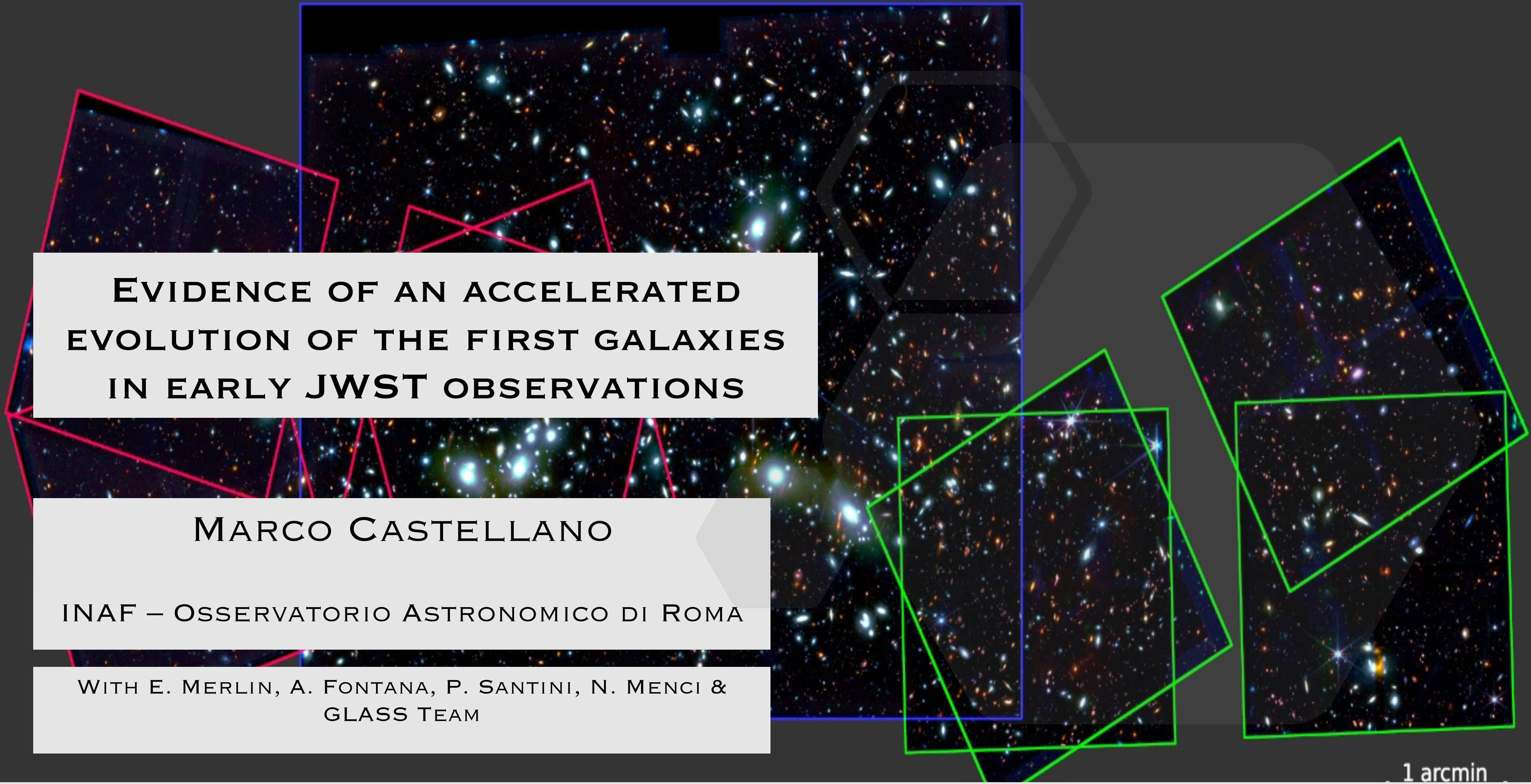


Evidence of an accelerated evolution of the first galaxies in early JWST observations

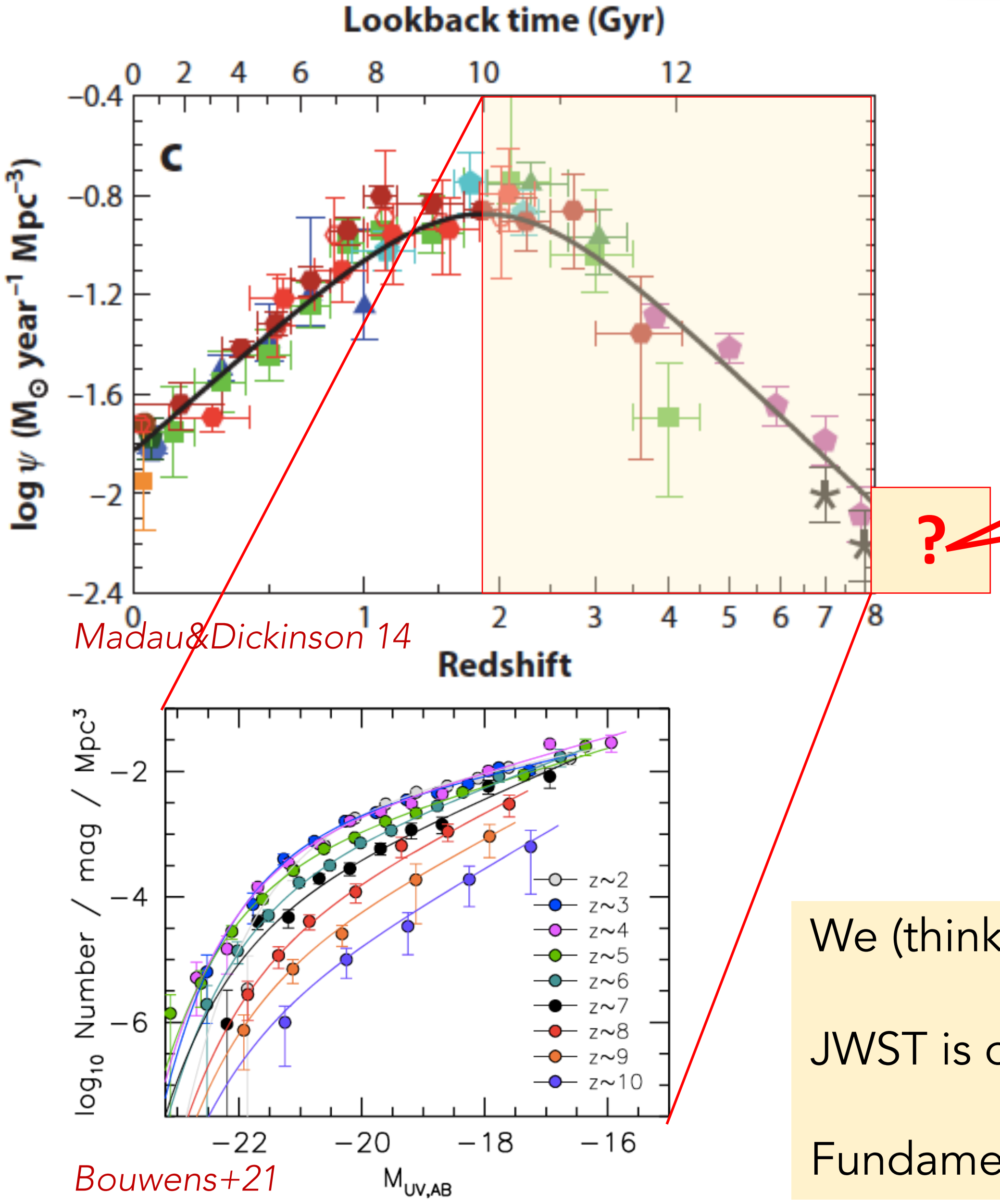
Marco Castellano

INAF – Osservatorio Astronomico di Roma

With E. Merlin, A. Fontana, P. Santini, N. Menci & GLASS Team

MOND40 Conference – St. Andrews June 7 2023

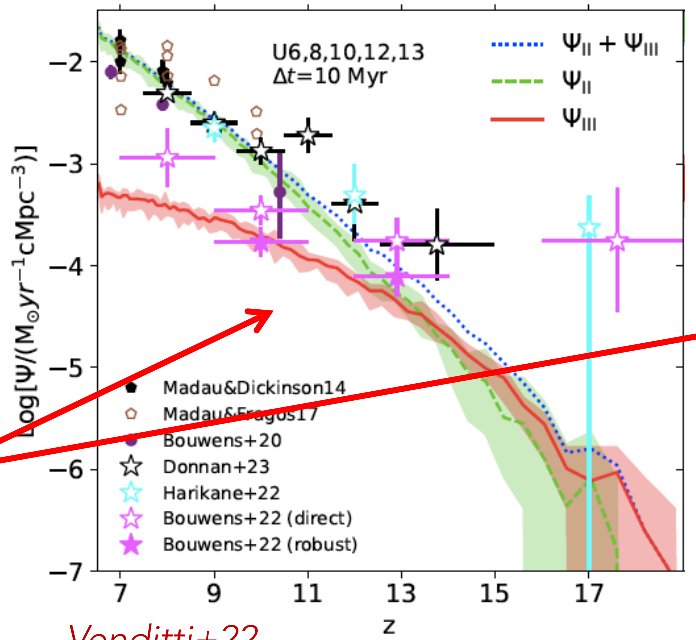
Searching for the first sources of light



Madau&Dickinson 14

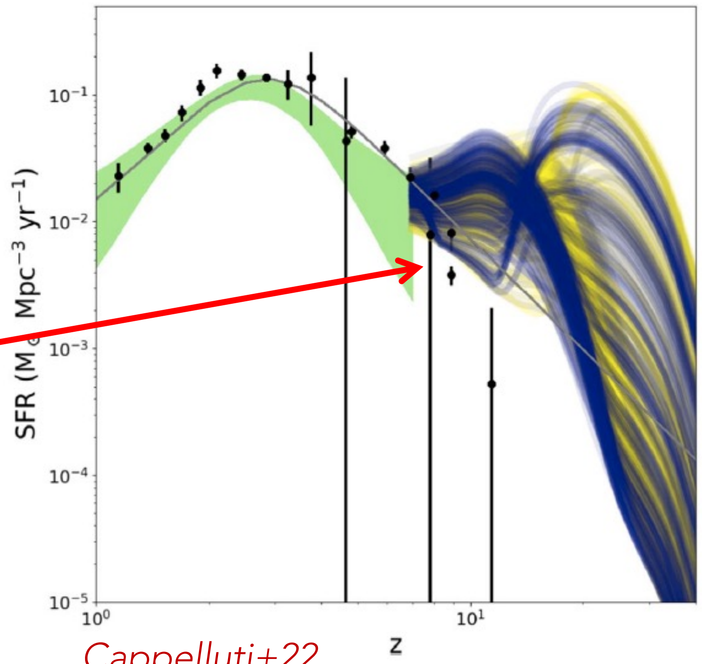
Bouwens+21

PopIII SFRD?



Venditti+22

PBH-ΛCDM SFRD?



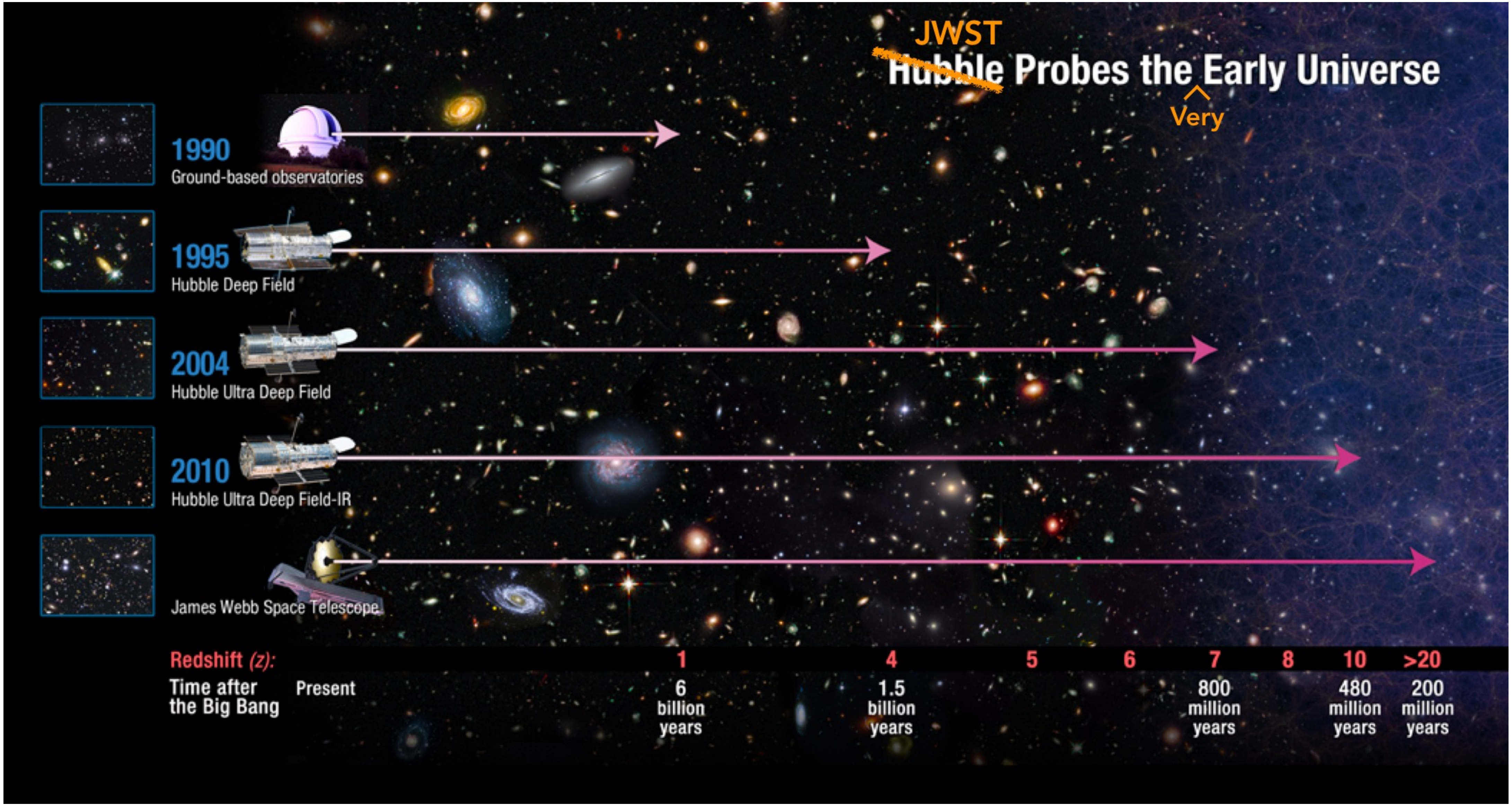
Cappelluti+22

We (think we) know well the evolution of the SFRD after reionization

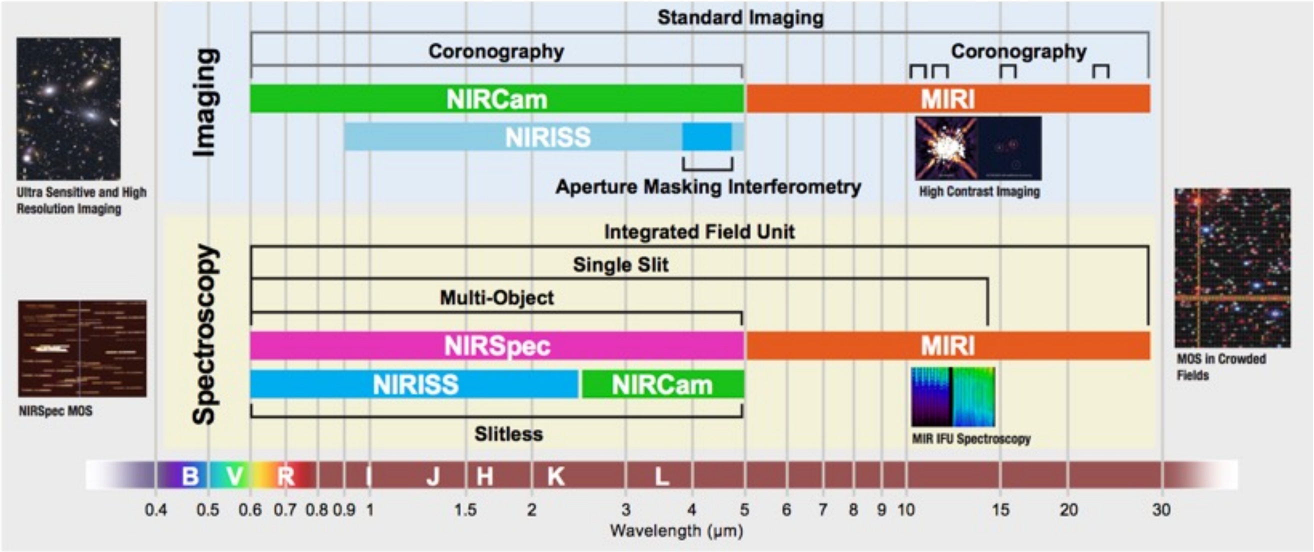
JWST is opening the exploration of the SFRD at z>10.

