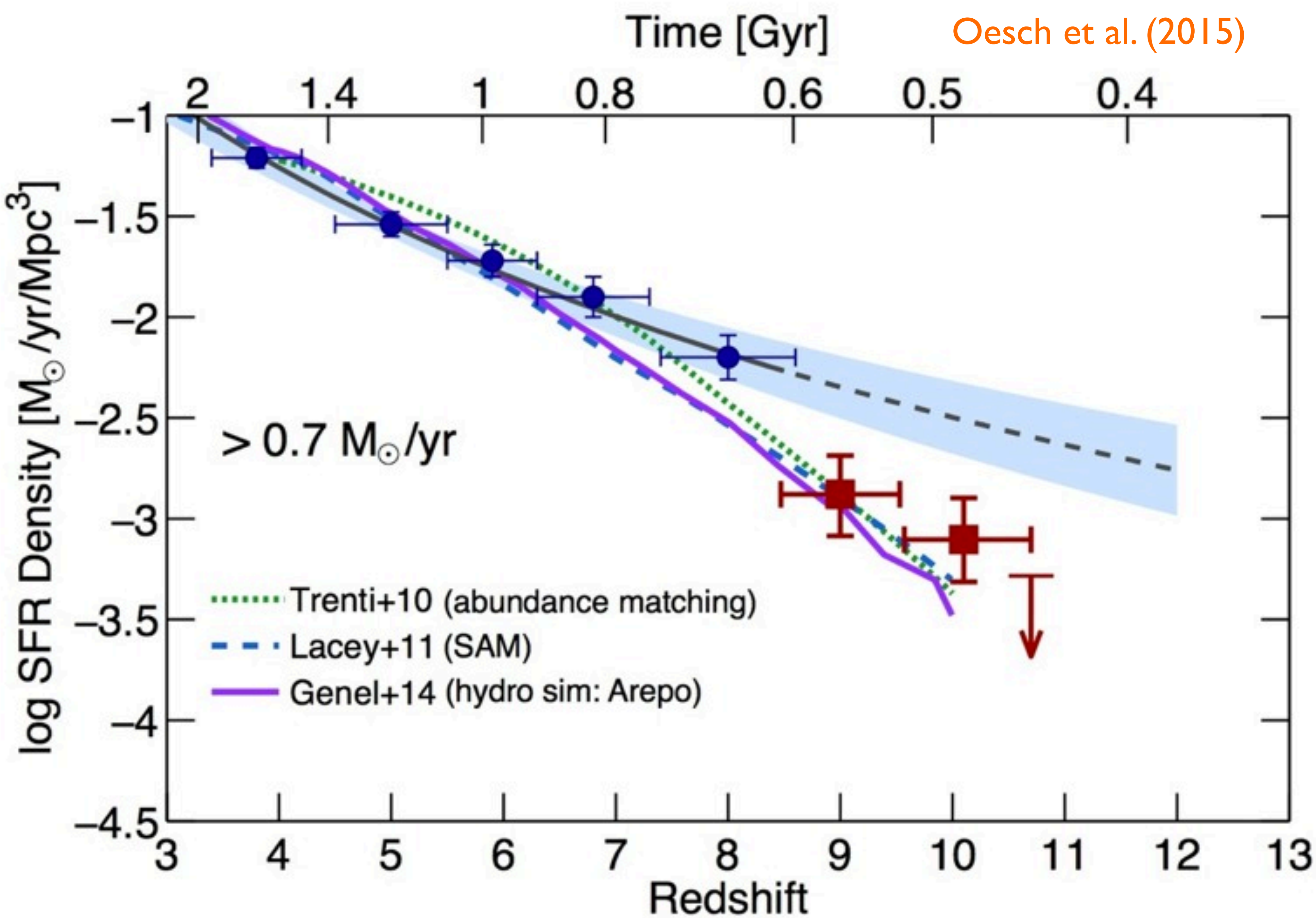

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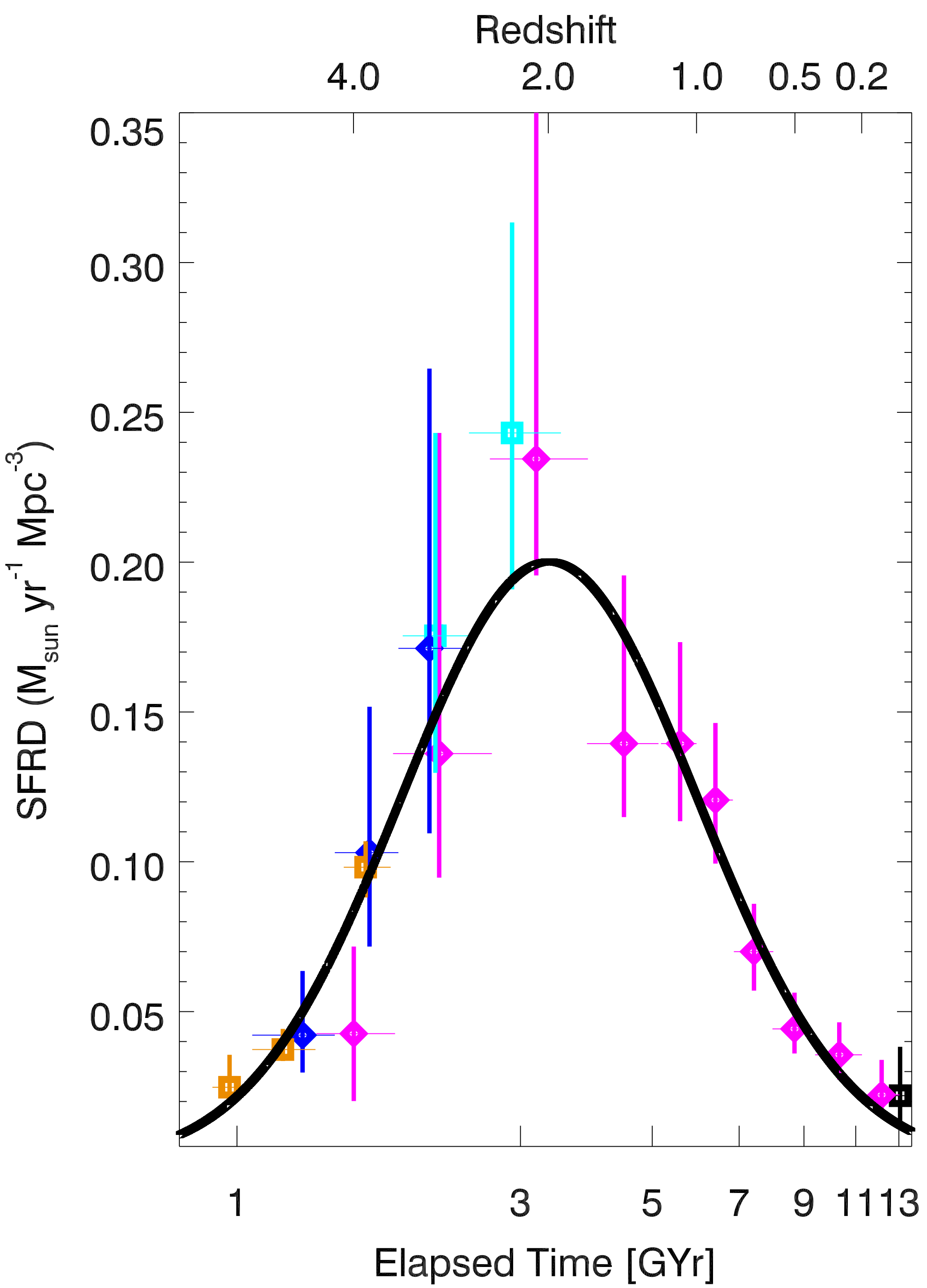
The Peak of Star Formation History



Gladders et al. (2013)

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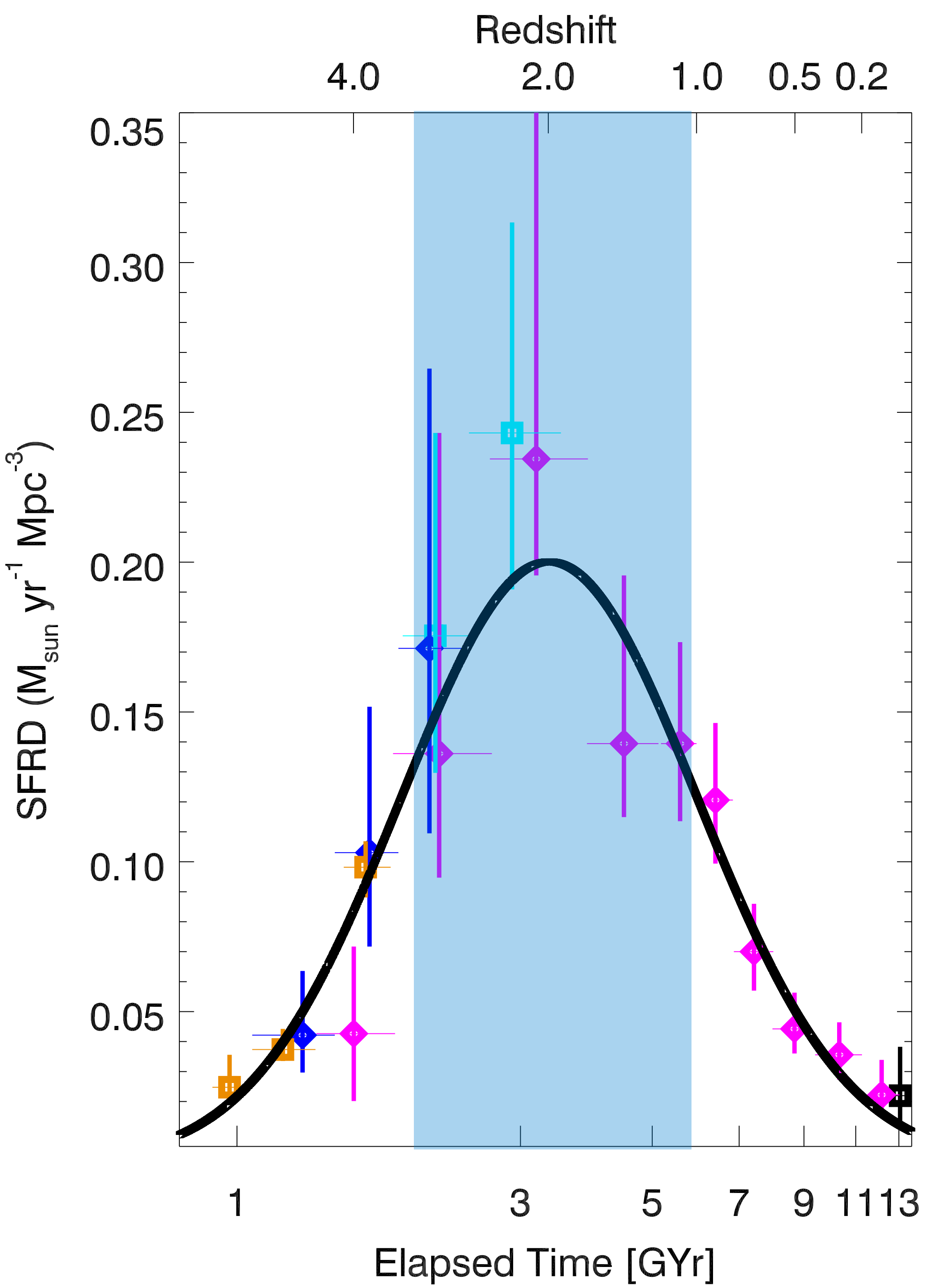