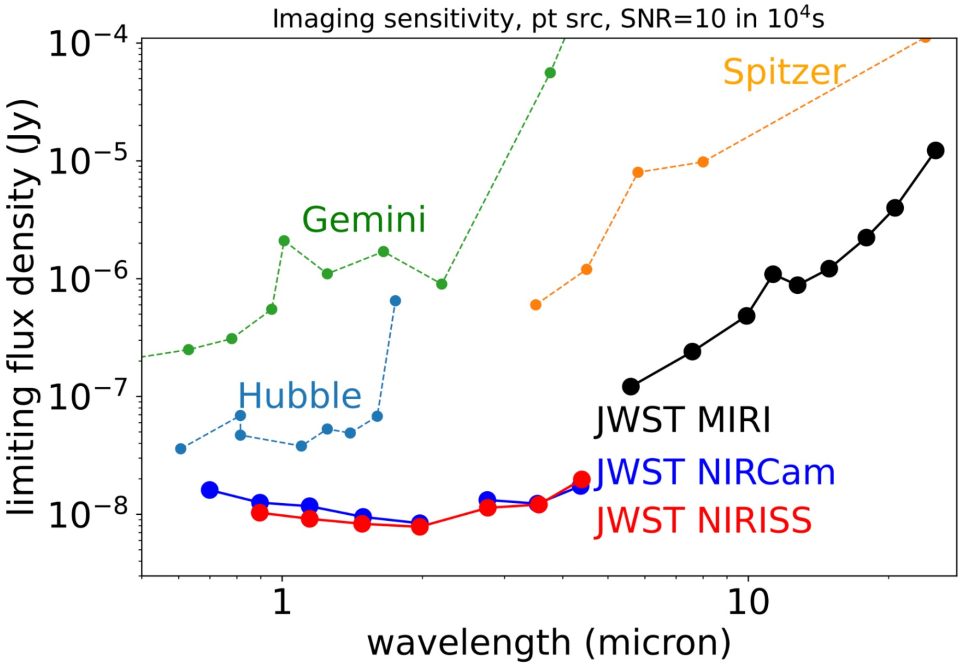
Fundamental for reionization, BH seeds, first stars, chemical evolution, etc

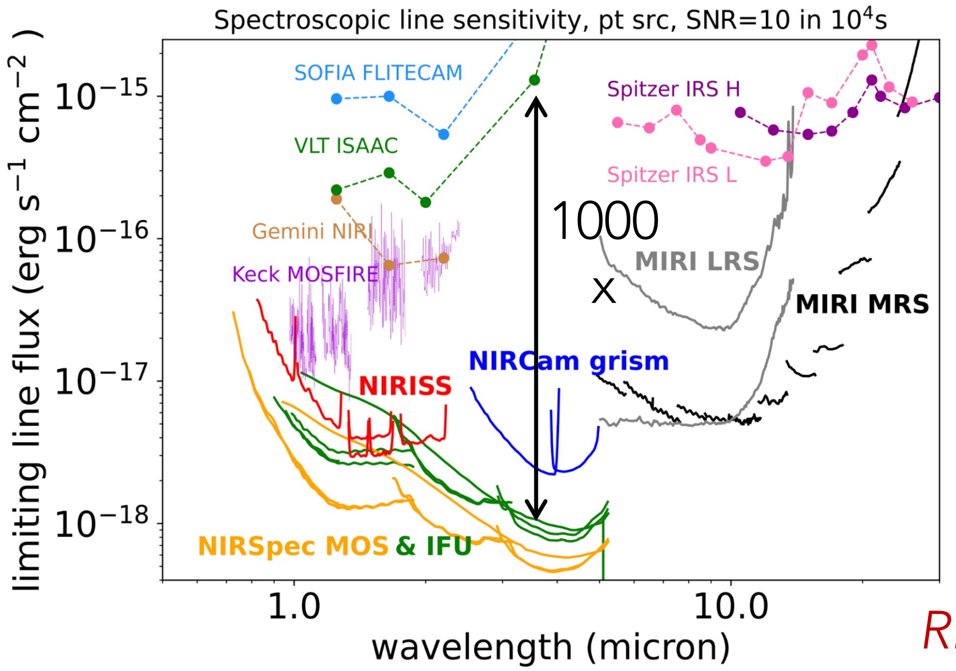
The ideal instrument for cosmic dawn



The ideal instrument for cosmic dawn

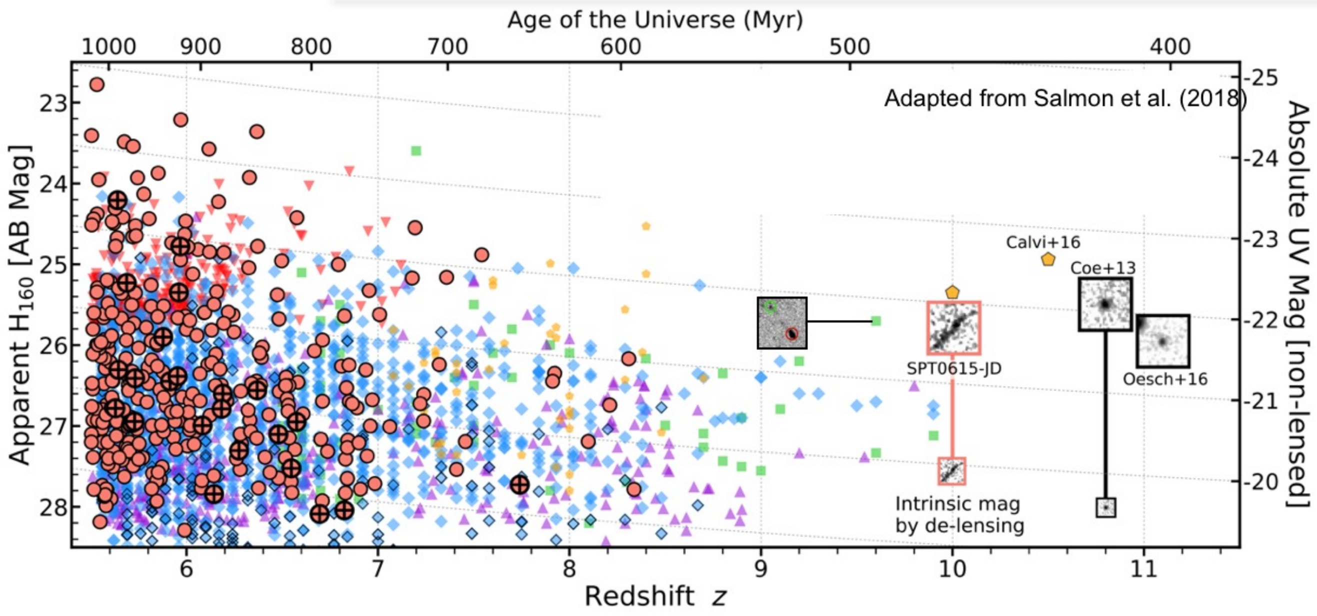


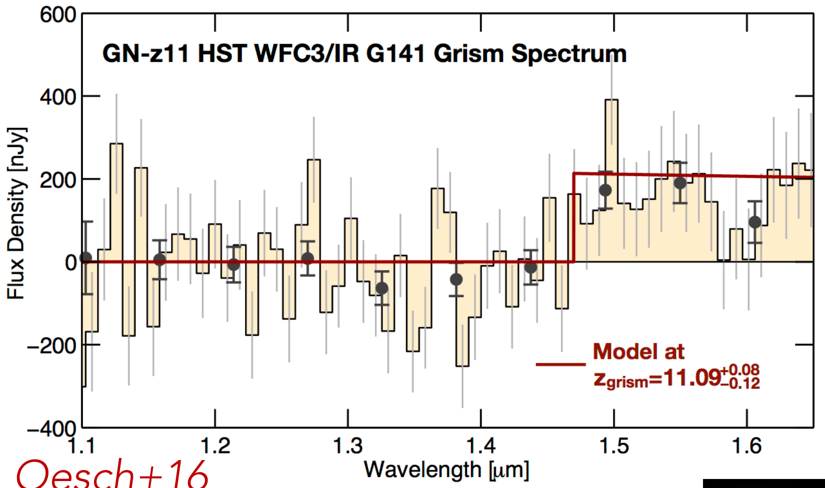




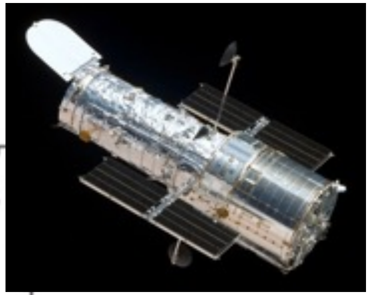
Rigby+23

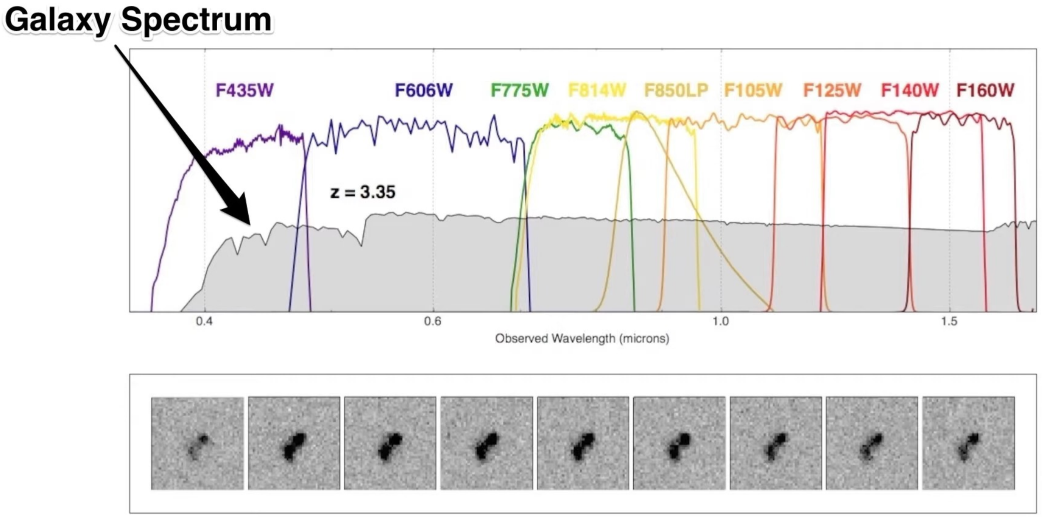
The Hubble legacy



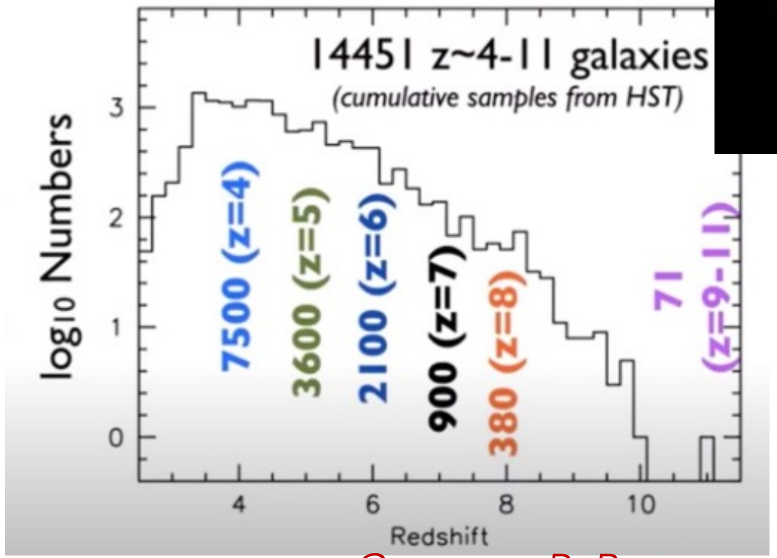


Oesch+16



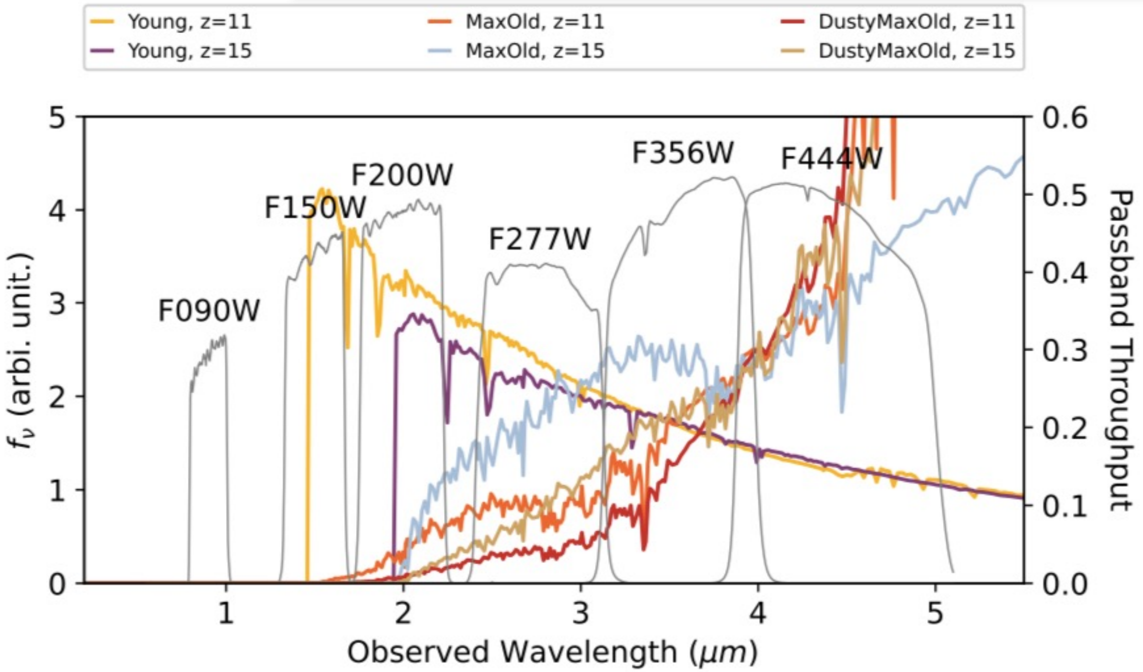


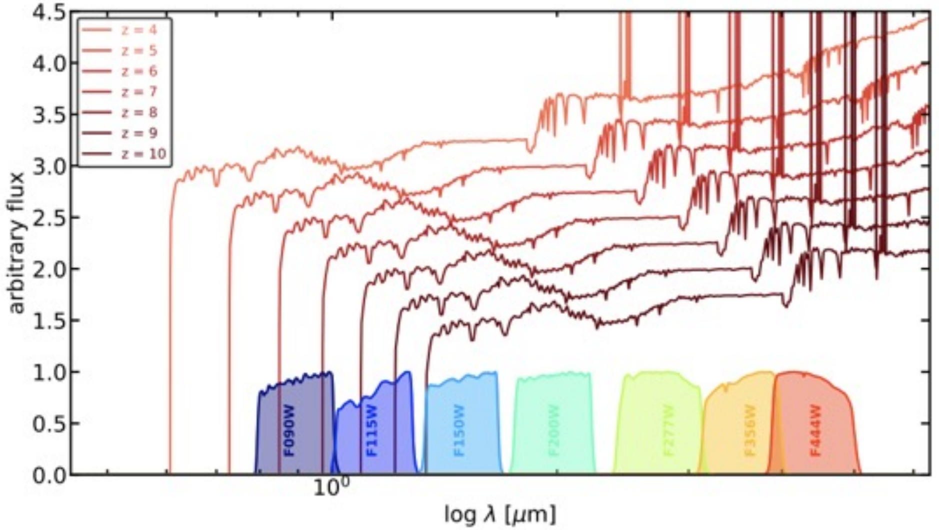
Credit: D. Magee, R. Bouwens, P. Oesch, & G. Illingworth

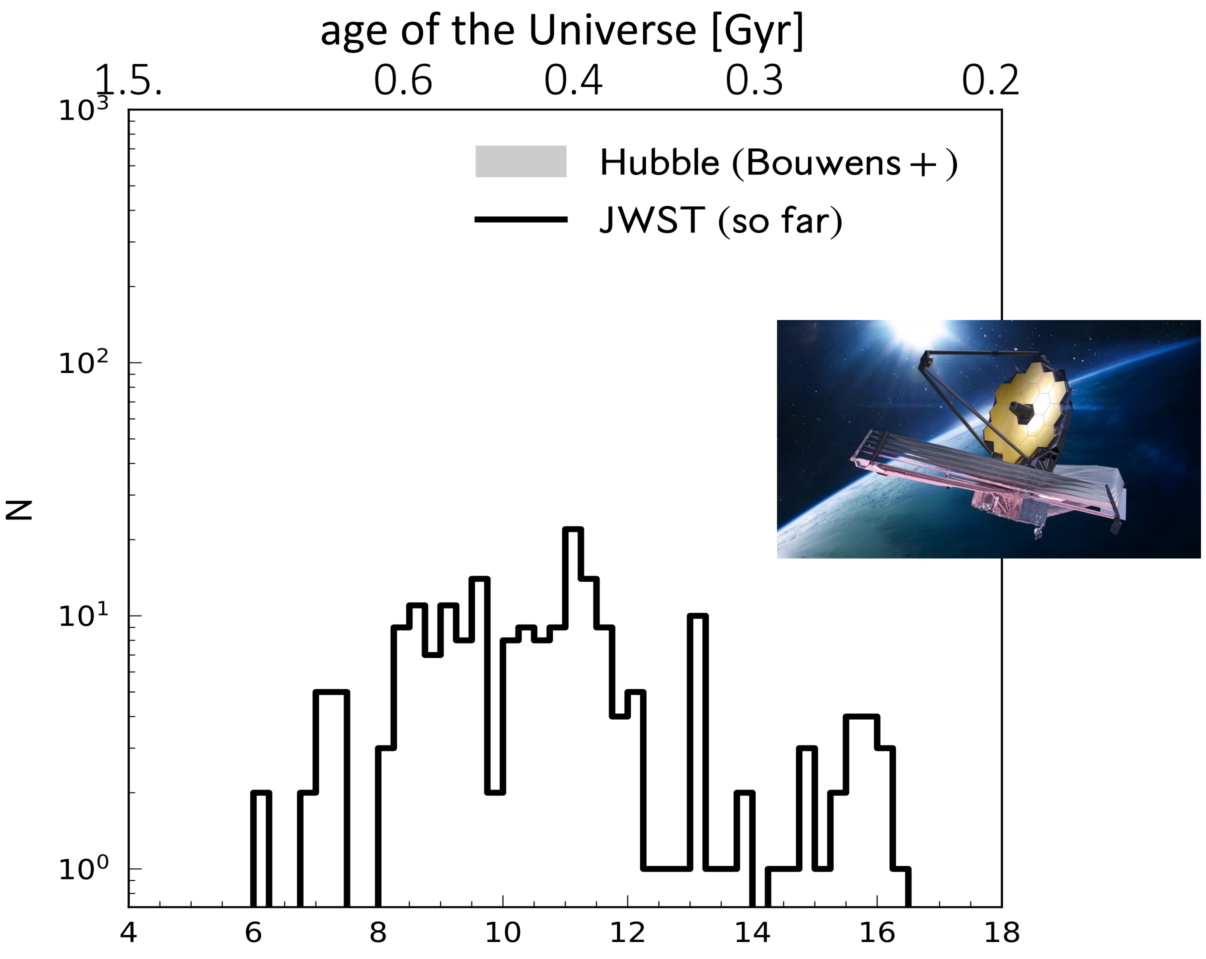


Courtesy: R. Bouwens

The ideal instrument for cosmic dawn

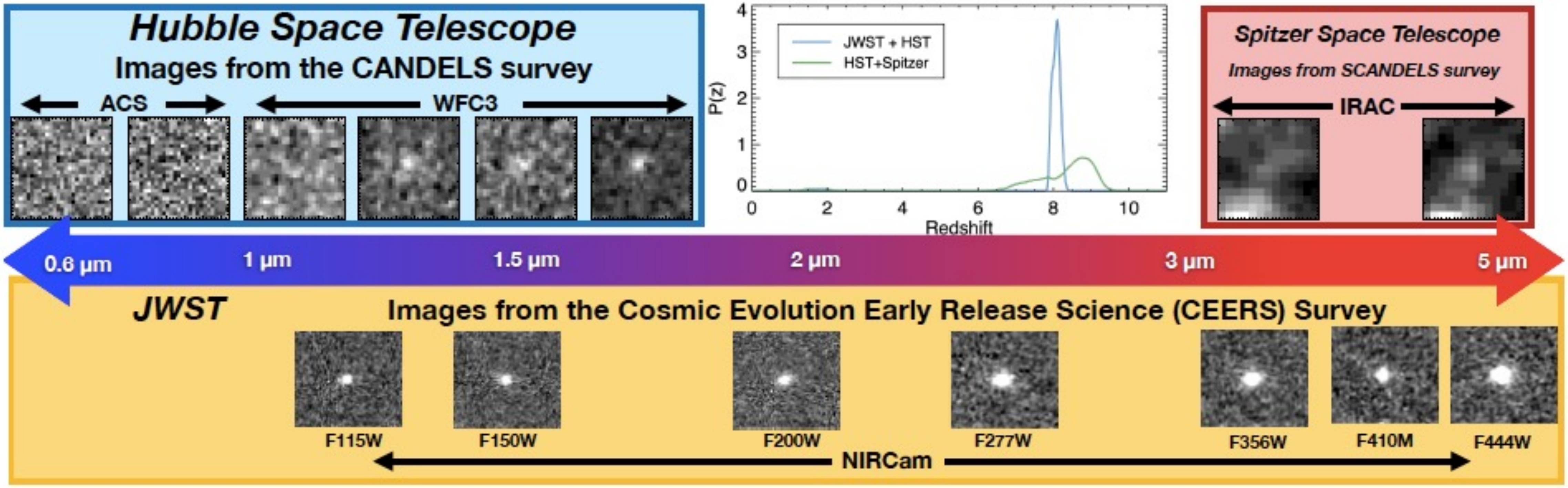






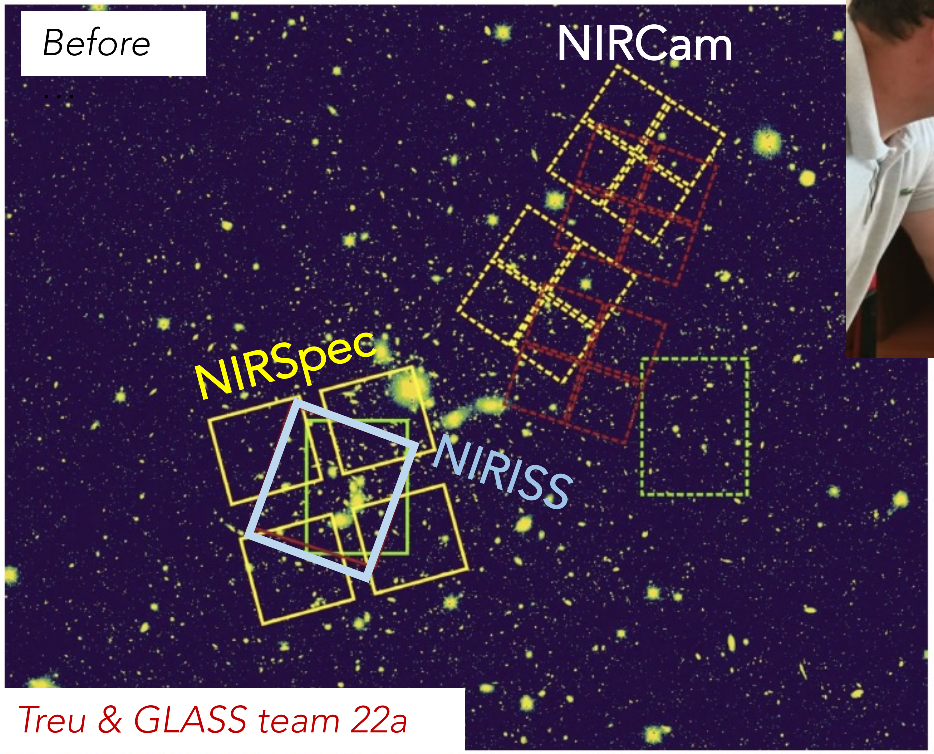
Courtesy: S. Wilkins

The ideal instrument for cosmic dawn: galaxy selection

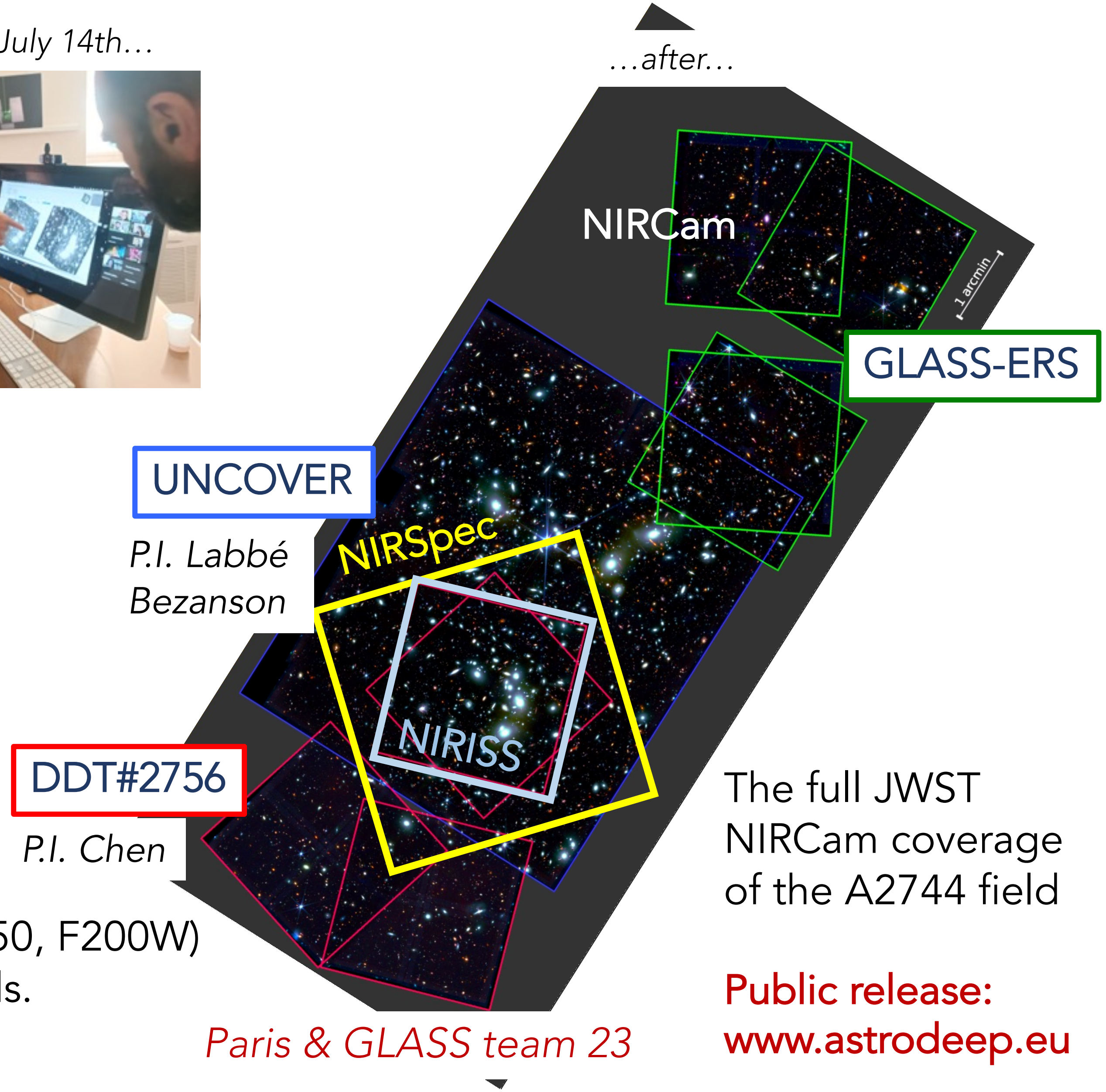


Finkesltein & CEERS team 22

JWST SURVEYS ON THE A2744 FIELD



Survey scheme from the ERS presentation paper

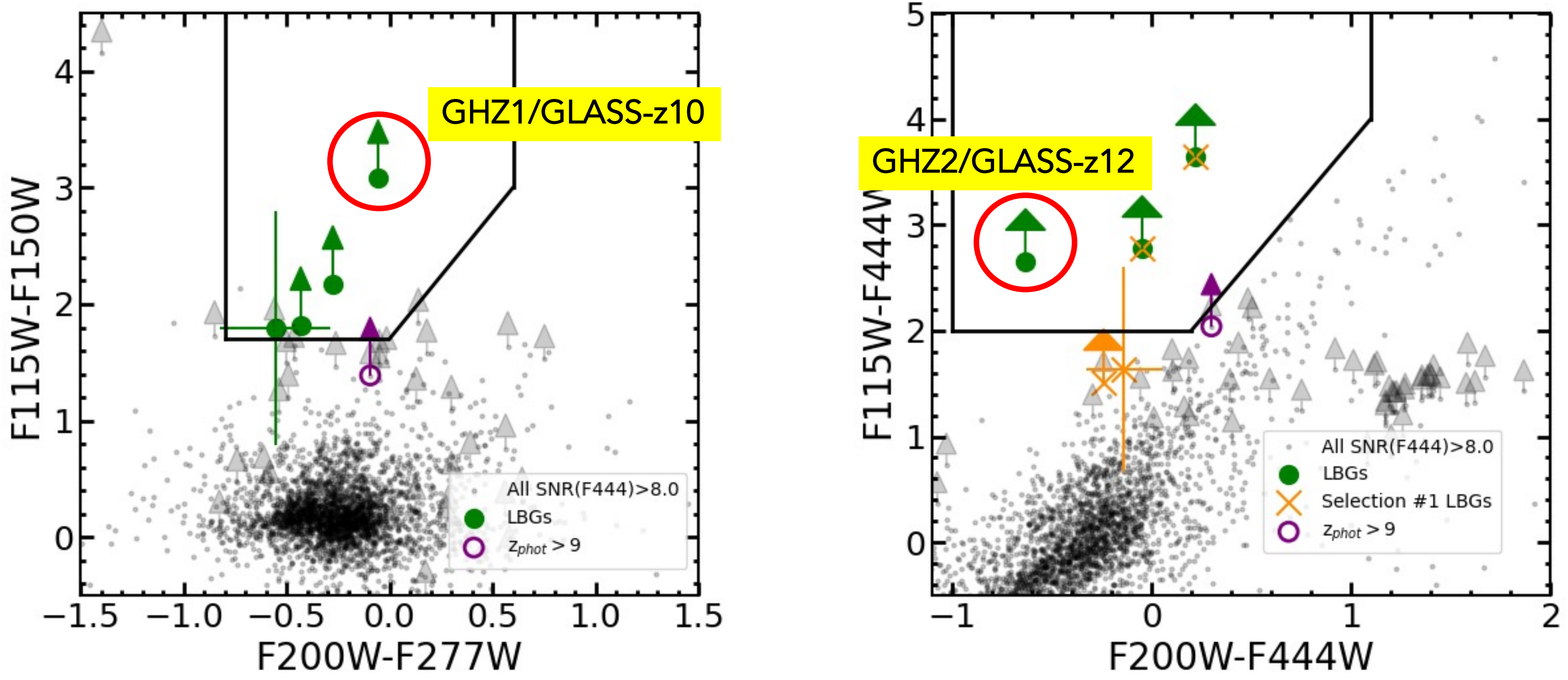


Deepest extragalactic ERS:
NIRSPec (F100LP, F170LP, F290LP) and NIRISS F115, F150, F200W) on the HFF. Two NIRCam parallel pointings in seven bands.

The full JWST NIRCam coverage of the A2744 field

Public release:
www.astrodeep.eu

High-redshift galaxies in GLASS-JWST

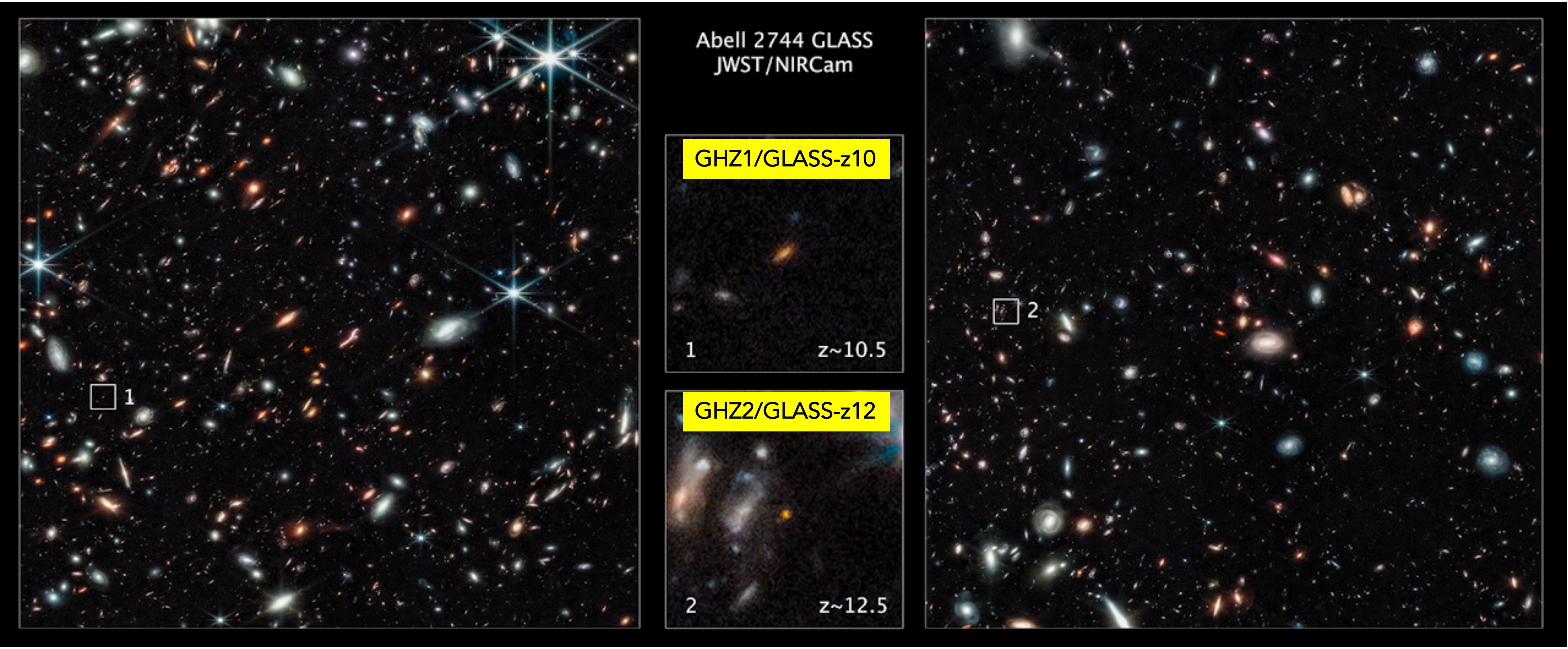


Six color-selected candidates, one additional from photo-zs.

Two extremely robust, bright objects. Other candidates show double photo-z solutions.