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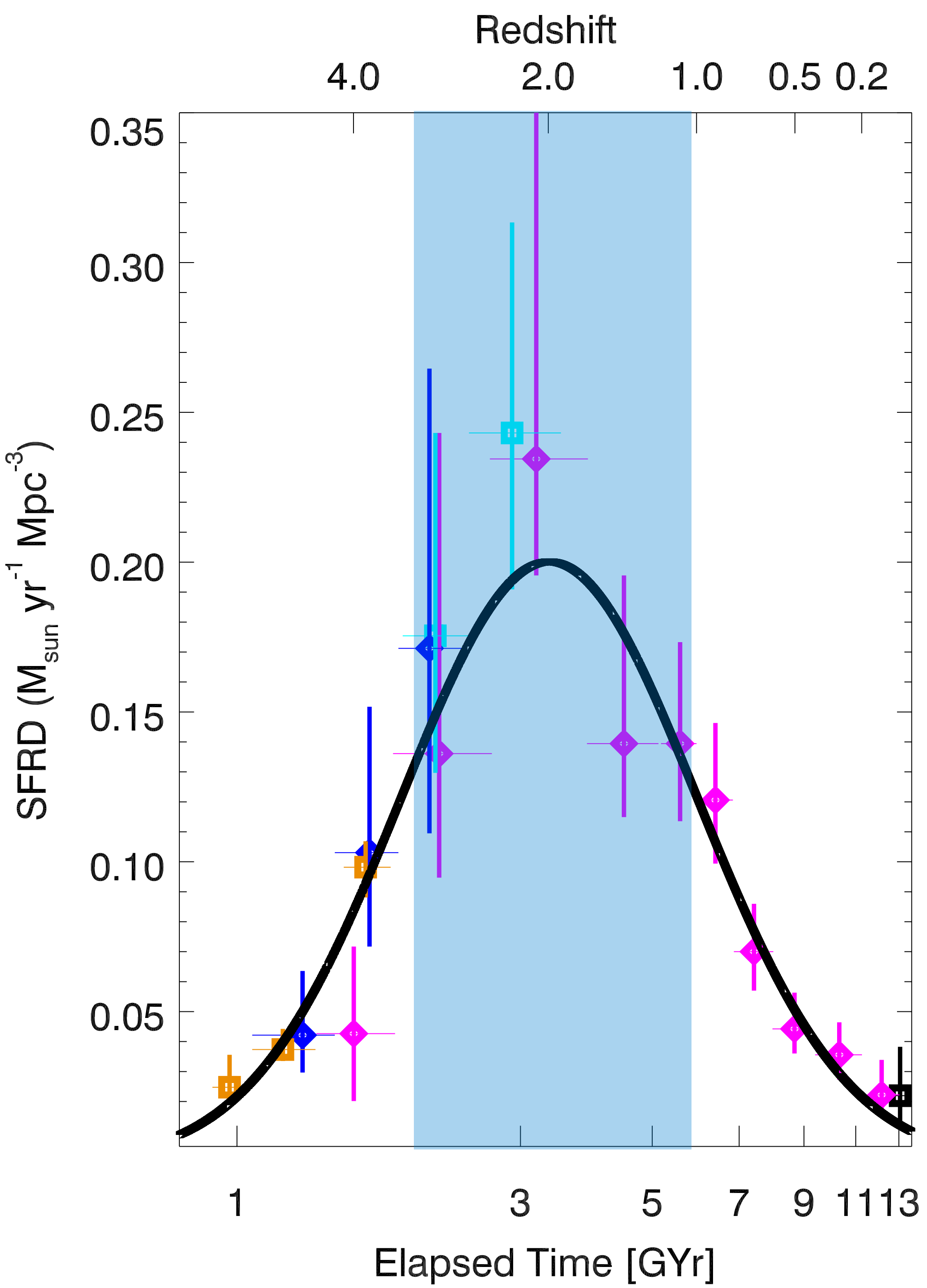
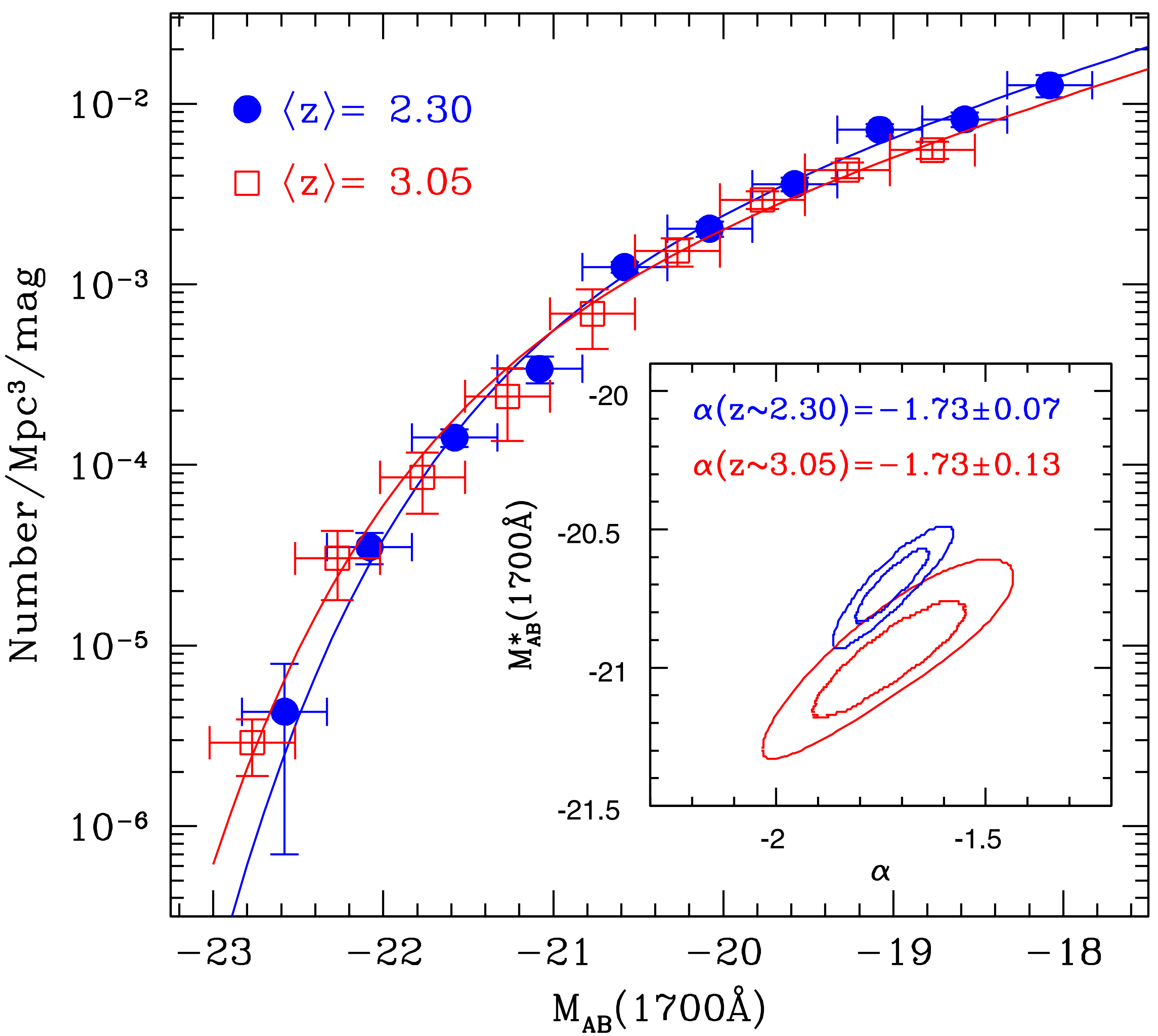


Gladders et al. (2013)

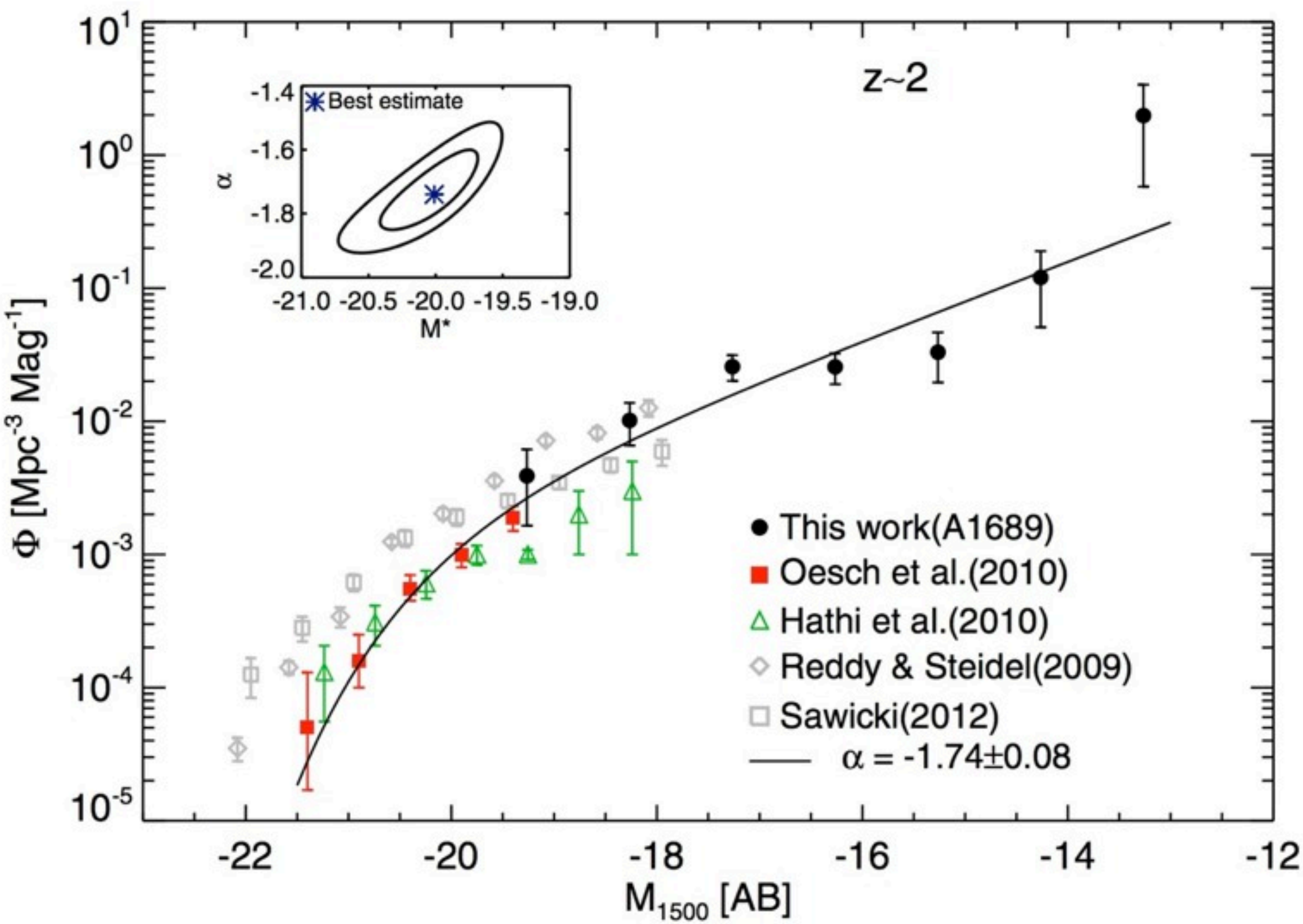
Reddy & Steidel (2009)