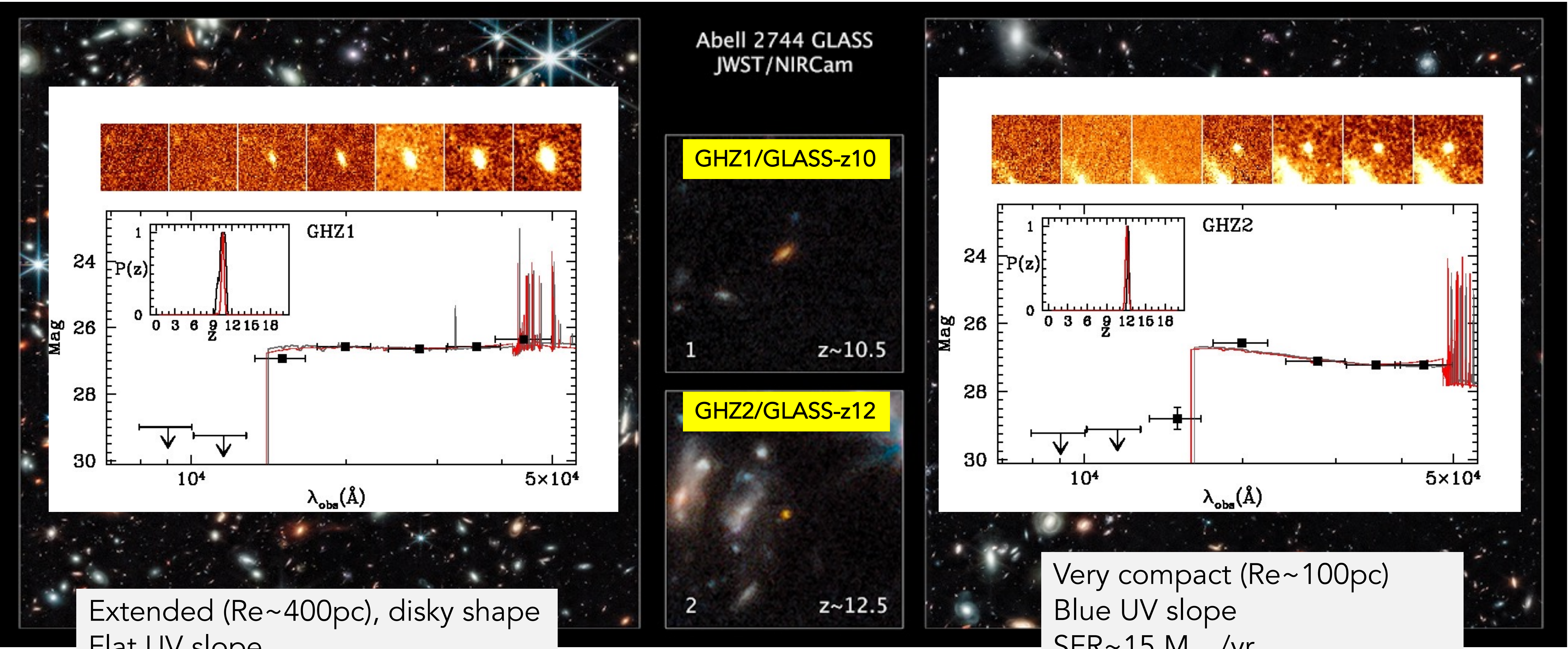
MC & GLASS team 22a

High-redshift galaxies in GLASS-JWST



Among the most robust candidates in early JWST observations, selected by all independent analysis of GLASS-ERS (MC+22a, Naidu+22a, Bouwens+22, Donnan+23, Harikane+23). Image from NASA Press Release Nov. 2022.

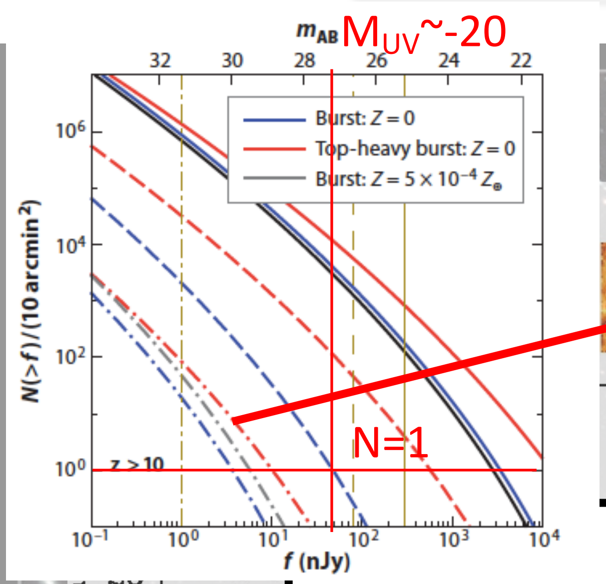
High-redshift galaxies in GLASS-JWST

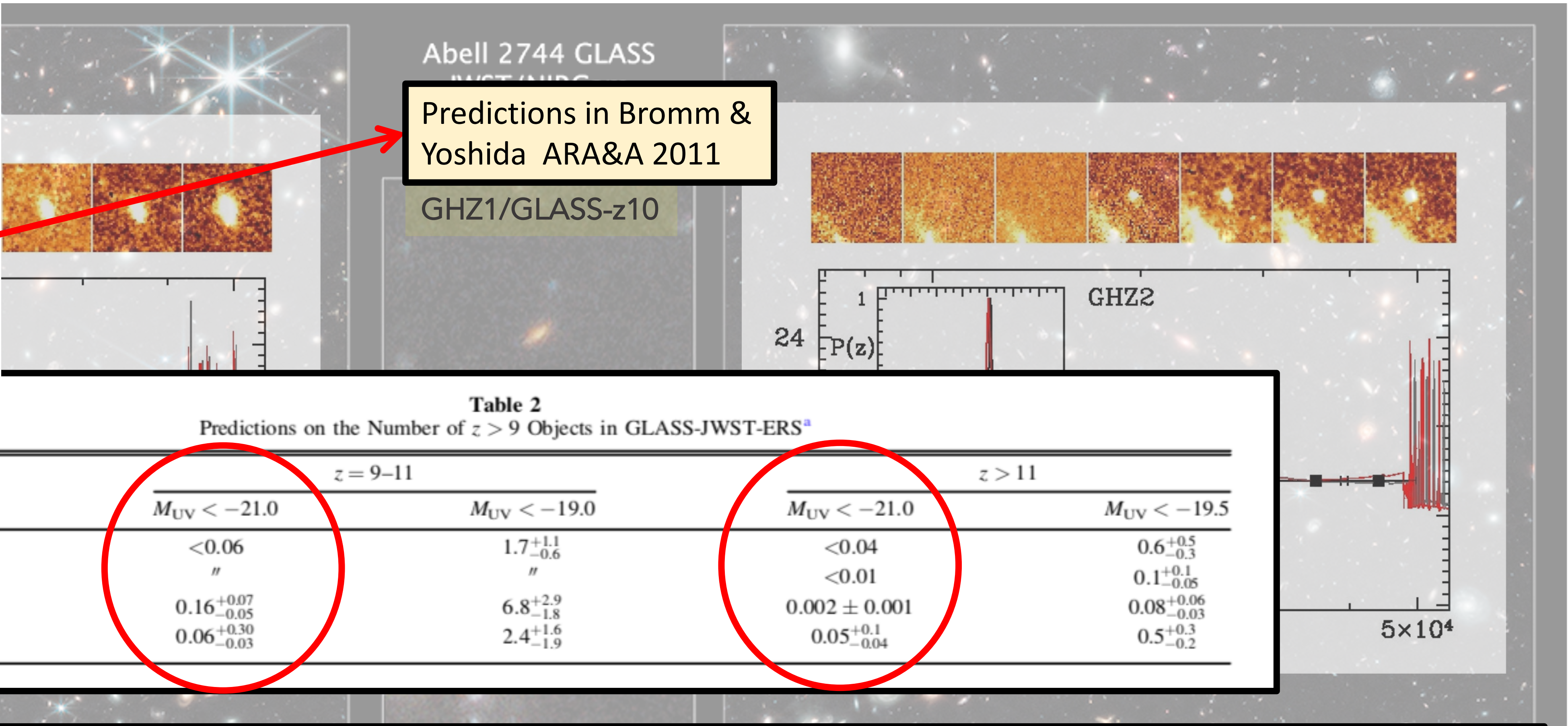


Extended (Re~400pc), disky shape
Flat UV slope
SFR~10 M_{sun}/yr

Very compact (Re~100pc)
Blue UV slope
SFR~15 M_{sun}/yr
High sSFR > 150 Gyr^{1}
High Σ_{SFR} ~ 100 Msun/yr/kpc^2

High-redshift galaxies in GLASS-JWST





Predictions in Bromm & Yoshida ARA&A 2011

Table 2
Predictions on the Number of $z > 9$ Objects in GLASS-JWST-ERS[a]

UV LF	$z = 9$–11		$z > 11$	
	$M_{UV} < -21.0$	$M_{UV} < -19.0$	$M_{UV} < -21.0$	$M_{UV} < -19.5$
Oesch+18[b]	<0.06	$1.7^{+1.1}_{-0.6}$	<0.04	$0.6^{+0.5}_{-0.3}$
LF(z) Bouwens+21[c]	″	″	<0.01	$0.1^{+0.1}_{-0.05}$
Mason+15[d]	$0.16^{+0.07}_{-0.05}$	$6.8^{+2.9}_{-1.8}$	0.002 ± 0.001	$0.08^{+0.06}_{-0.03}$
Bowler+20[e]	$0.06^{+0.30}_{-0.03}$	$2.4^{+1.6}_{-1.9}$	$0.05^{+0.1}_{-0.04}$	$0.5^{+0.3}_{-0.2}$

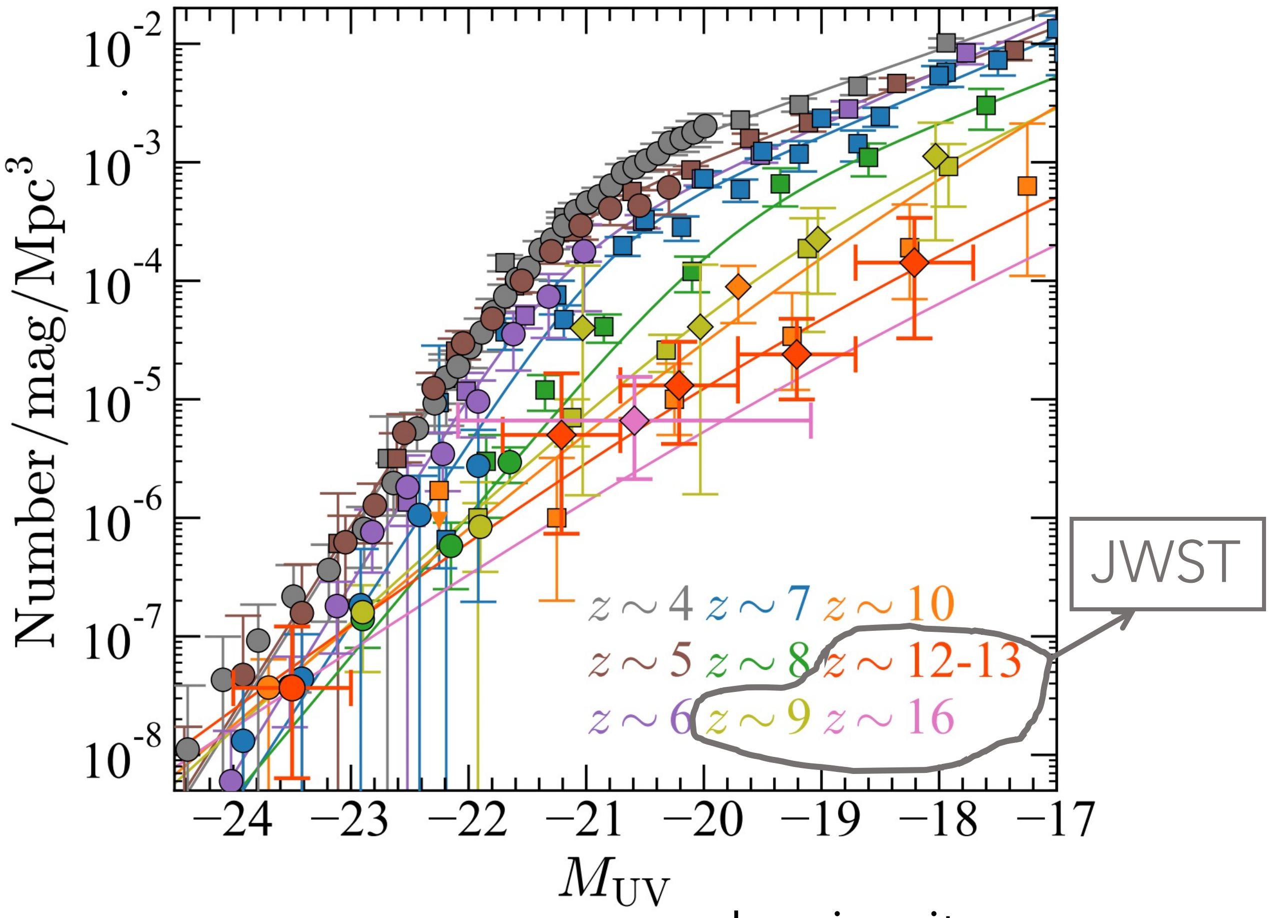
Low probability of finding these two objects in GLASS according to predicted evolution of the UV LF.

A high number-density compared to previous estimates and theoretical models.

Consistent results from other surveys: CEERS (Finkelstein+22a,b), MDS (Perez-Gonzalez+23)

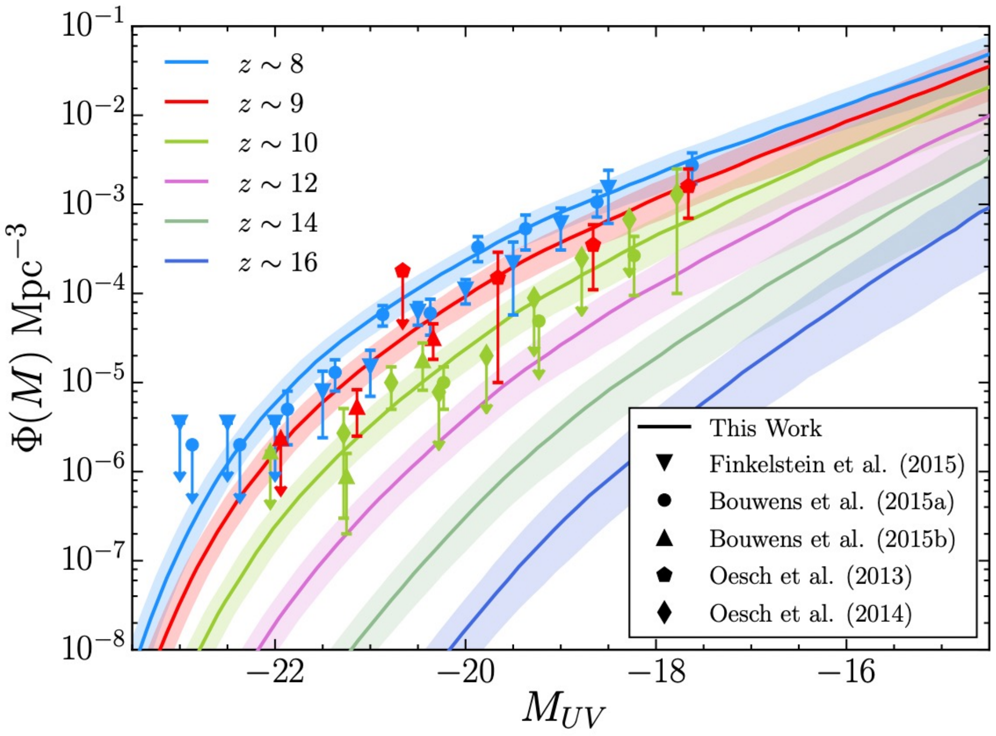
A High abundance of early galaxies

Weak evolution from z~16 to z~10



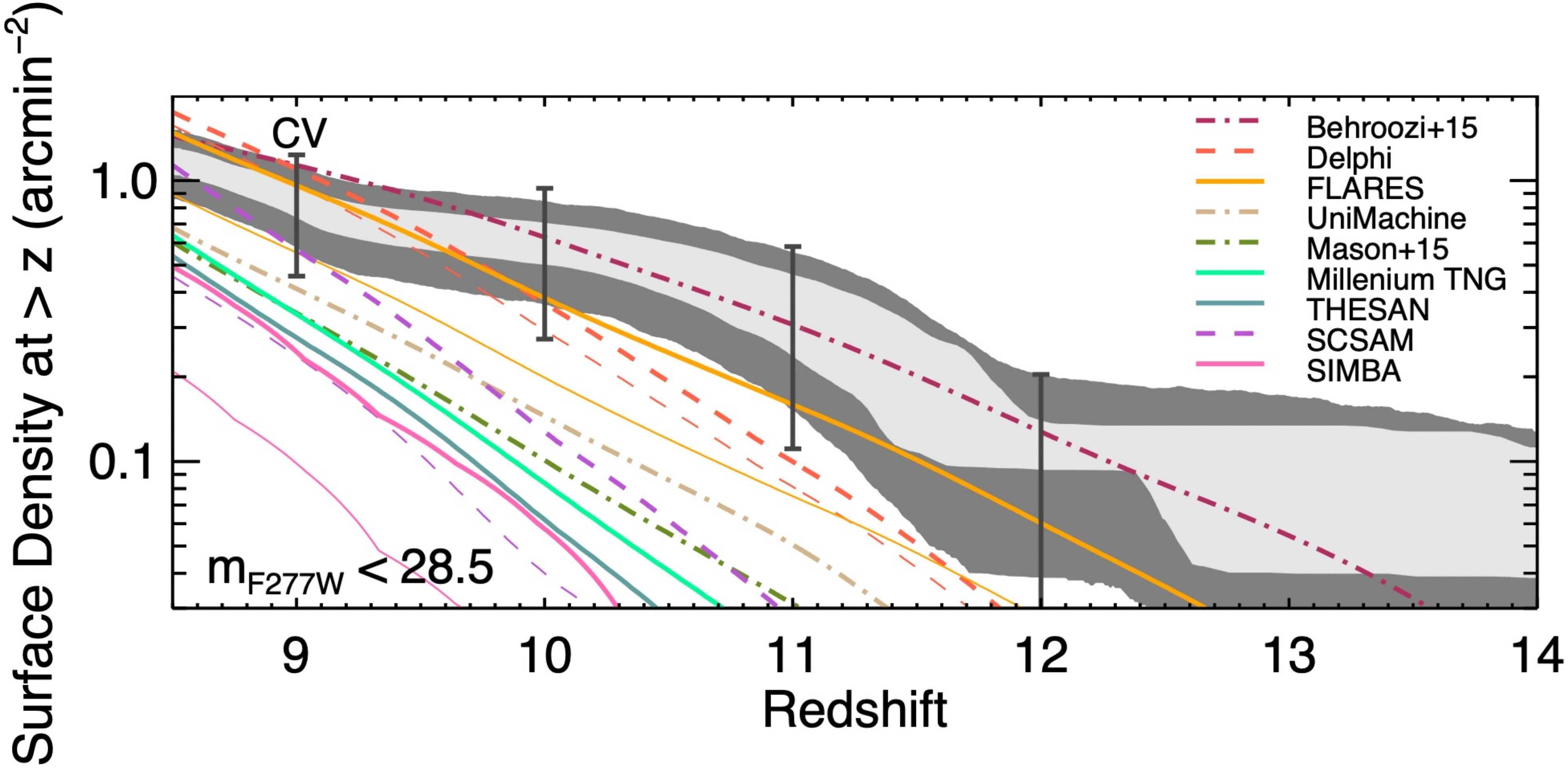
Harikane+23

These were the predictions…..



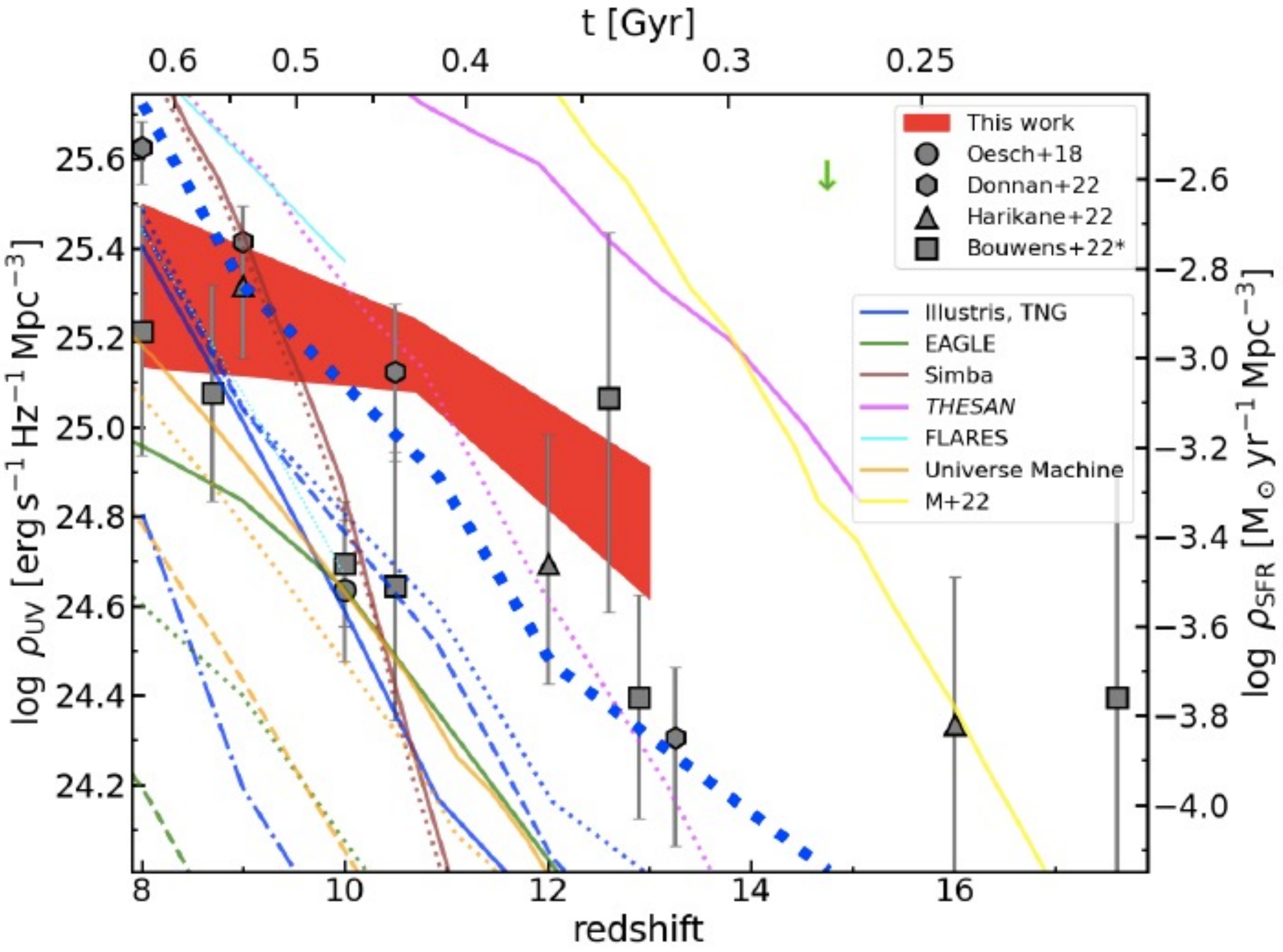
Mason+15

A High abundance of early galaxies



Finkelstein & CEERS team 22

A High abundance of early galaxies



Perez-Gonzalez+23

Excess of high-z bright galaxies: possible interpretations

- Decreasing dust attenuation, making galaxies brighter, almost compensates for the increasing shortage of their host halos (Ferrara+22). Dust could have been efficiently ejected during the very first phases of galaxy build-up (Ziparo+23, Fiore+23).

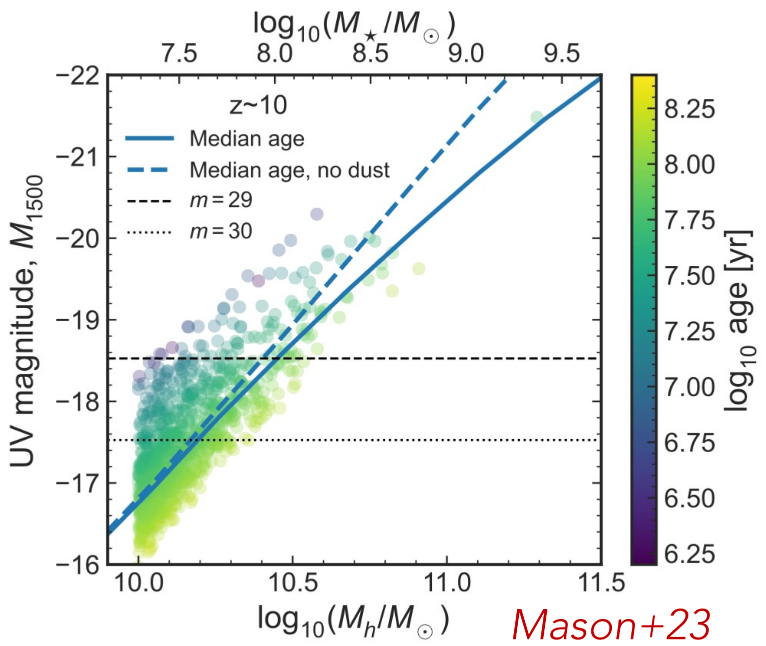
- "Selection effect": only the youngest (<10Myr) and most highly star-forming galaxies are detected so far, scattered up to 1.5 mag above the M_{UV}-M_h relation (Mason+23, Shen+23).

- Maximally efficient SF & ~10 Myr ages (max UV emission) (Mason+23).

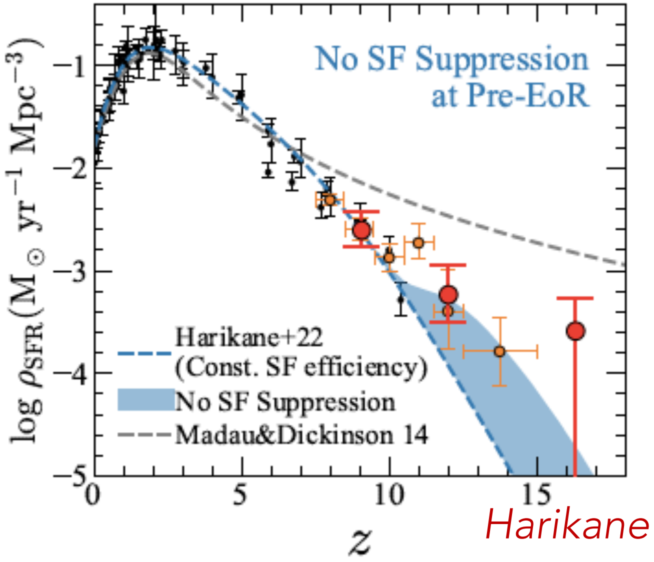
- Star-formation efficiency at z~12-16 higher than at z<10 due to no suppression of the star formation at the pre-reionization epoch (Harikane+23, Qin+23).

- High star-formation efficiency due to fast accretion and lack of feedback (Dekel+23).

- AGN or PopIII activity boosting UV emission, and/or presence of top-heavy IMFs (Kannan+22, Harikane+23, Haslbauer+22, Finkelstein+22b, Yung+23)



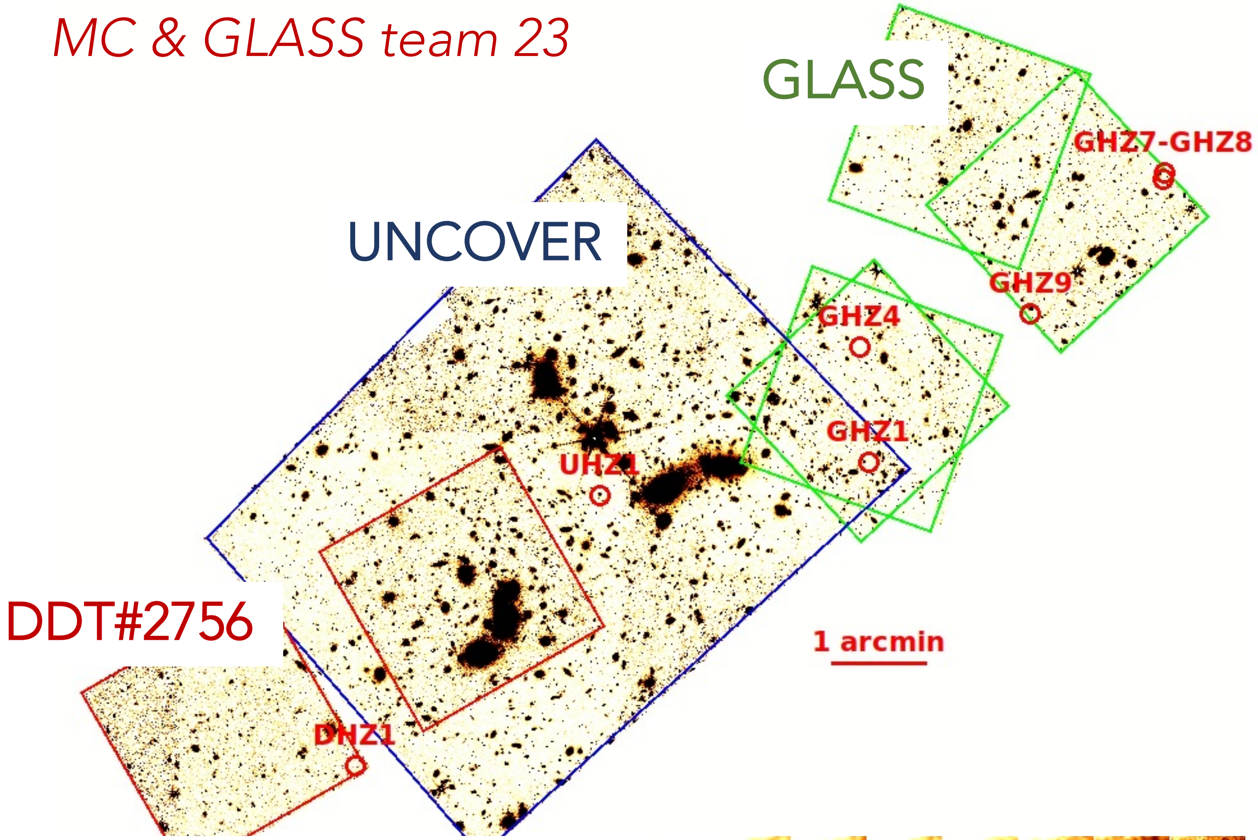
Mason+23

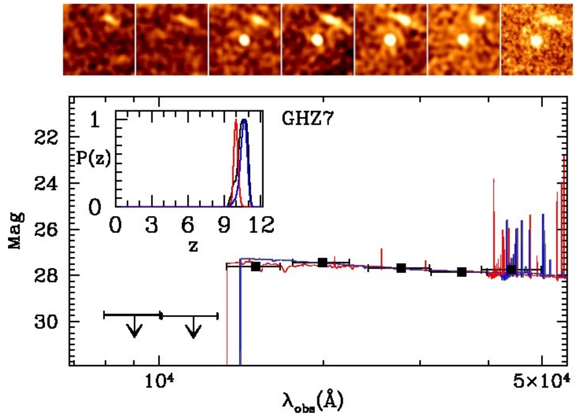


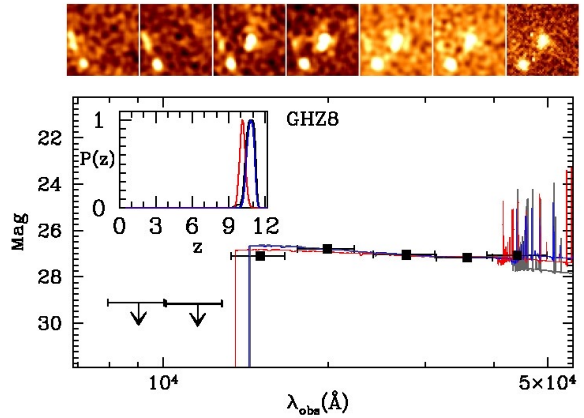
Harikane+23

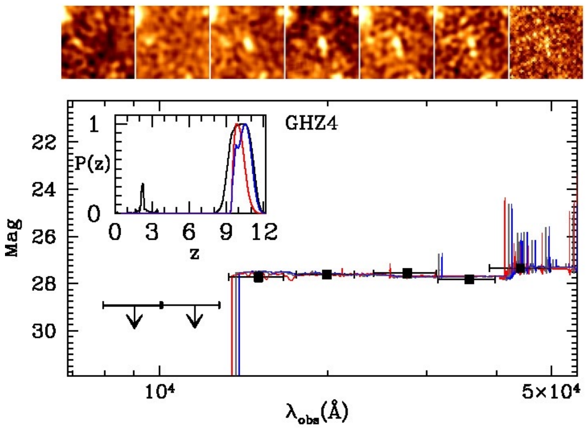
Even more High-redshift galaxies behind A2744