No Evidence of Turnover in the UV LF

UV LF at z~2 down to Muv=-13

Alavi et al. (2014)



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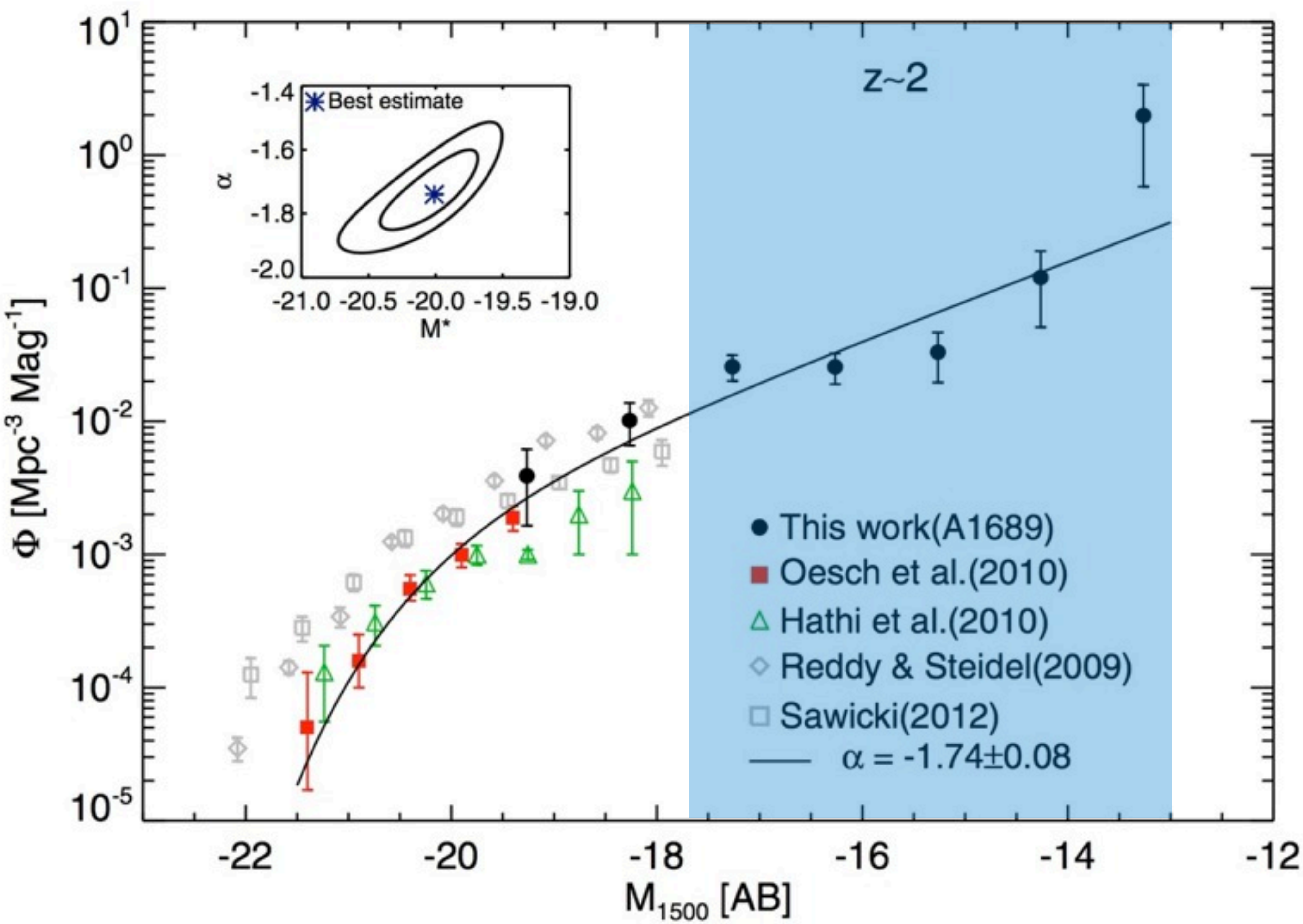


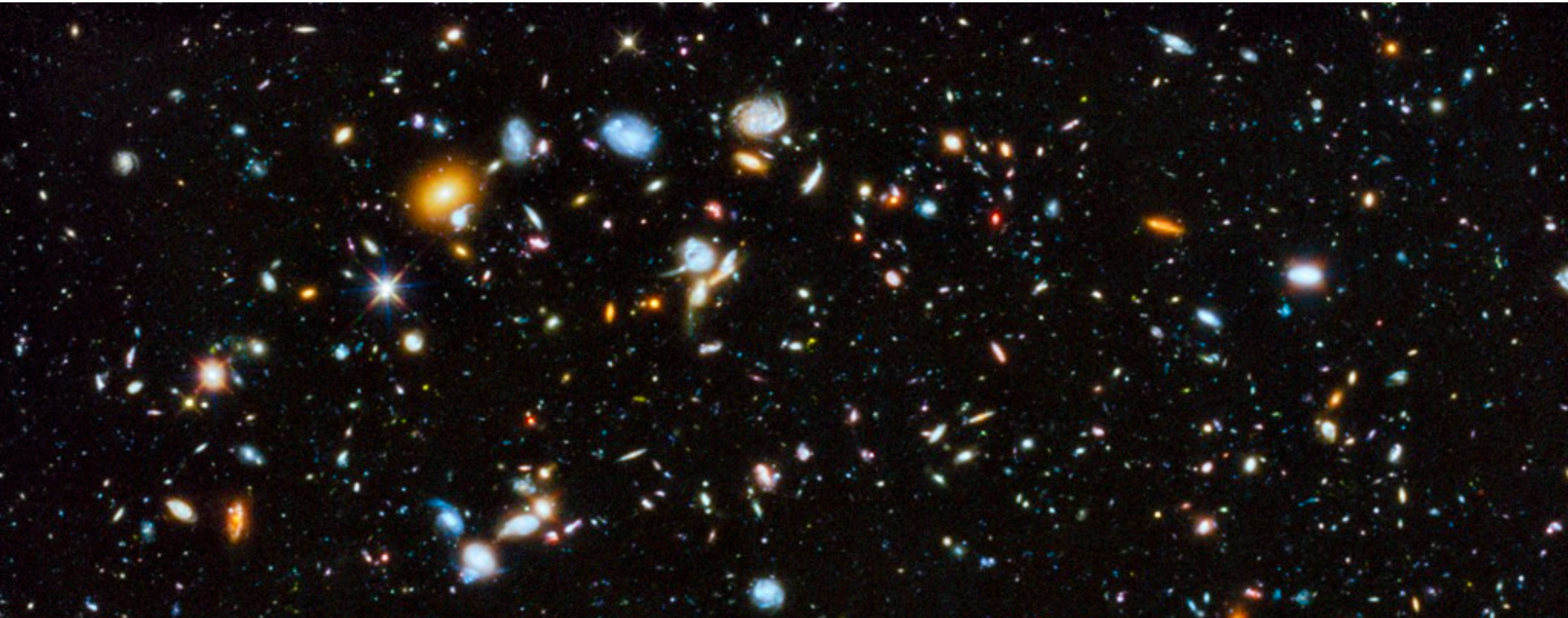
Can't See The Forest for the Trees ?

LBG

BzK

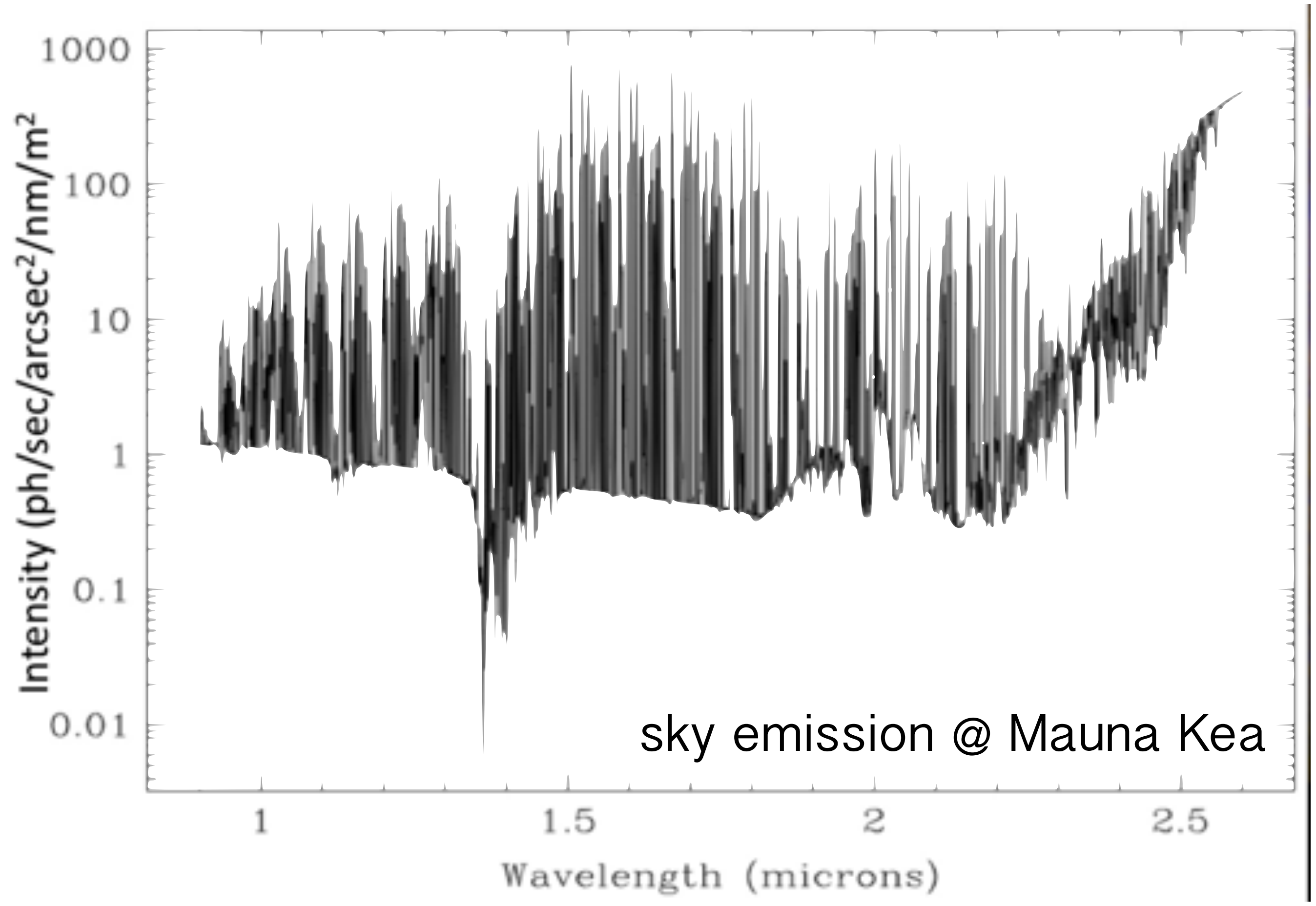
DRG

...