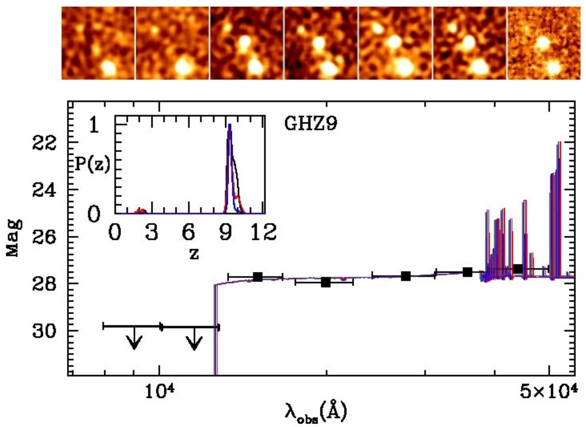
MC & GLASS team 23

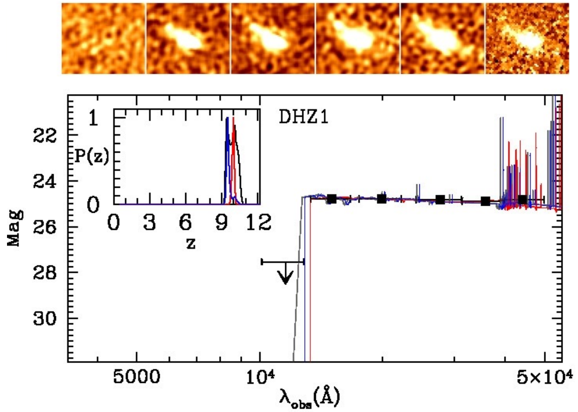


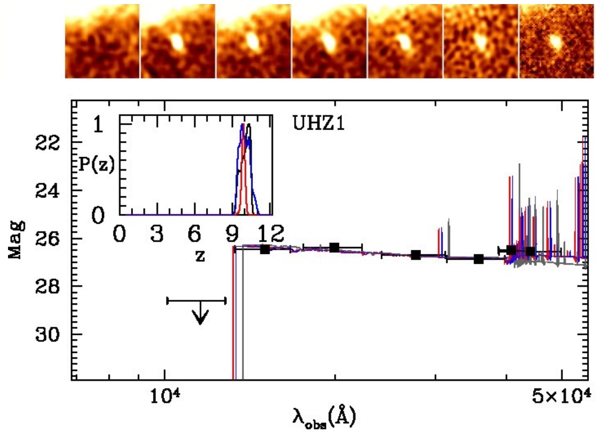


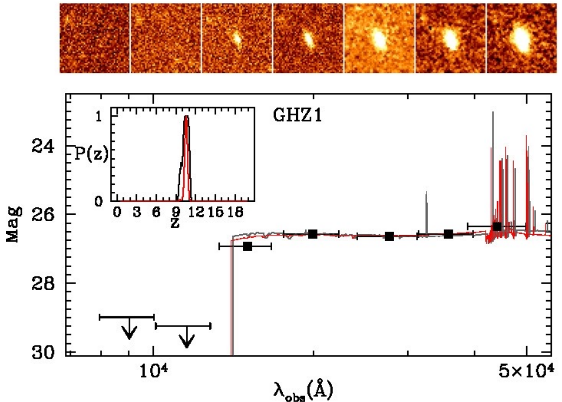






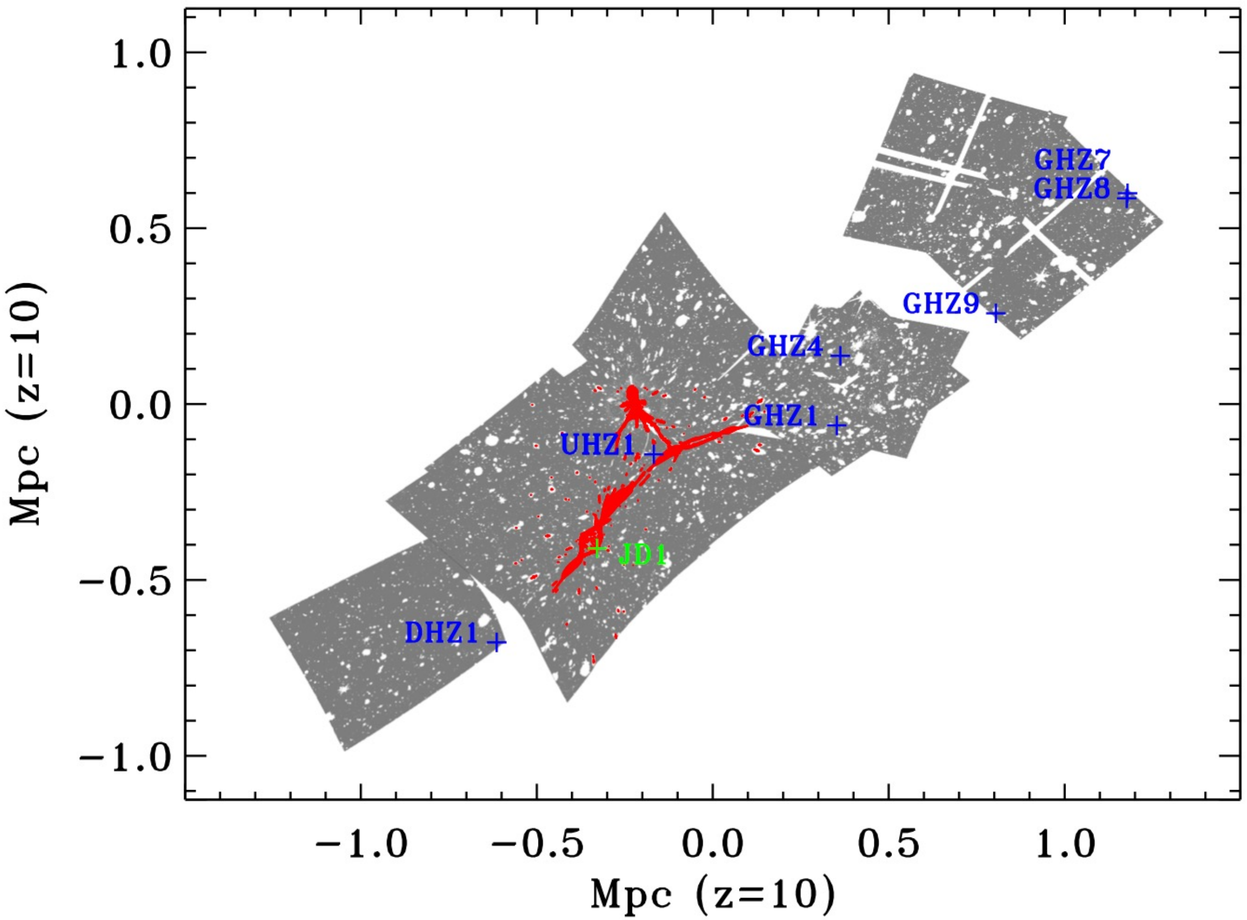




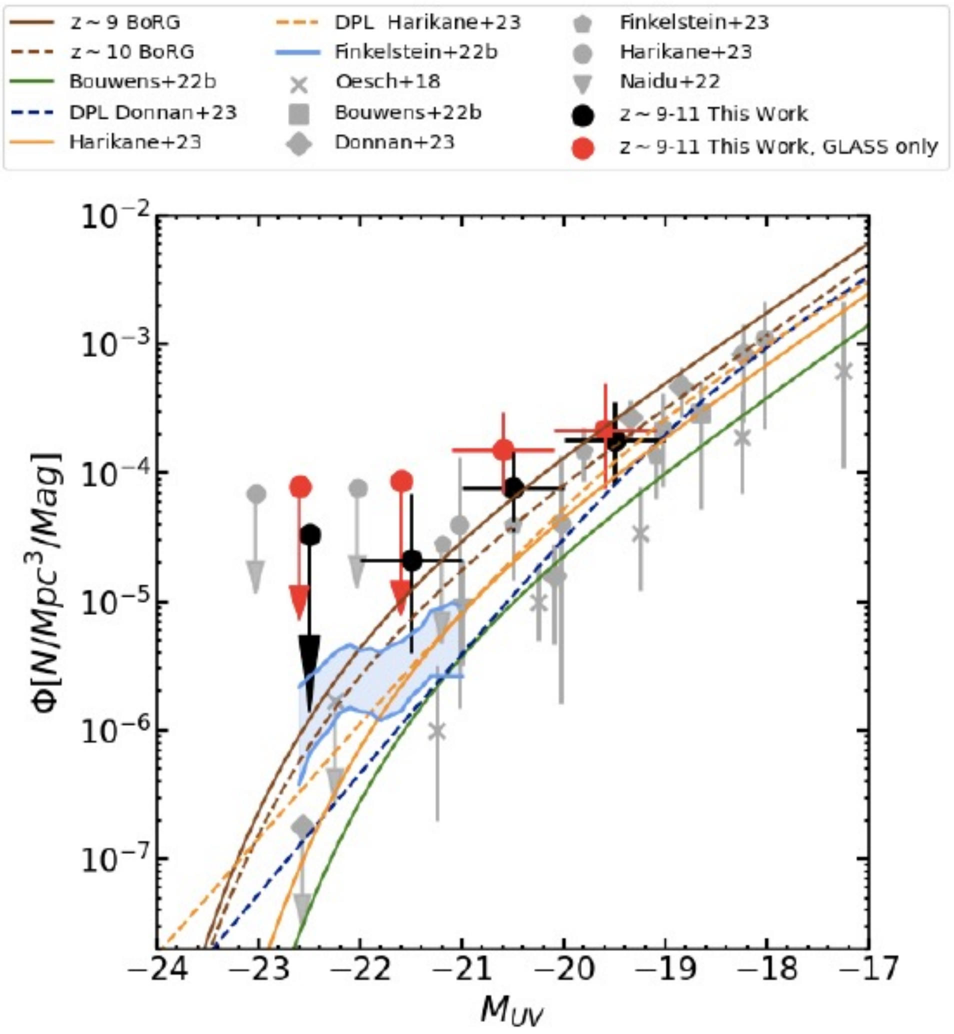


Seven z~10 candidates with ~2mags Lyman-breaks and single-peaked PDF(z)

A z~10 overdensity in GLASS-JWST?



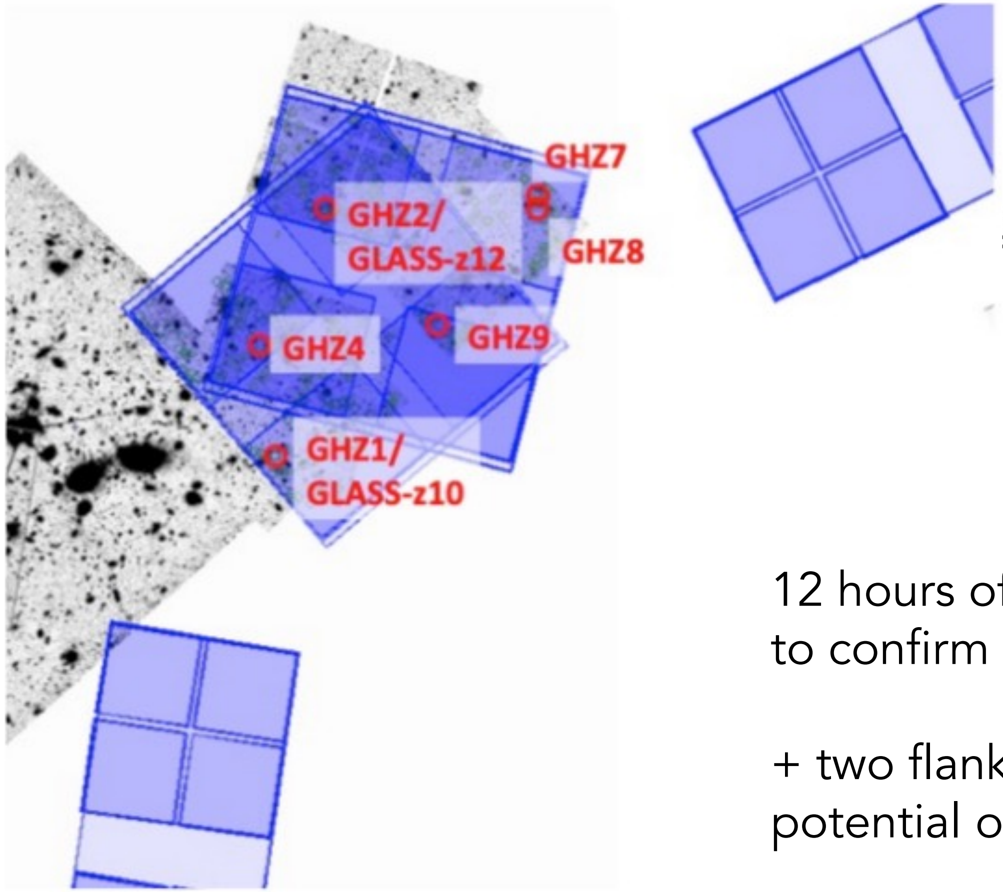
Need to take into account lensing in the A2744 field! (Bergamini+22, Bergamini+23)

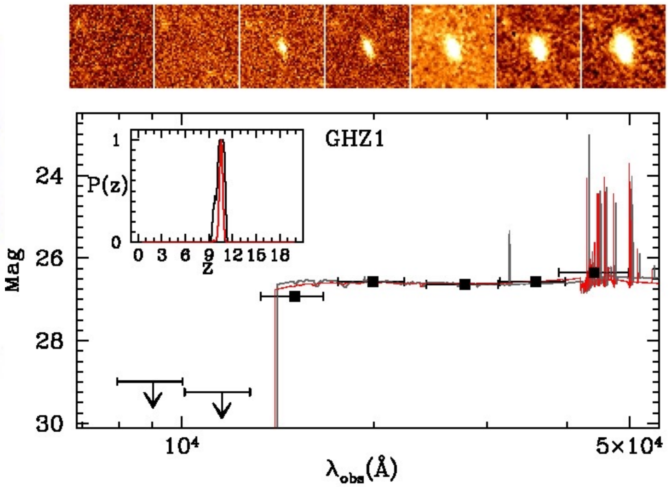


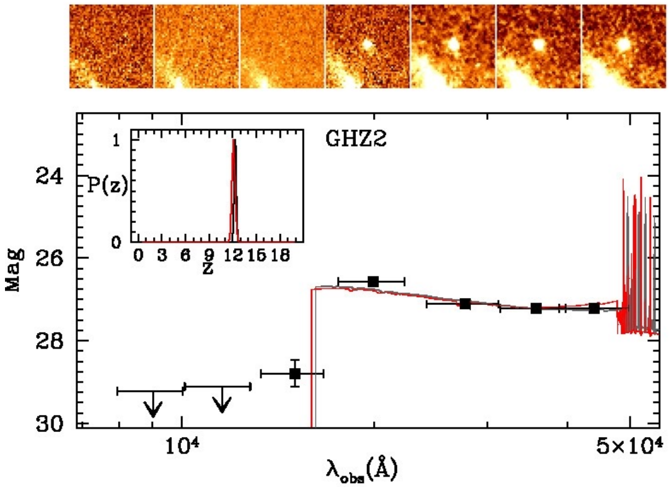
Number density in the region even higher than other JWST estimates

MC & GLASS team 23

Spectroscopic follow-up approved for cycle 2





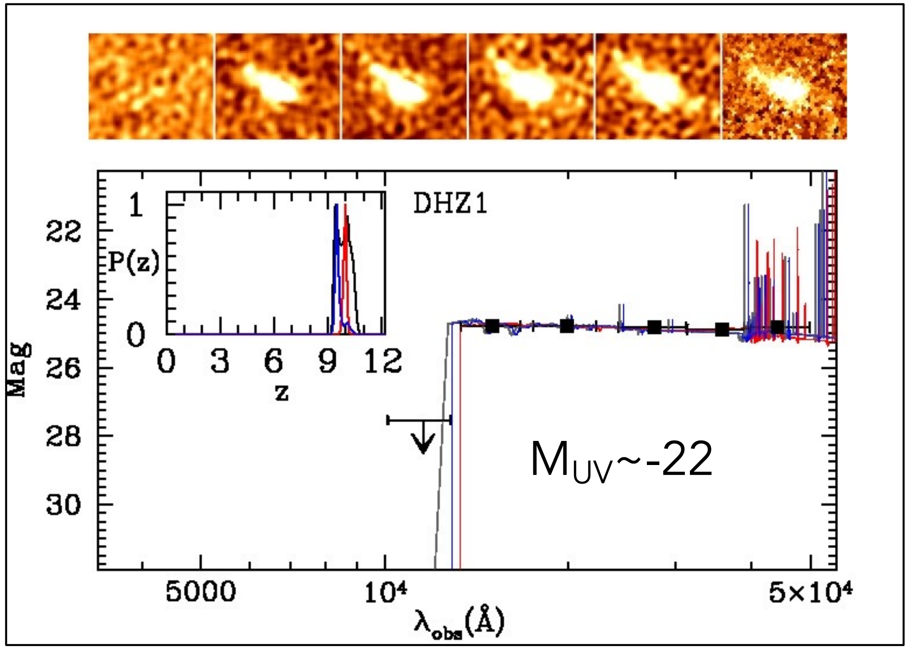


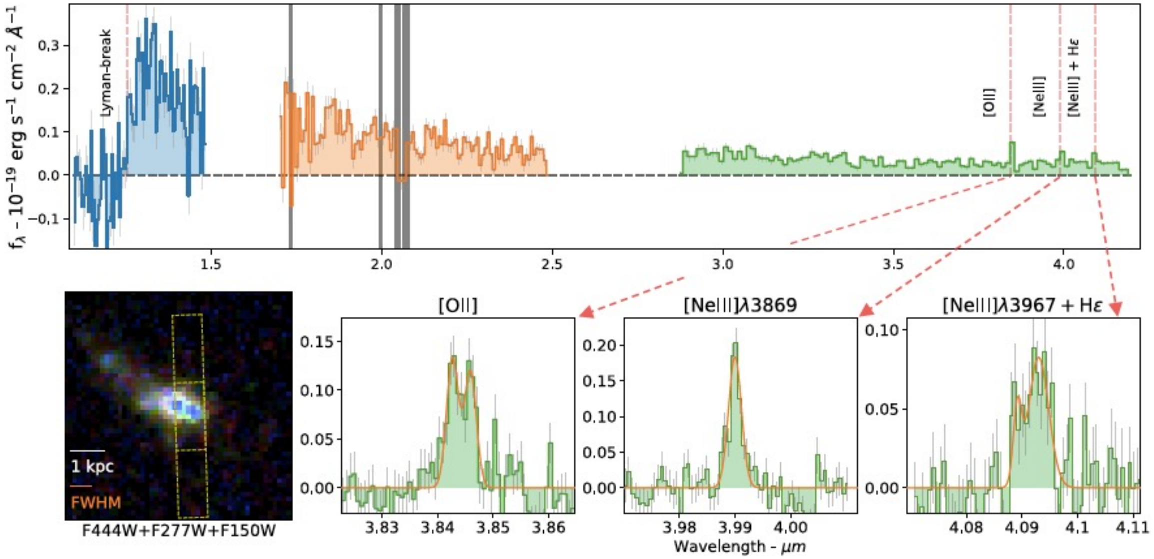
12 hours of NIRSpec PRISM
to confirm z~9-12 galaxies in the GLASS-ERS parallel

+ two flanking fields with NIRCam to extend the sample and map the potential overdensity

3073	Spectroscopic confirmation of an unexpected population of bright galaxies at cosmic dawn	PI: Marco Castellano	12	19.33/10.1	NIRSpec/MOS

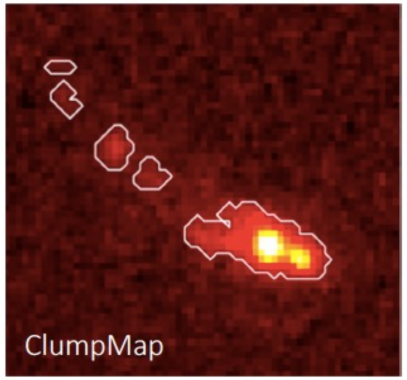
Spectroscopic confirmation of DHZ1

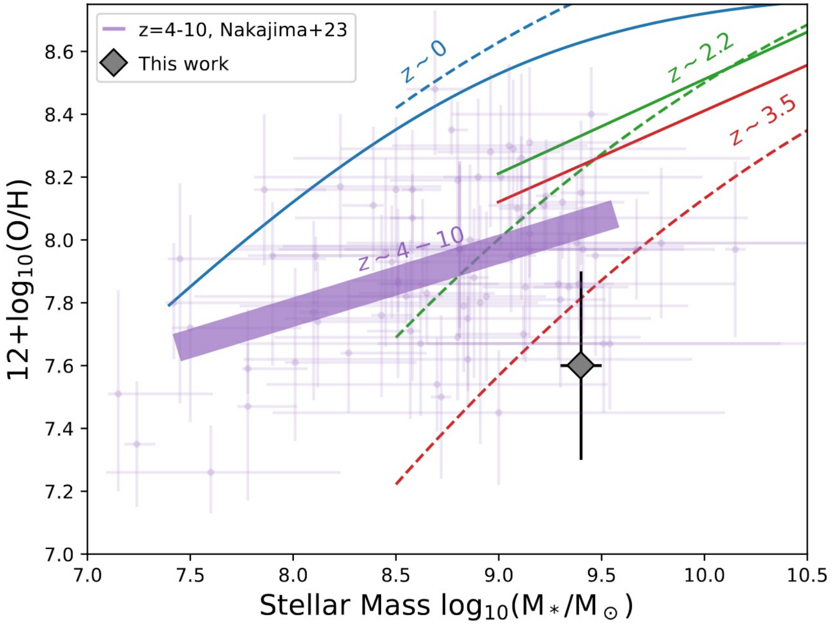




Mstar~2.5 10^9 Msun
SFR~25Msun/yr
Z~0.1Zsun

Main clump~10Myr
Extended halo~130Myr





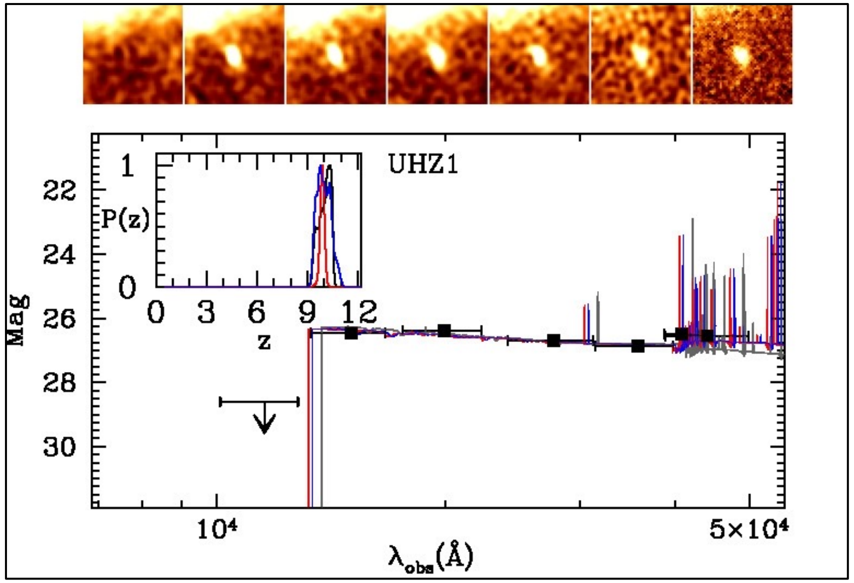
Spectroscopically confirmed at z=9.3127

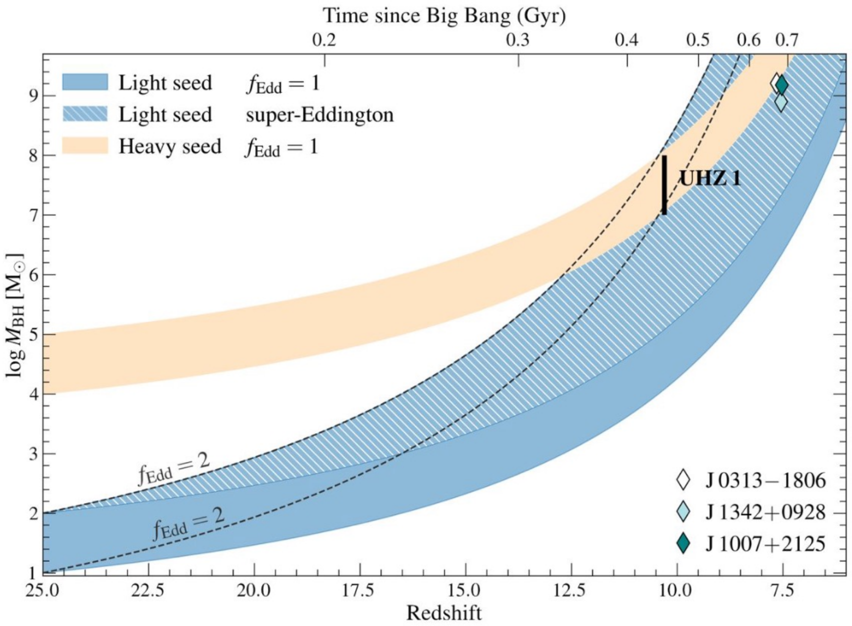
Bright and massive!

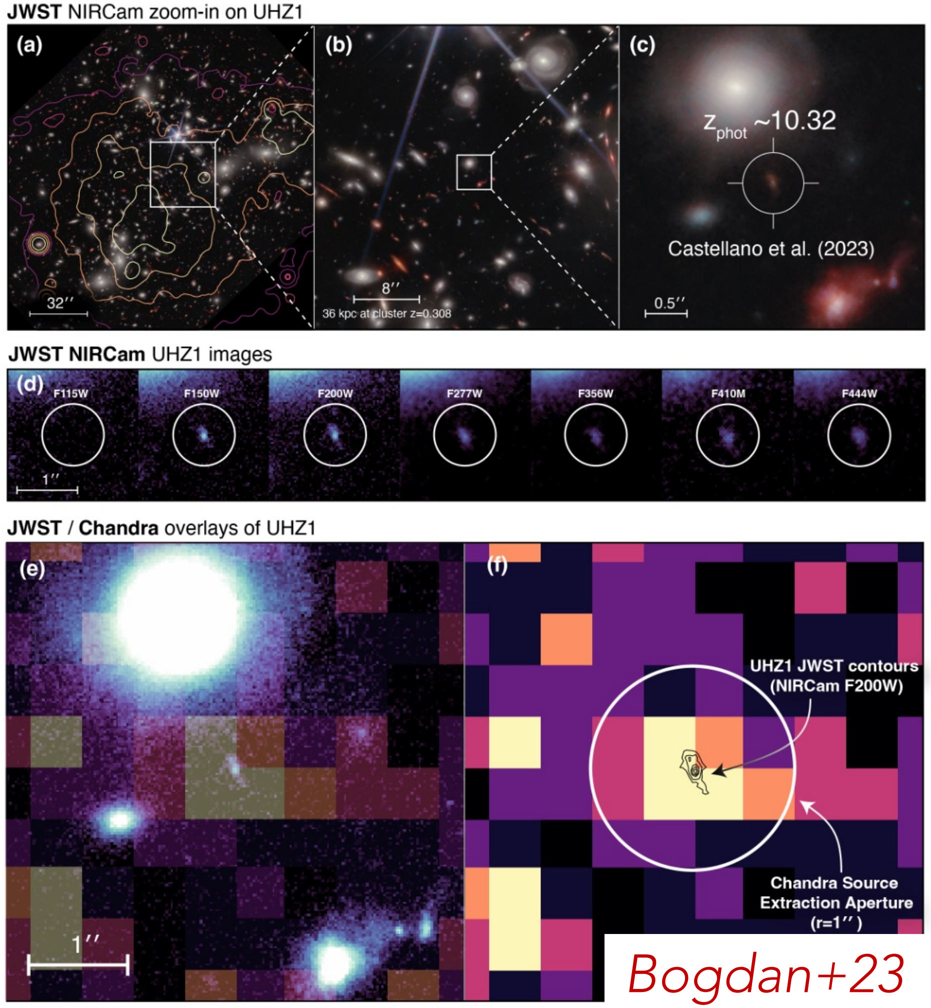
Disturbed morphology
Indicative of interaction or merging between two systems

Boyett & GLASS team 23

A SMBH in Uhz1







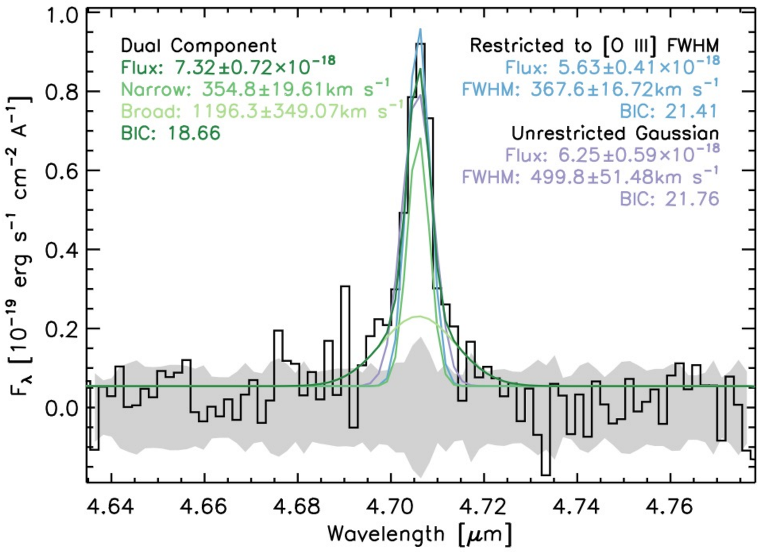
Bogdan+23

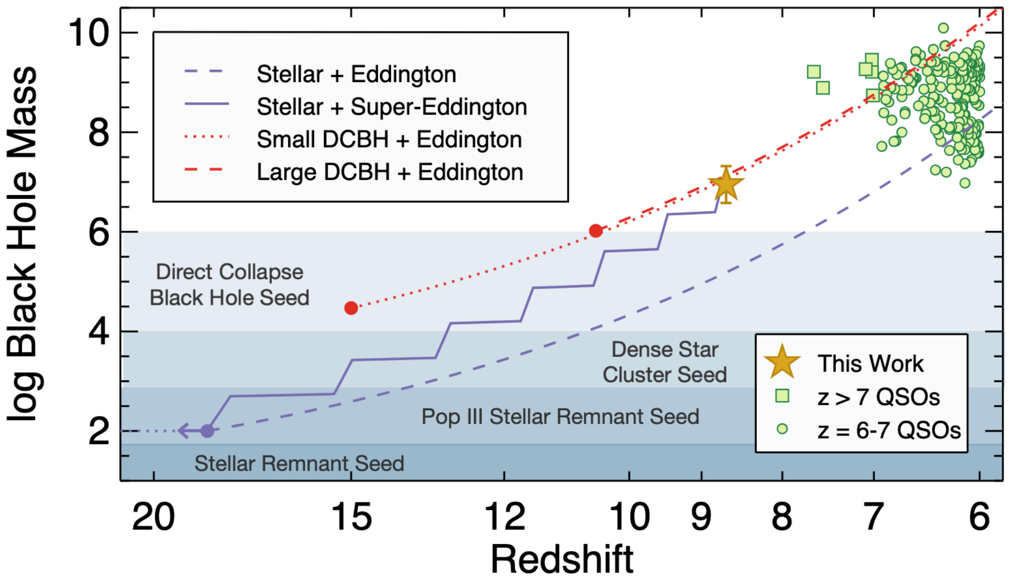
A SMBH in one of our z~10.3 candidates

$L_{bol}=5\times10^{45}$ erg/s

$M_{BH}\sim4\times10^{7}$ M_{sun} *comparable to the stellar mass*

Rapid SMBH formation at high-z

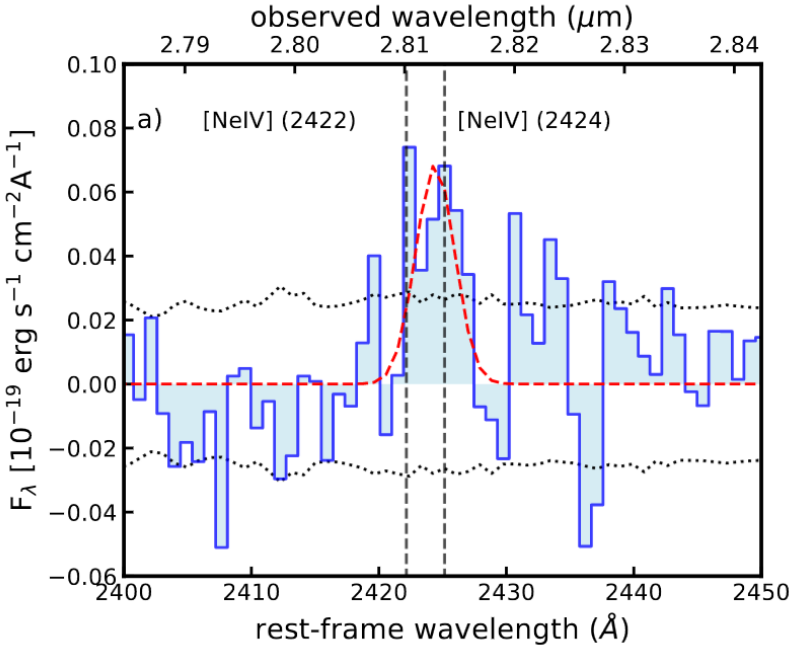


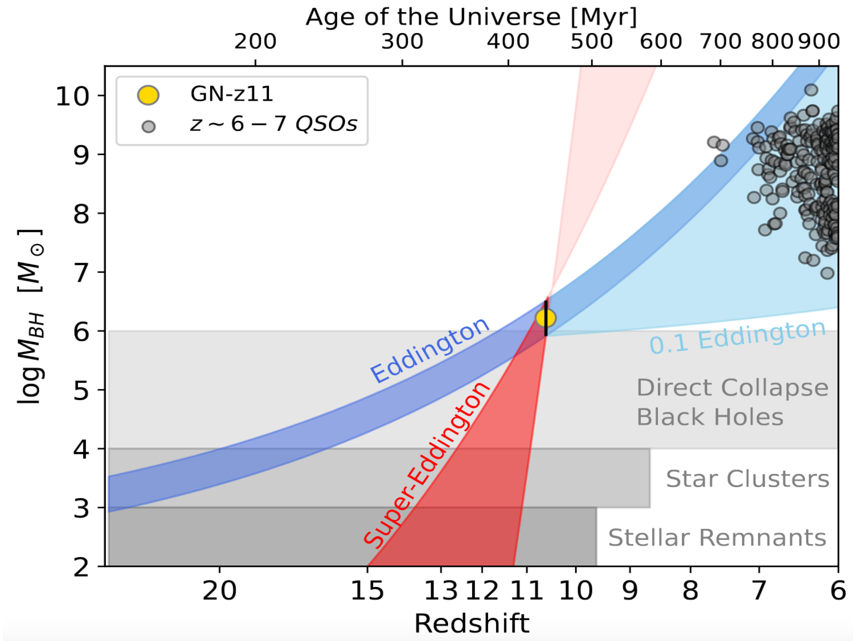


CEERS_1019

AGN at z=8.7

Larson & CEERS team 23





GN-z11

AGN at z=10.6

Maiolino & JADES team 23

The other side of the coin: massive galaxies at high z

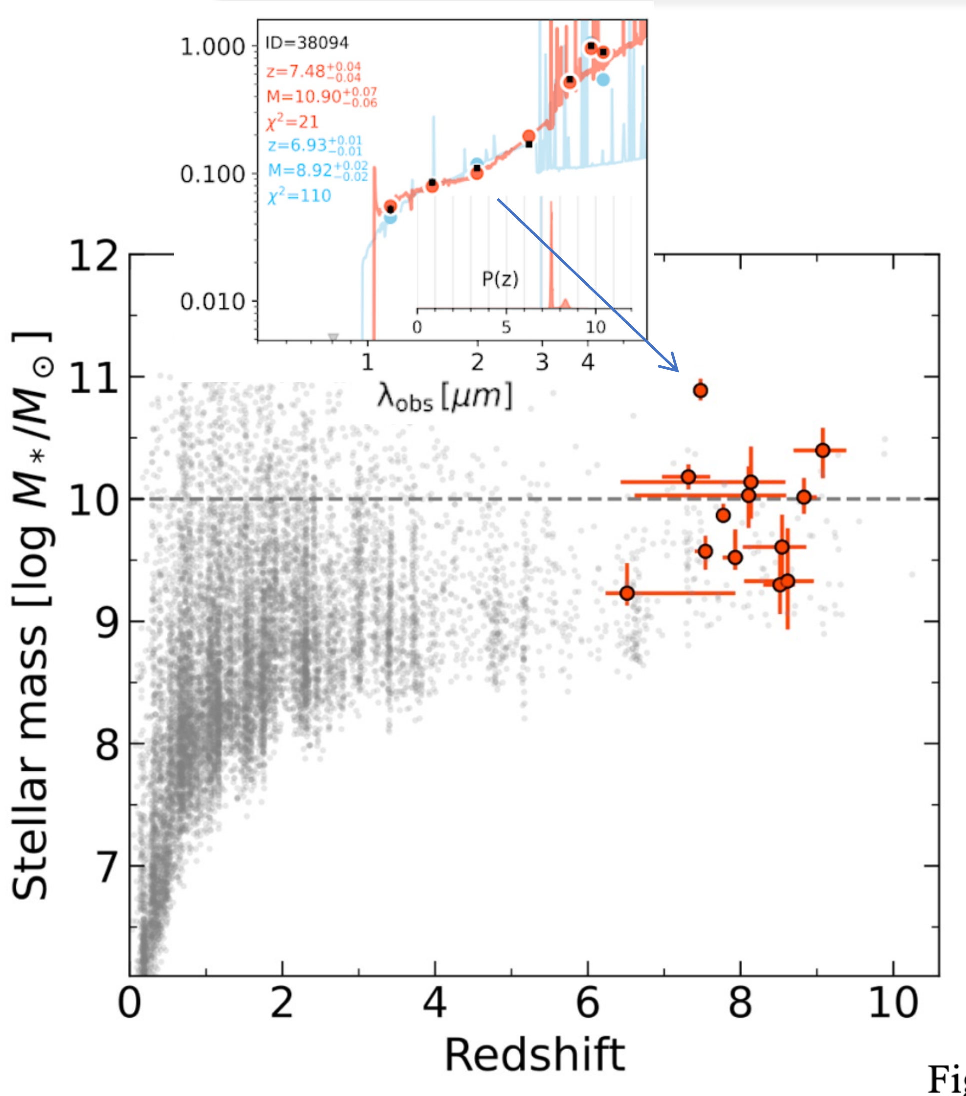


Figure 1: **Redshifts and tentative stellar masses of double-break selected galaxies.**