a large and deep spectroscopic survey

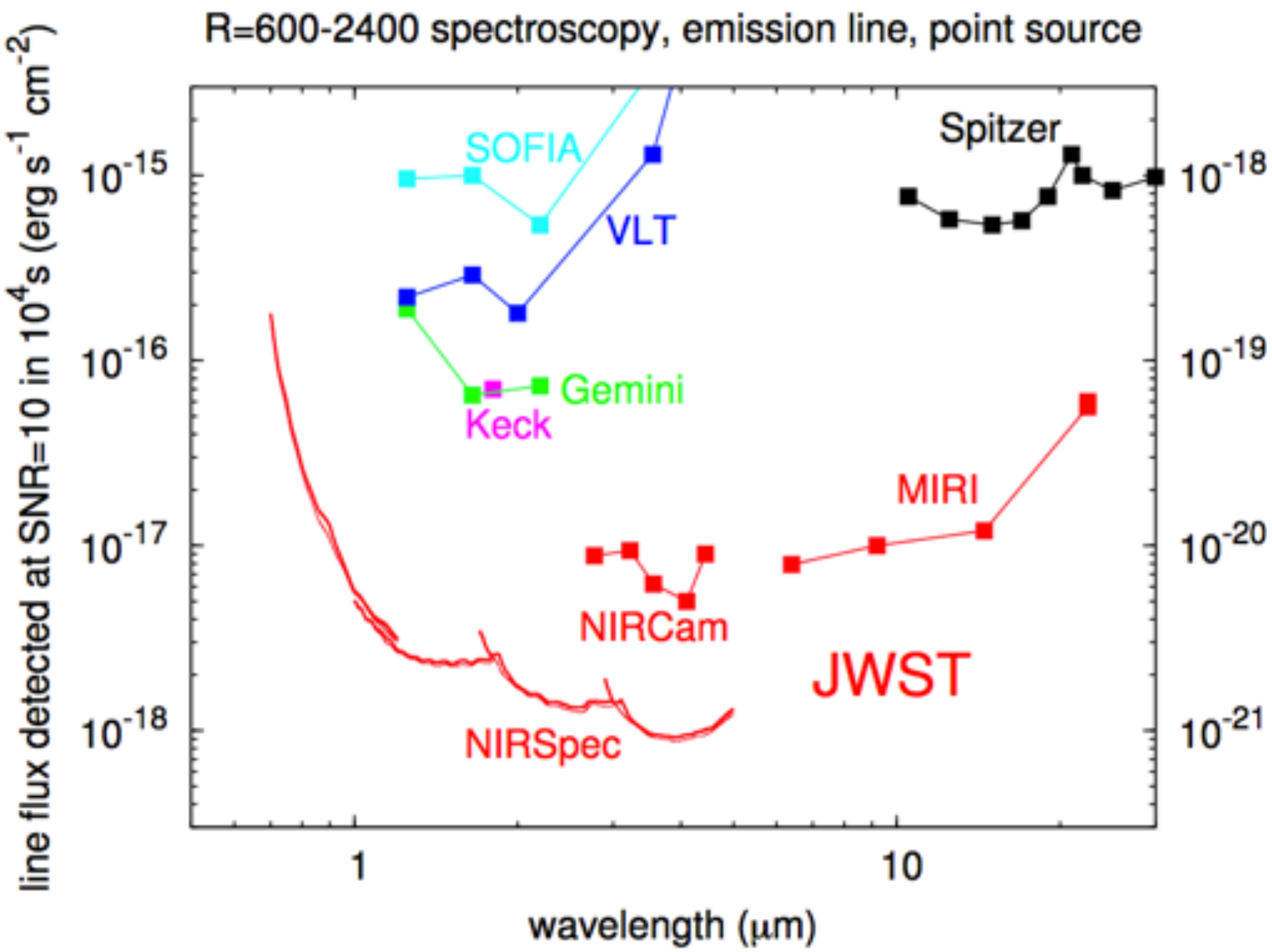
optical emission lines
shifted to the infrared

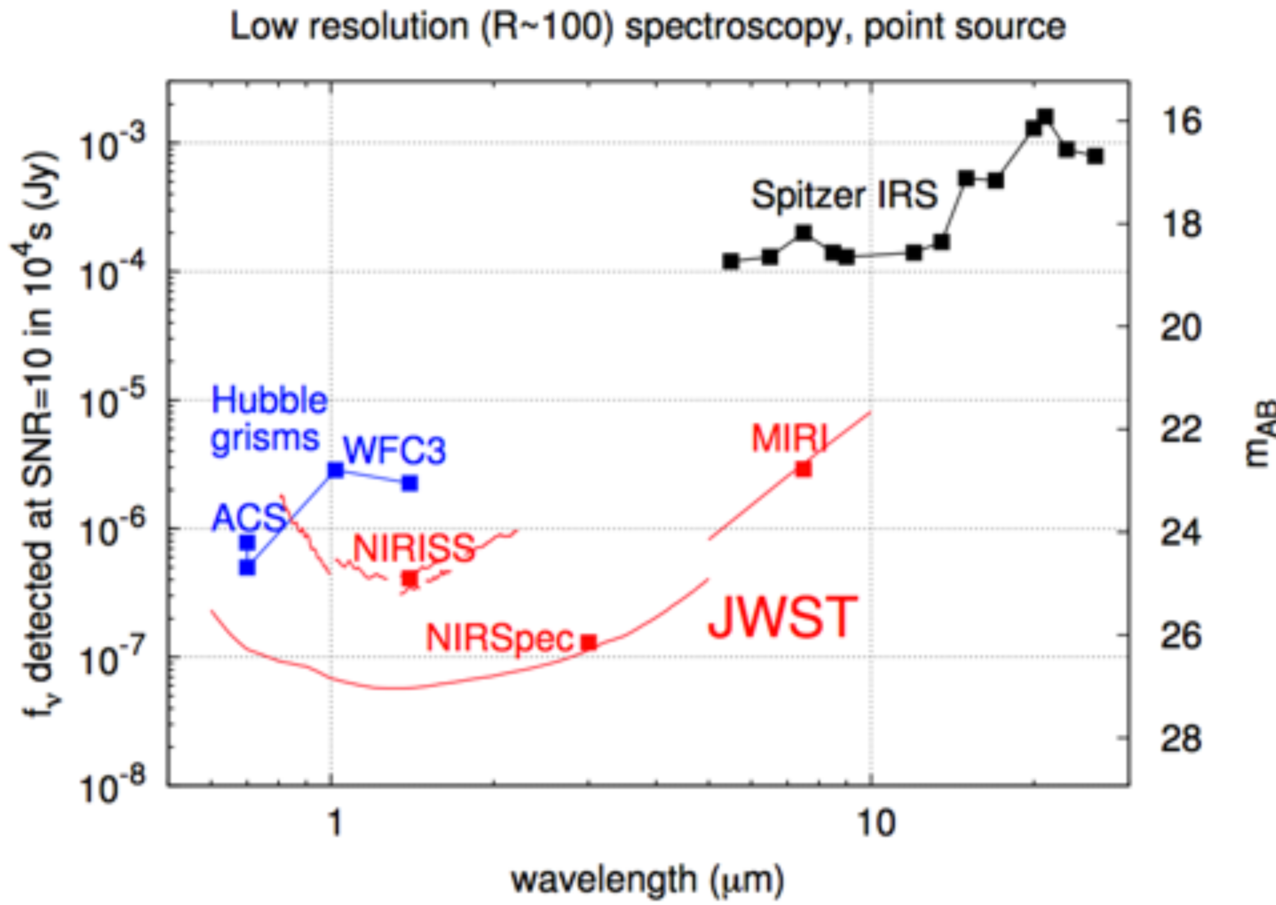


NIR Spectroscopy from Space

JWST Spectroscopic Performances

- NIRSpec: 1) to confirm candidates for very high-redshift galaxies (z>10) and look for spectral signatures of young, extremely-metal-poor stellar populations. 2) to explore in great detail the peak epoch of star formation
- NIRISS observations: slitless spectroscopy enables a blind search for z>7 galaxies (is the Lyman-alpha emission still a good tracer beyond z=7 ?)
- candidates selected from NIRCam and/or NIRISS observations
- MIRI: Optical emission line diagnostics at z>7

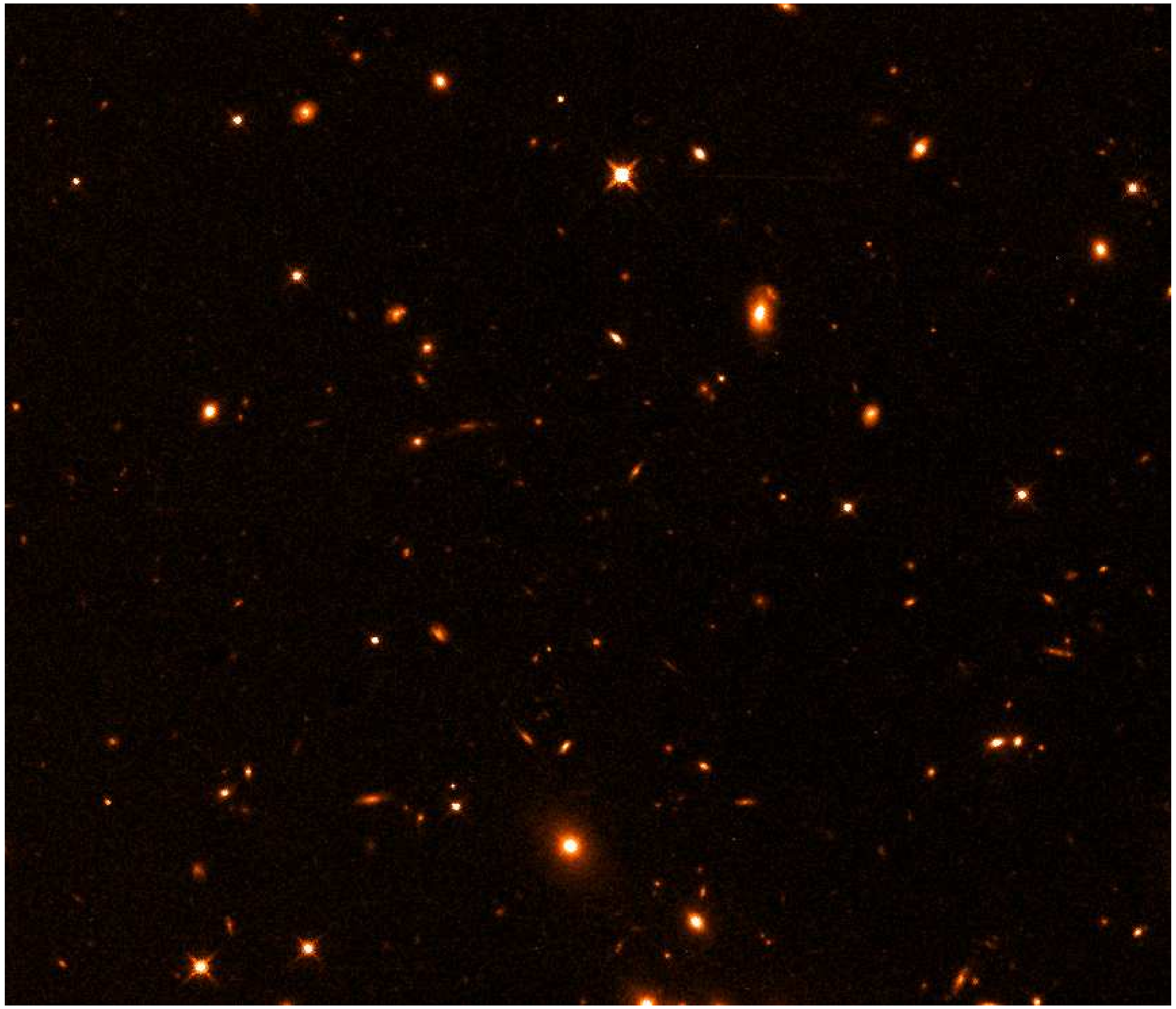




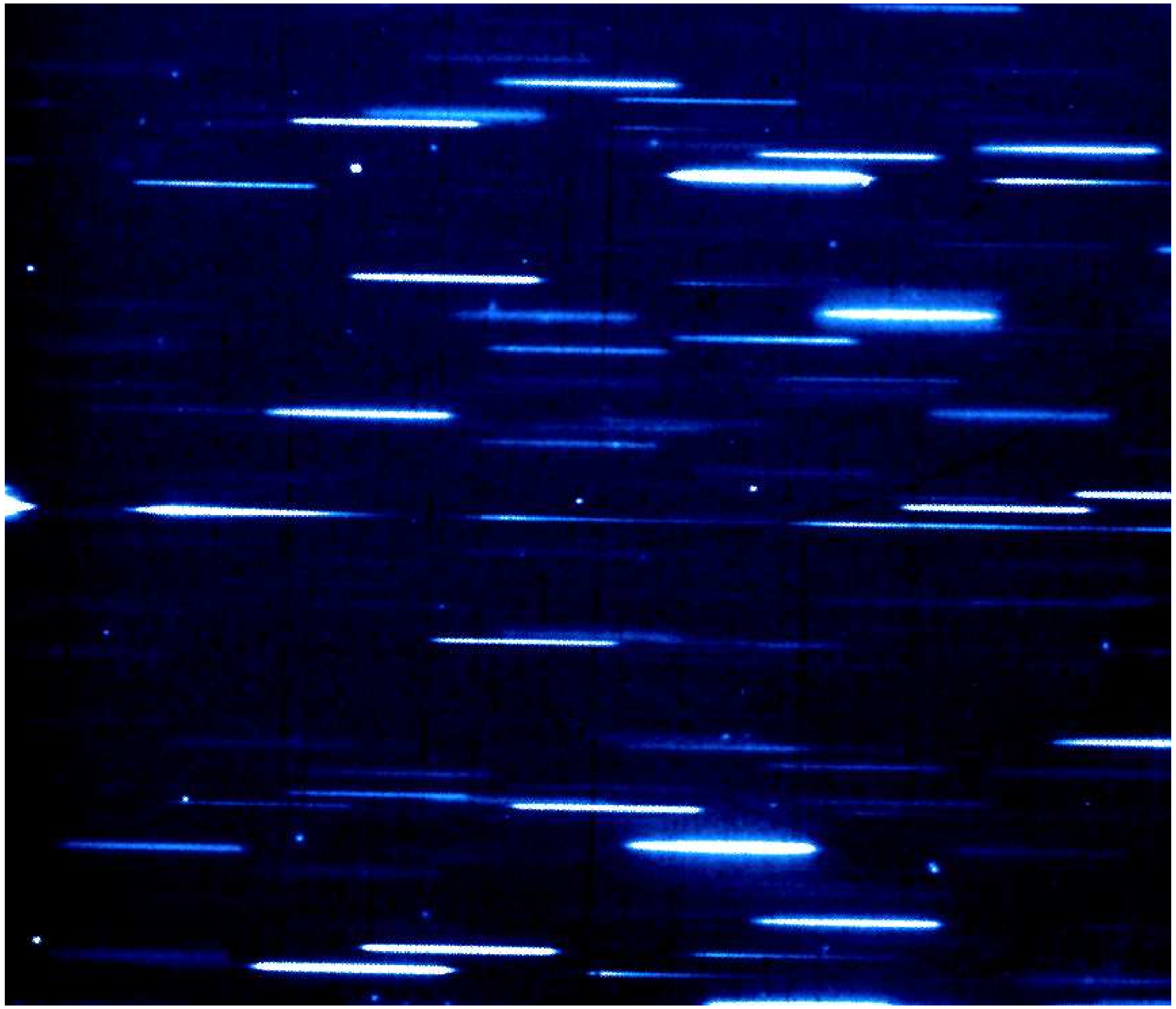
cf. Le Fevre's talk

WFC3/IR Grism spectroscopy

Direct Image



Dispersed image



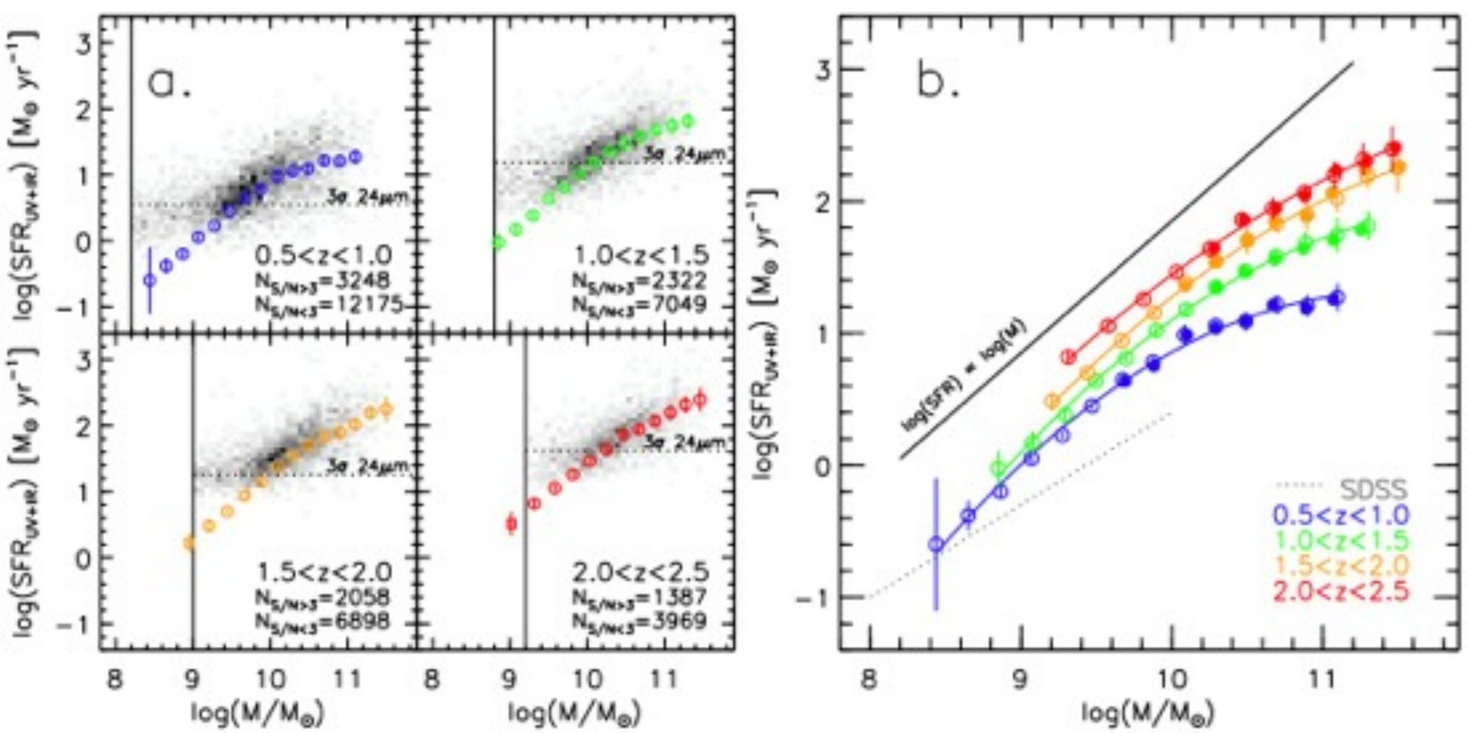
WISP (Atek et al. 2010), 3D-HST (Brammer et al. 2012), ERS (Straughn et al. 2010), AGHAST (PI Weiner), GLASS (Schmidt et al. 2014), FIGS (PI Rhoads)

The SFR-Mass Relation

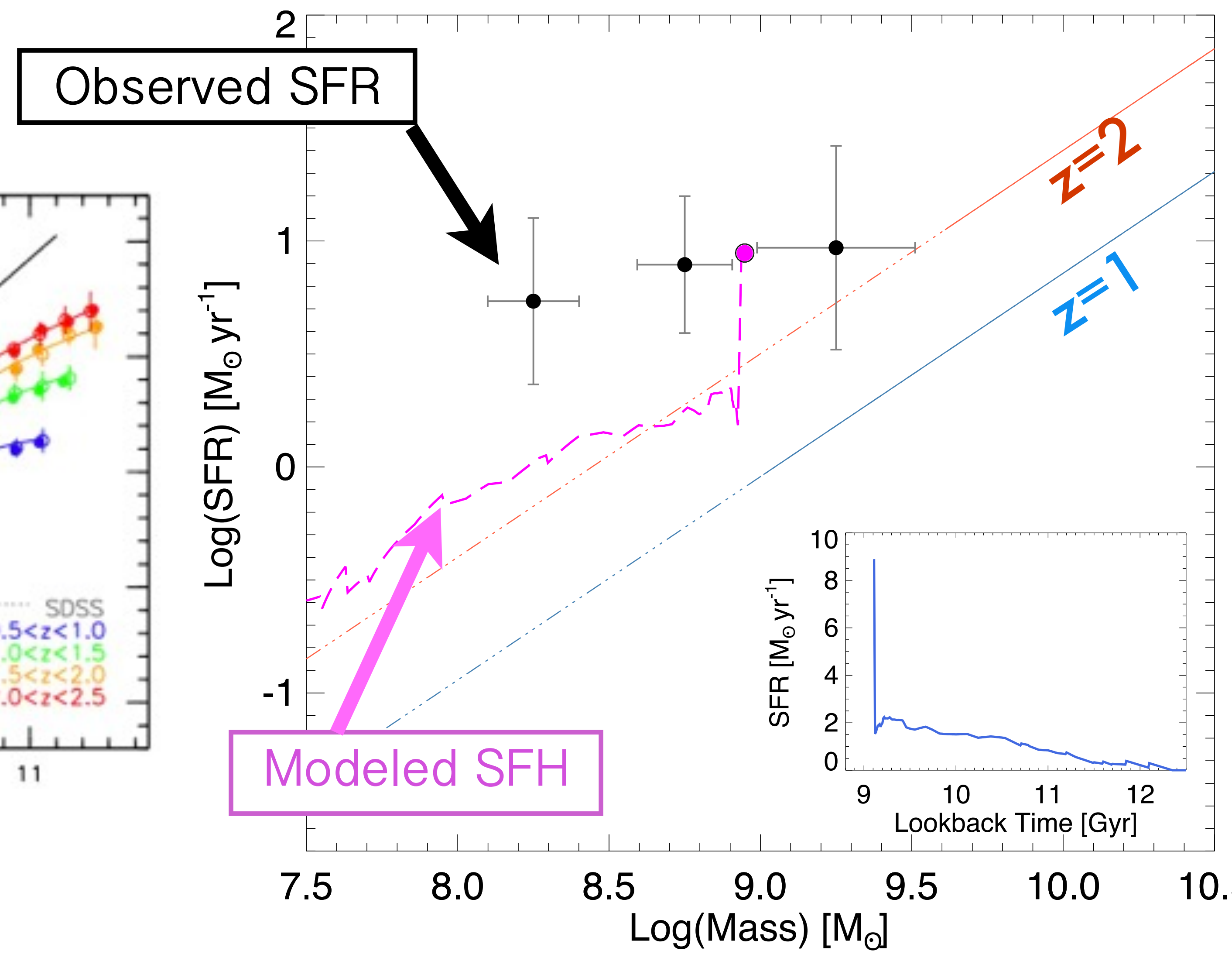
Quantifying the stellar mass buildup in galaxies Brinchmann et al. (2004), Daddi et al. (2007), elbaz et al. (2007), Noeske et al. (2007), Whitaker et al. (2012), Rodigheiro et al. (2012), Puech et al. (2014), Sobral et al. (2014), Speagle et al. (2014)

$$SFR \propto M^{\alpha}$$

Withaker et al. (2015)

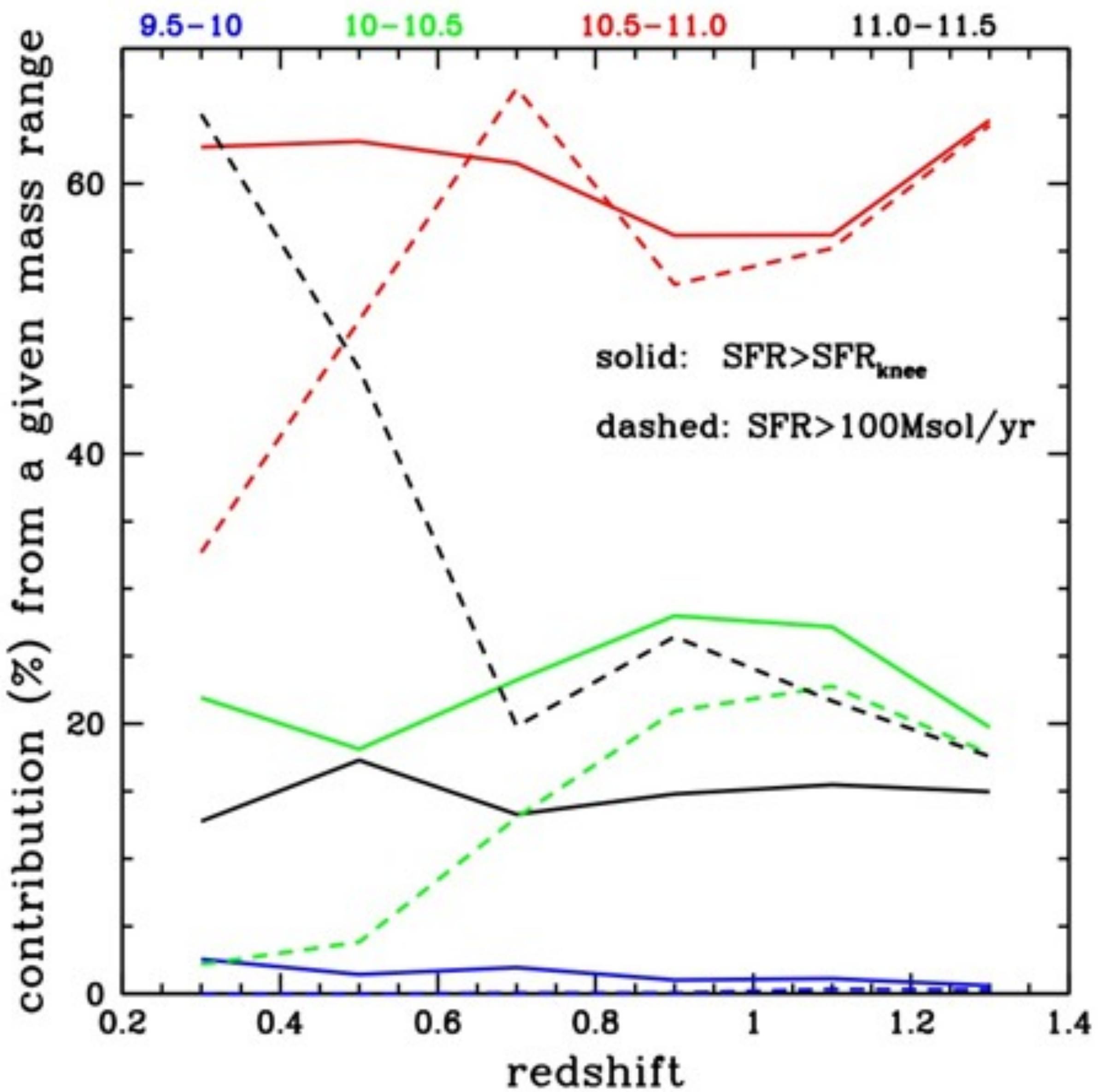


Atek et al. (2014c)

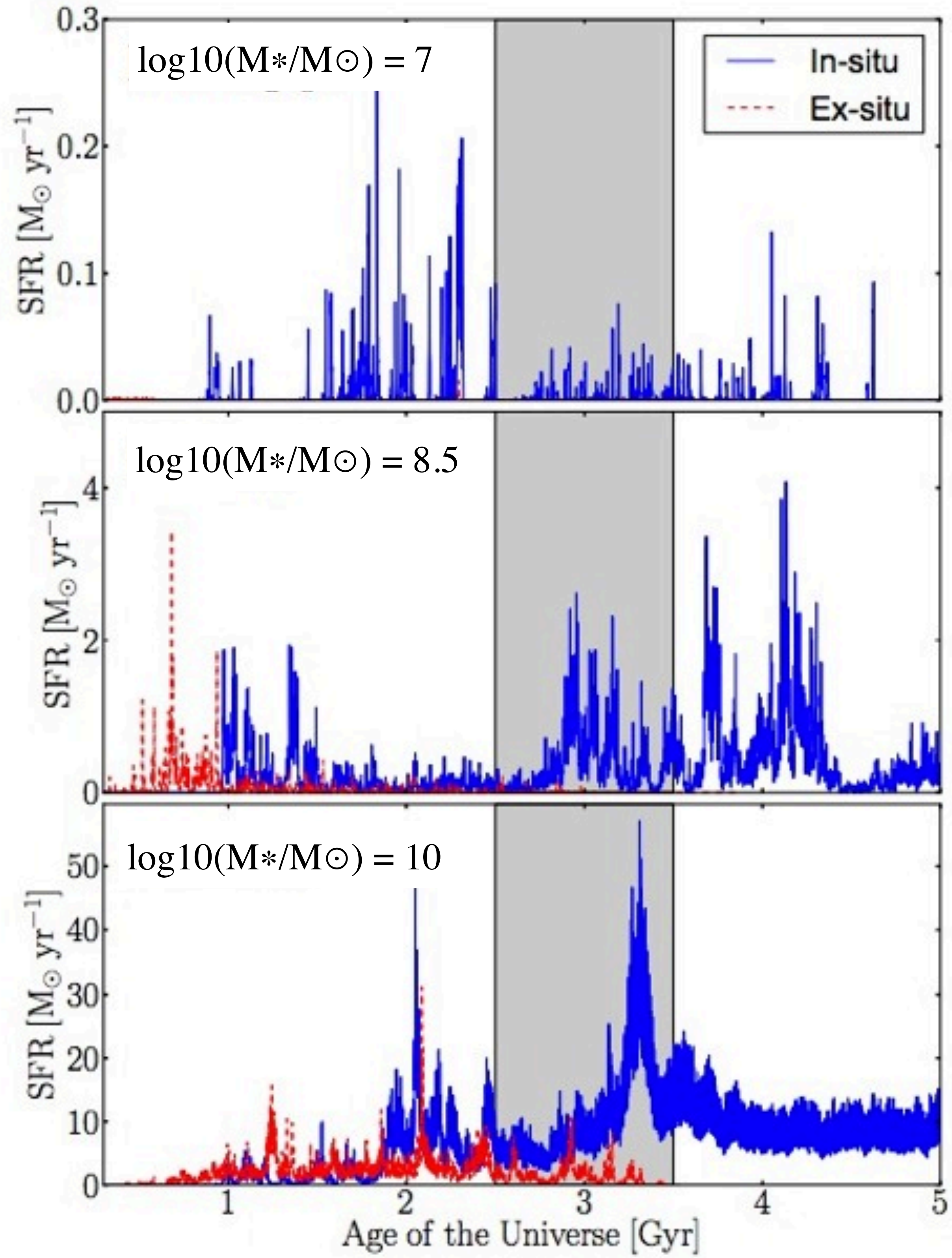


Contribution of Low-mass galaxies to SFRD

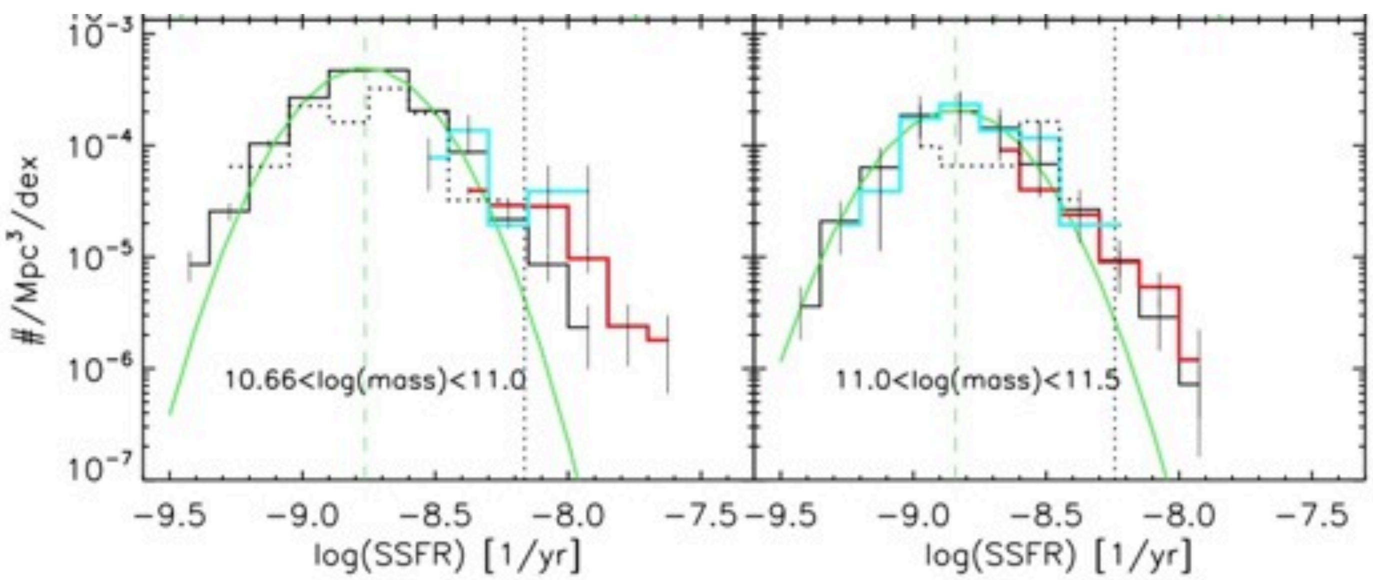
Ilbert et al. (2014)

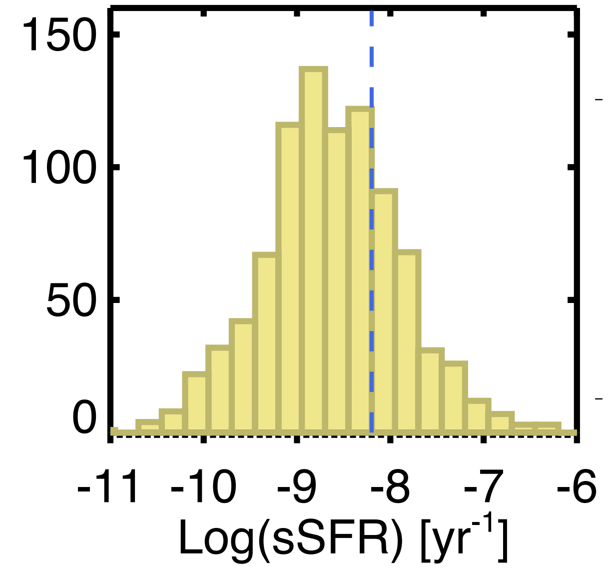


Dominguez et al. (2014)



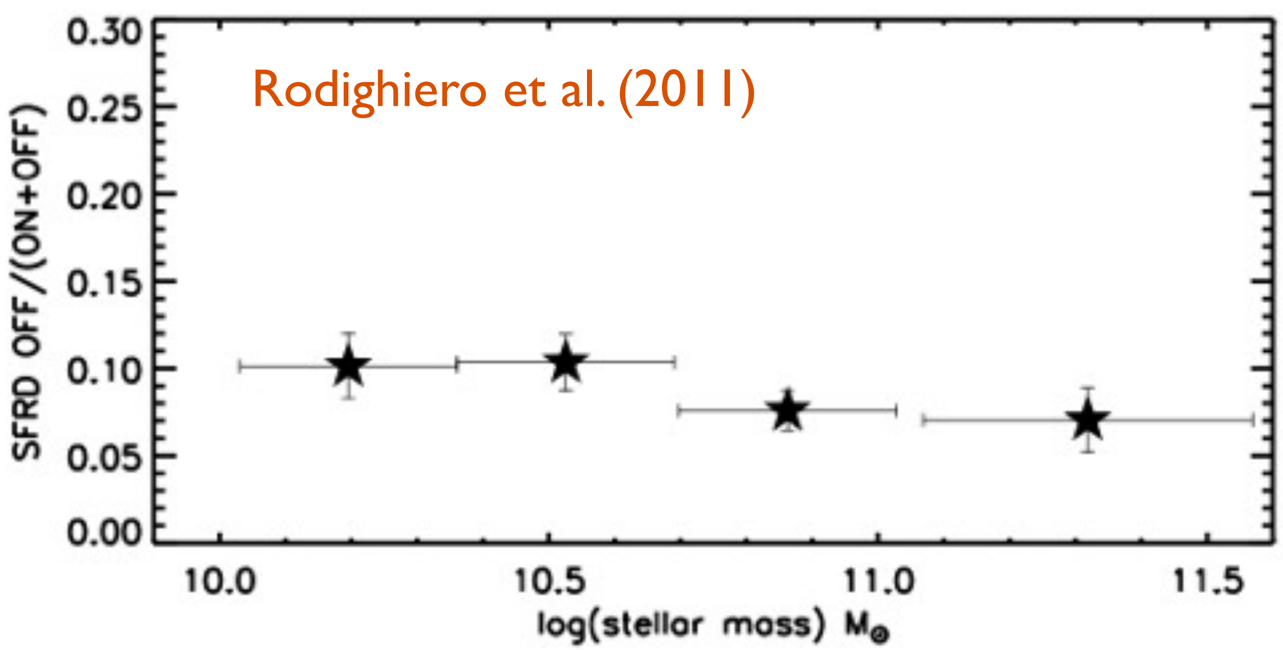
The Important Role of Starbursts in the SFH of the Universe





EELG contribution to the total SFRD

EW > 300 A : 13%
EW > 200 A : 18%
EW > 100 A : 34%



Evidence for an increase in the contribution of starbursts in lower mass galaxies

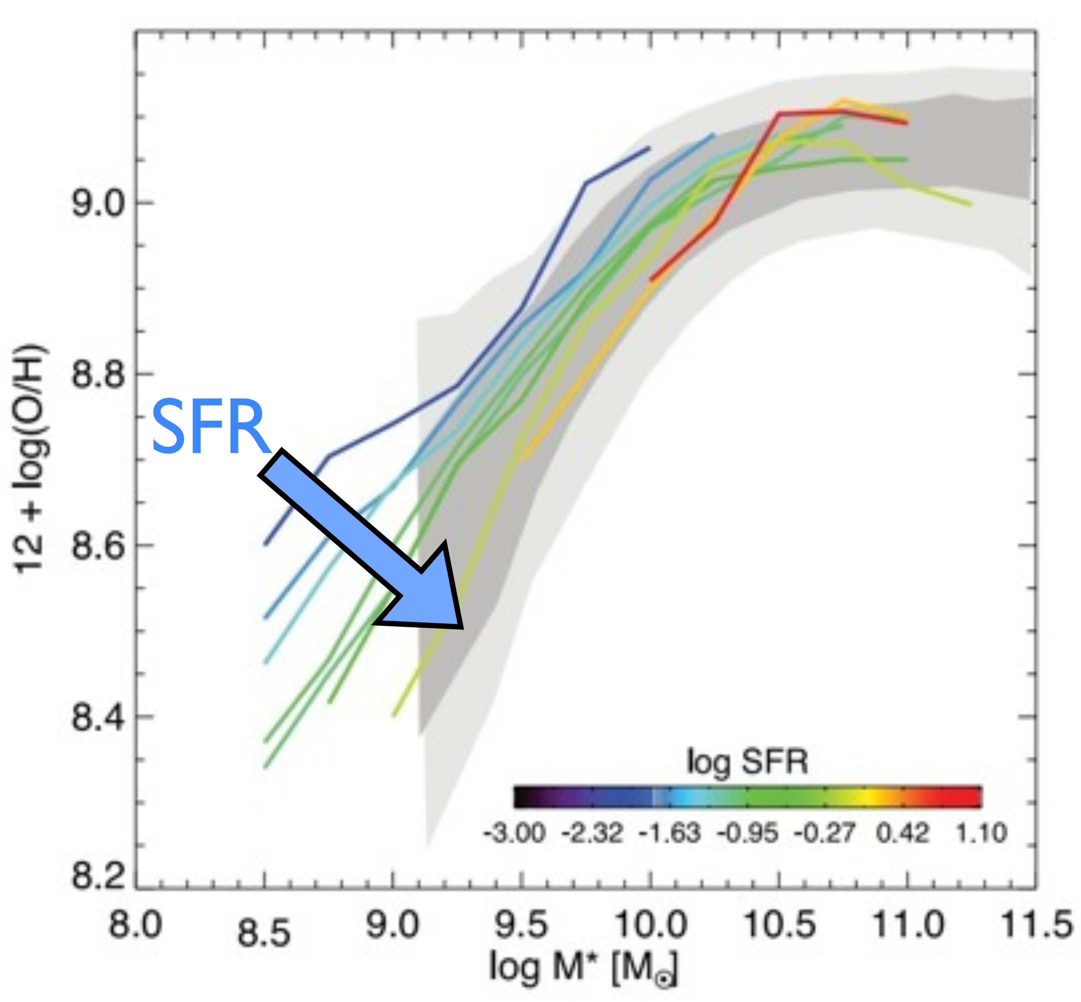
The prevalence of starbursting dwarf galaxies increases with redshift (Atek et al. 2011, Shim et al. 2011; Fumagalli et al. 2012, Stark et al. 2013, Schenker et al. 2014, Smit et al. 2014).

The Cycle of Gas and Metals in Galaxies

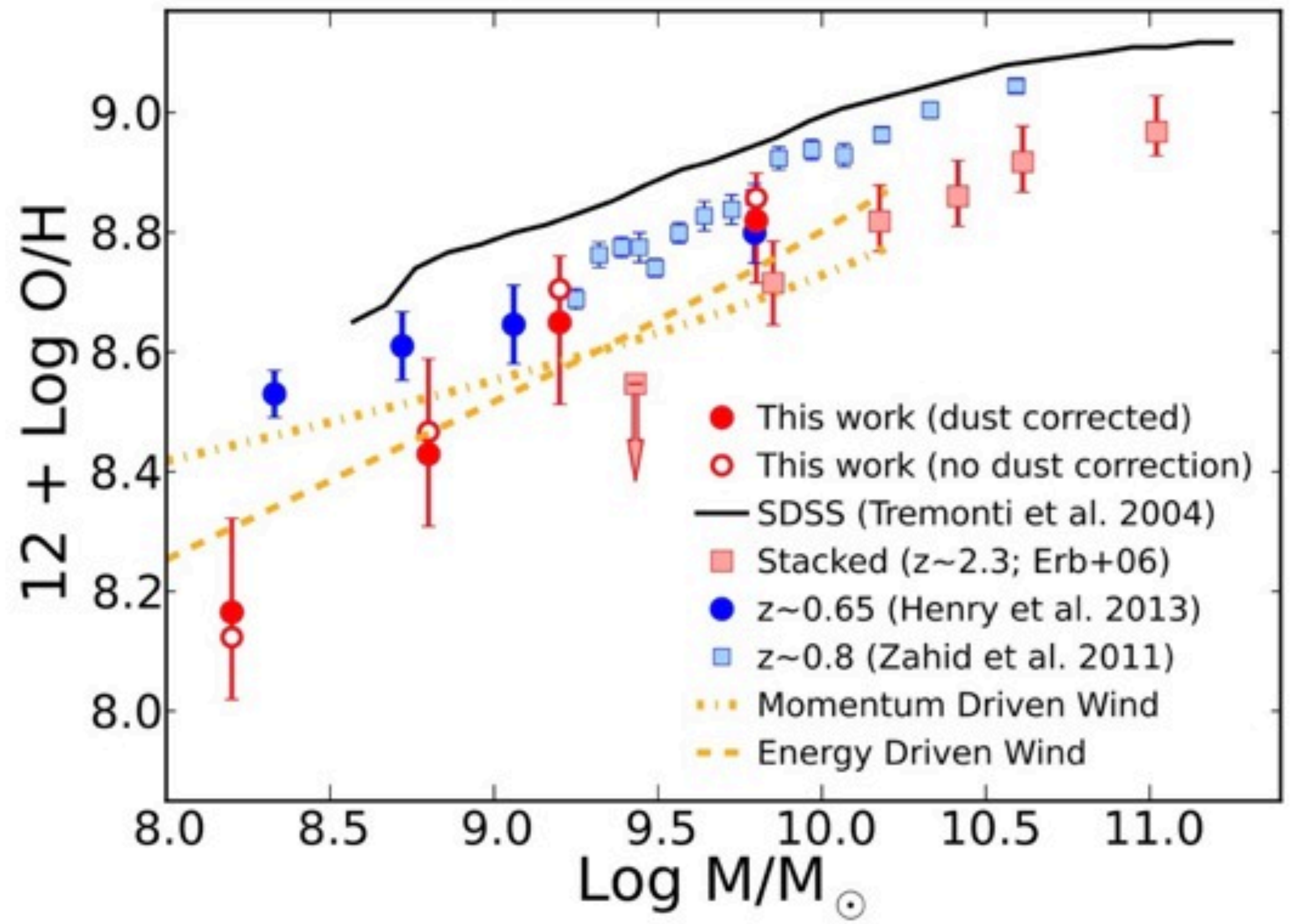
- The Mass-Metallicity relation is an important test for galaxy evolution models (cf. Brooks et al. 2007, Finlator & Davé 2008; Davé et al. 2010, Peeples & Shankar 2011)

- JWST will easily extend the fundamental relation (MZ-SFR) to low-mass galaxies at z>2 (cf. Mannucci et al. 2010, Lara-Perez et al. 2010, Andrews & Martini 2013)

Bothwell et al. (2013)

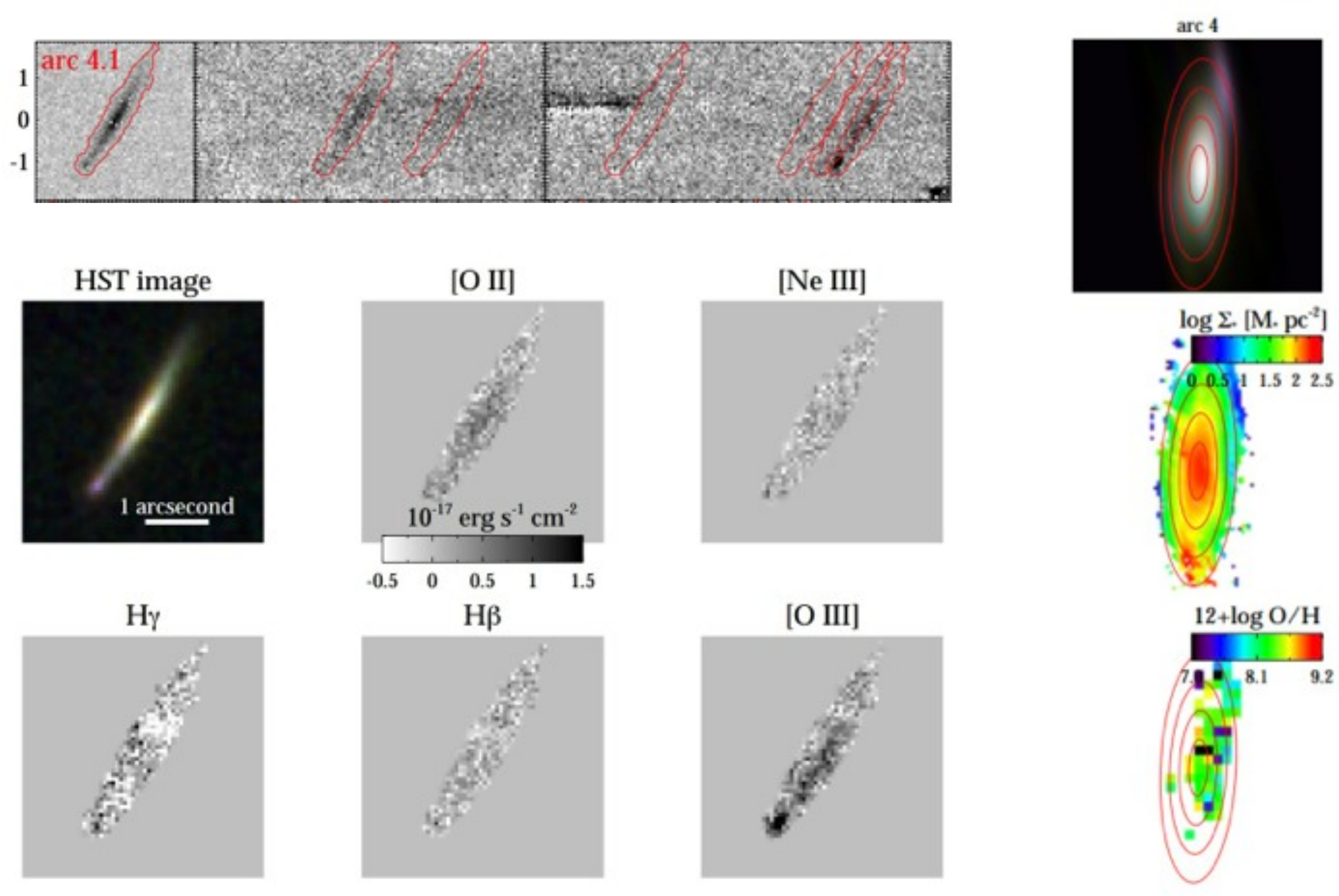


Henry et al. (2013)



The Cycle of Gas and Metals in Galaxies

NIRSpec IFU observations will enable metallicity gradient mapping in distant galaxies --> direct implications for galaxy growth scenarios (see Yuan et al. 2011, Swinbank et al. 2012, Troncoso et al. 2014) and ionized gas kinematics

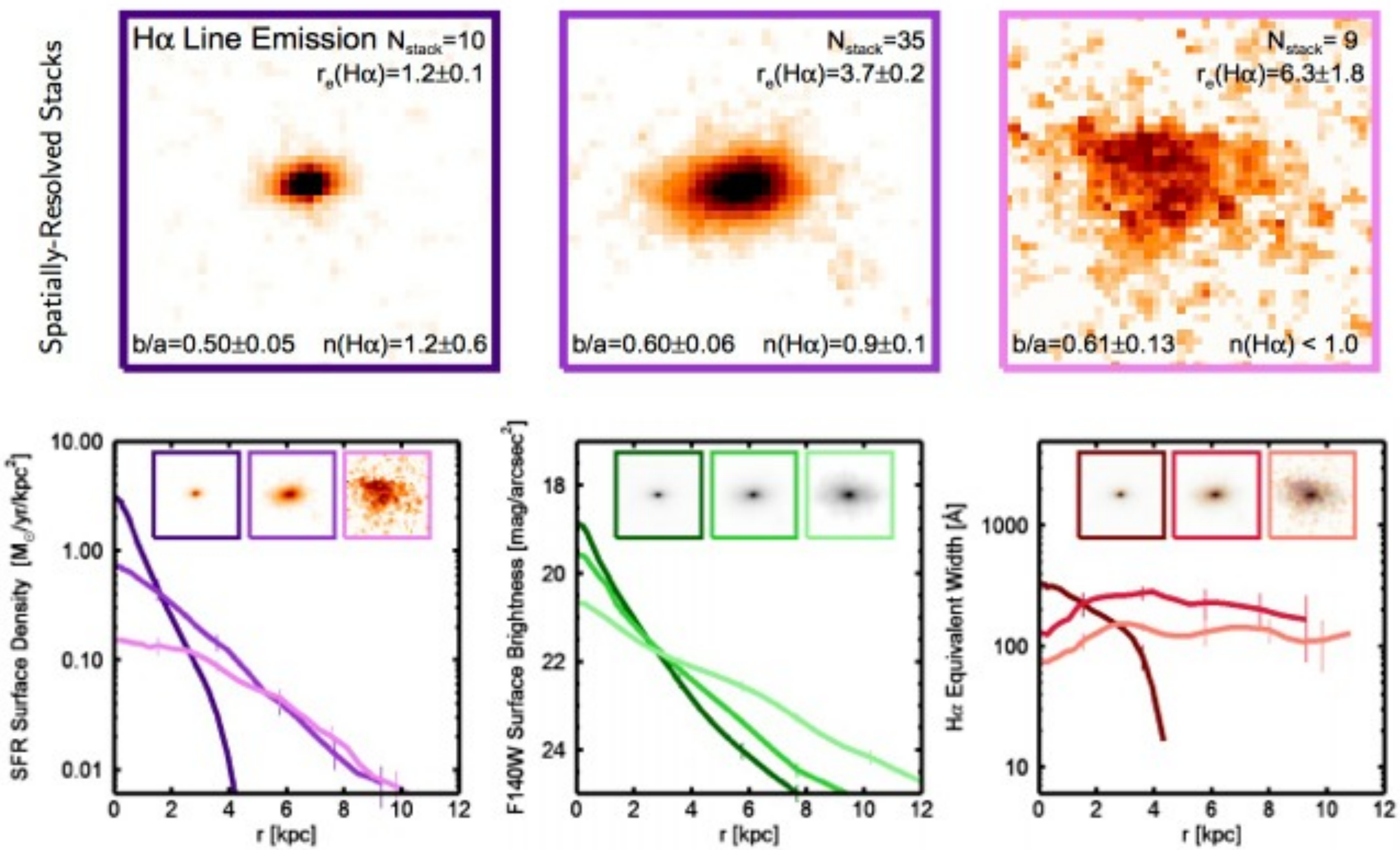


Jones et al. (2015)

Spatially Resolved Star Formation

NIRSpec IFU studies of spatial distribution of star formation in z>2 galaxies (Genzel et al. 2008; Shapiro et al. 2008; Cresci et al. 2009; Förster Schreiber et al. 2009; Law et al. 2009; Jones et al. 2010; Mancini et al. 2011)

--> The study of the young and old SED enables the reconstruction the star formation history of galaxies (spatially resolved)



Nelson et al. (2014)

Conclusion

The JWST will dramatically change our views on galaxy formation and evolution:

- **NIRCam, MIRI** will reach the first generation of galaxies, 1-2 magnitude fainter than any galaxy known at z>6
- Track back galaxy formation at z>20 with accurate SED constraints
- Multiple Spectroscopic solutions in the IR, an important shift from HST (with a much better spitzer on the way)

Need to increase legacy surveys in the UV and optical with HST now !

- Orders of magnitude in line flux sensitivity + multiplexing capabilities (MOS, slitless).

Deep spectroscopic survey at z>8 need to solve the Lyman-alpha issue (CIII], [CIV] ?)

- **NIRSpec IFU** spectroscopy will enable spatially resolved star formation, metallicity, kinematics

The combination with gravitational lensing will push the flux and the resolution limits by 1-2 orders of magnitudes >> Detecting the faintest galaxies in the Universe ?

First Call for Proposals
Fall 2017