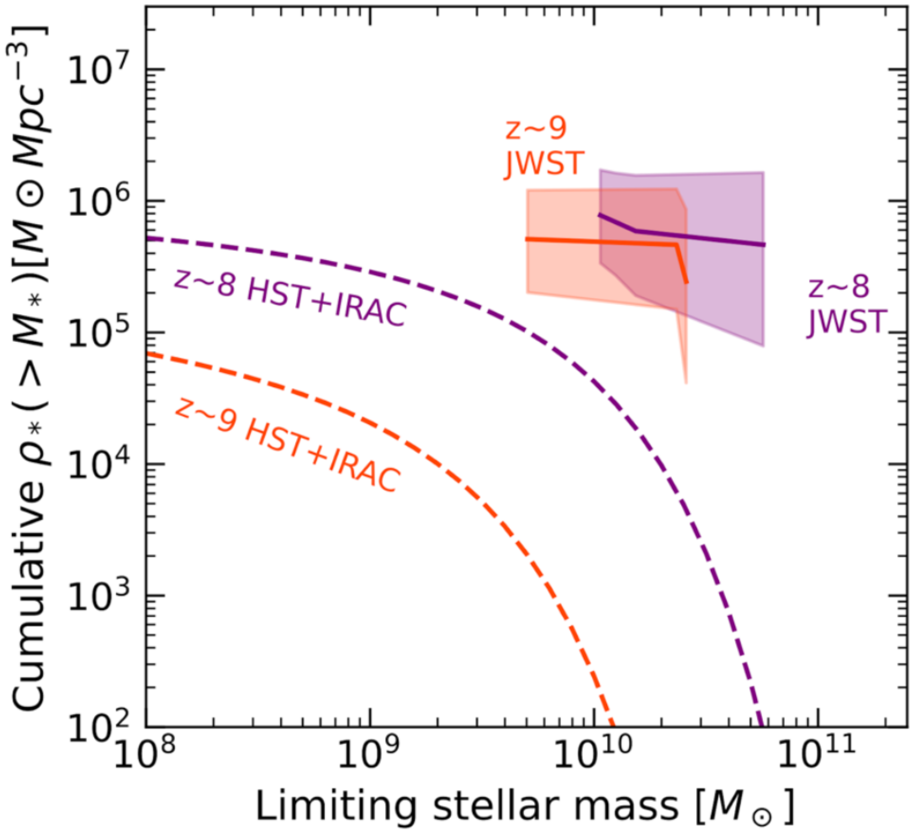
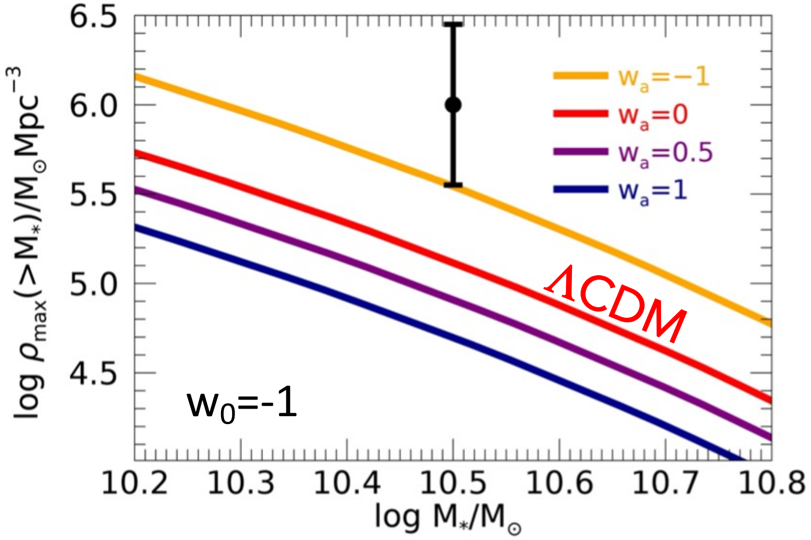


Figure 4: **Cumulative stellar mass density, if the fiducial masses of the *JWST*-selected red galaxies are confirmed.** The solid symbols show the total mass density in two redshift

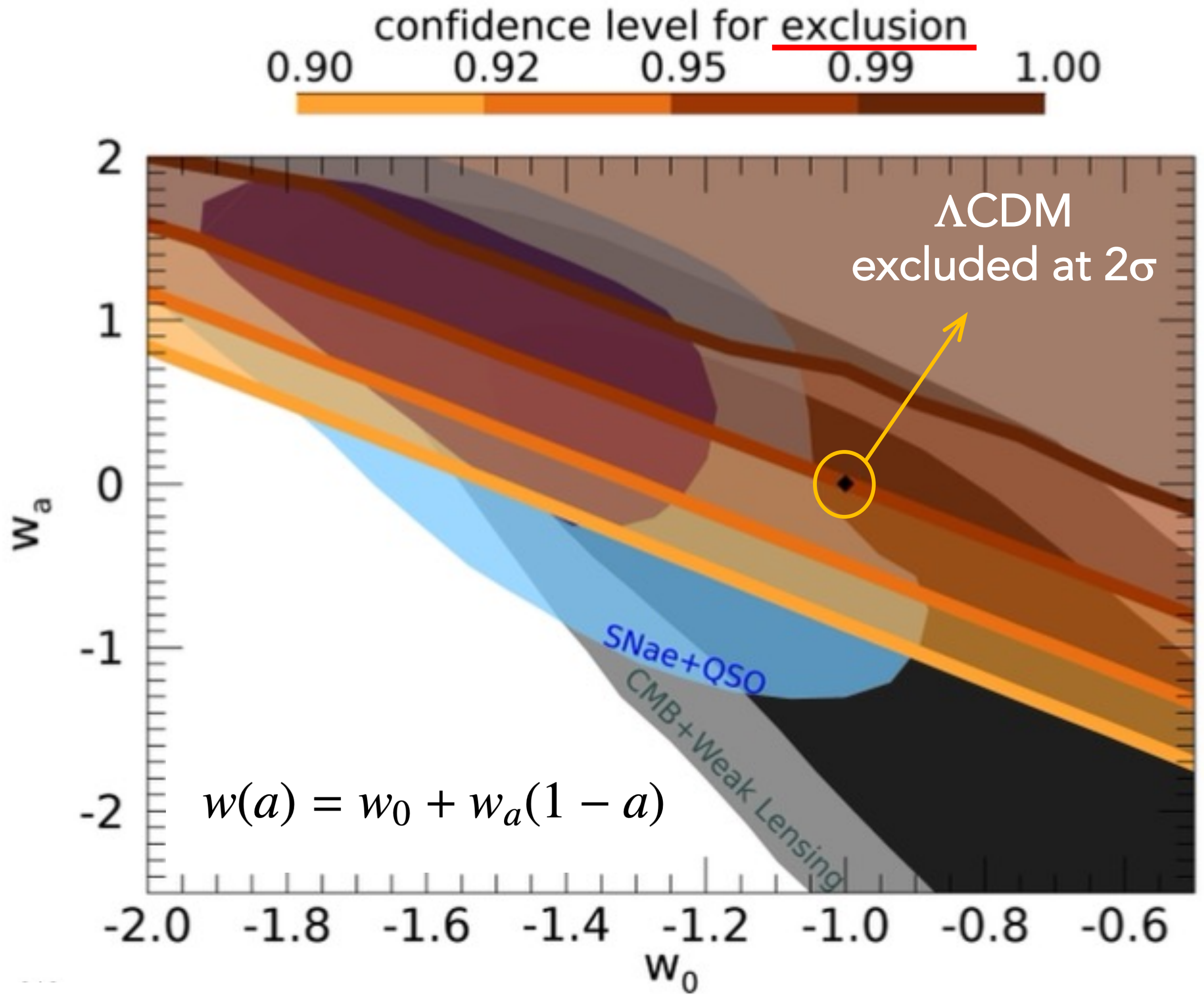
Labbé+23

DDE models: not enough available baryons?



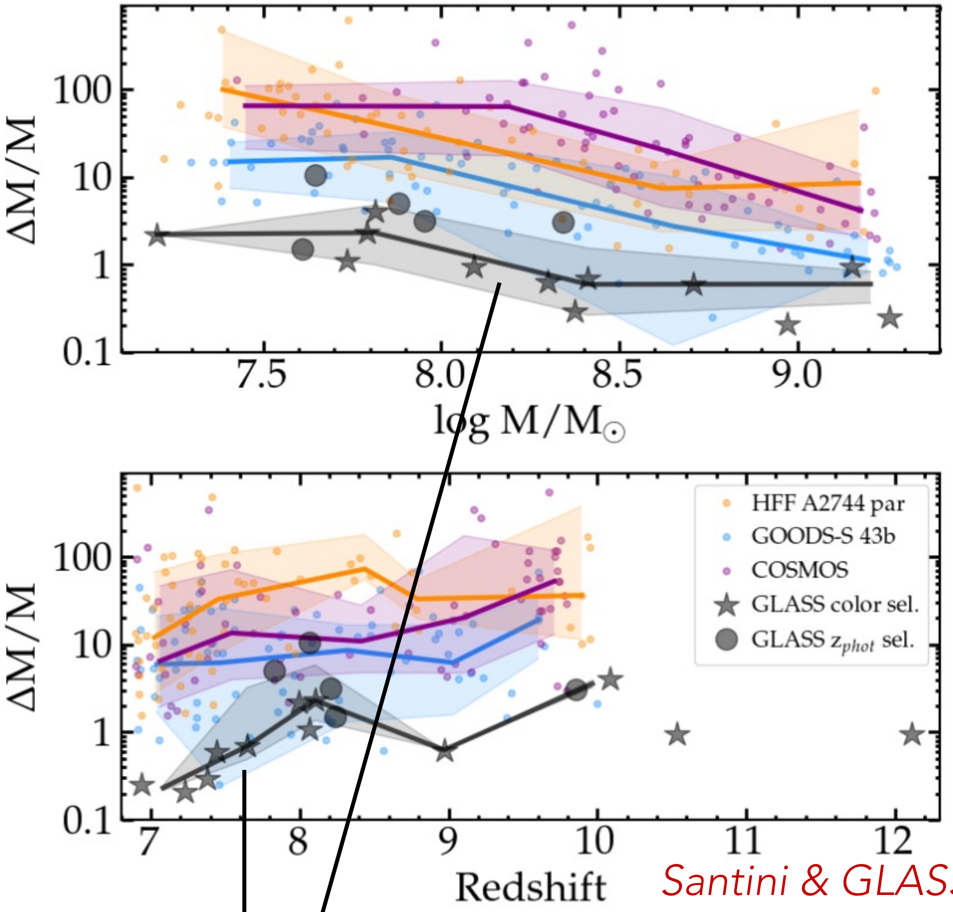
conservatively assume max SF efficiency (=1)

- ΛCDM excluded at 2σ
- In tension with a wide class of cosmological models

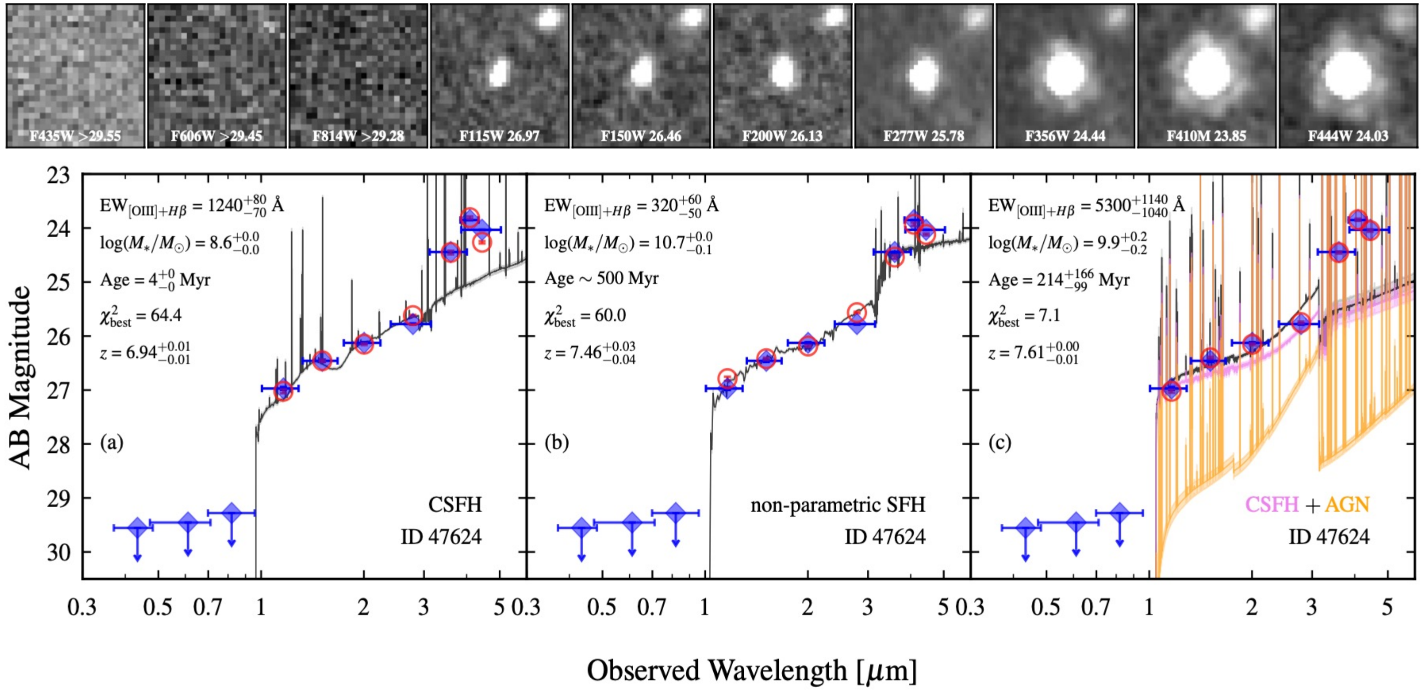


Menci, MC et al. 22

THE NEED FOR SPECTROSCOPIC FOLLOW UP



Santini & GLASS team 23

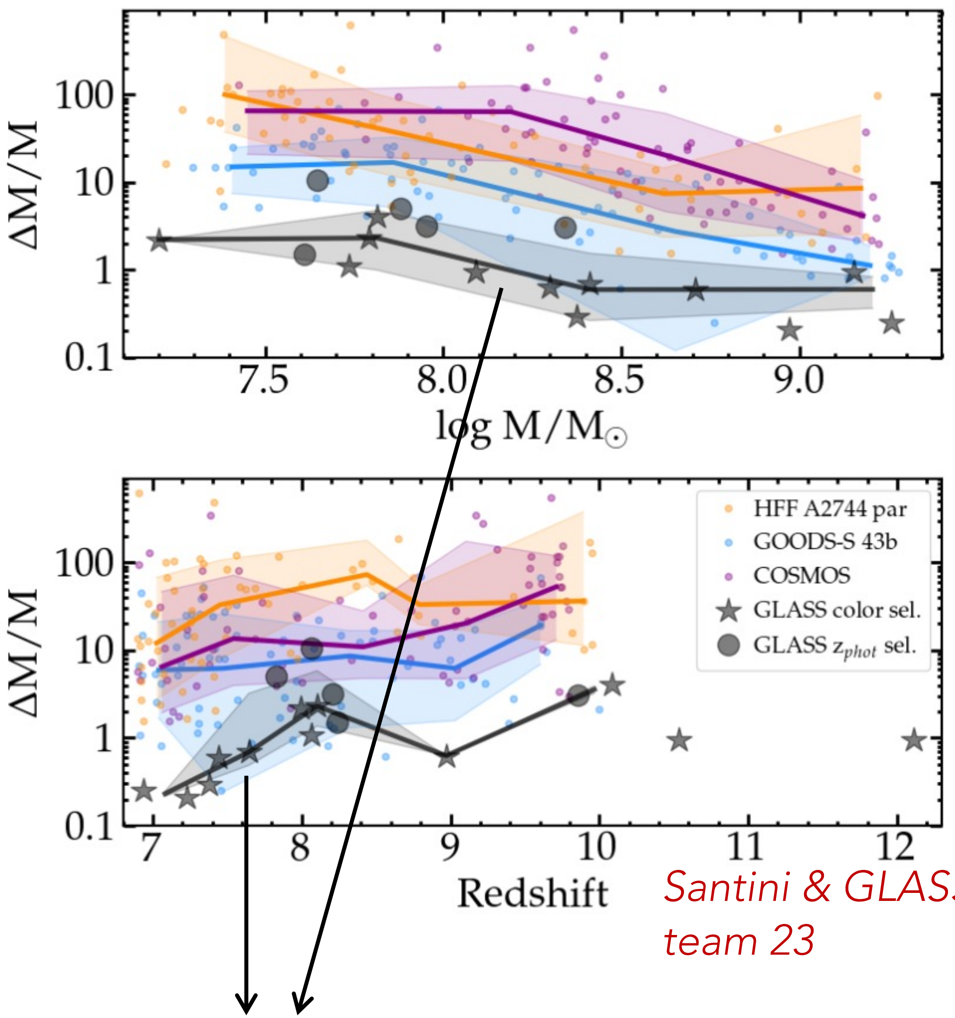


Endsley+22

JWST improves by >10x the accuracy of stellar mass estimates

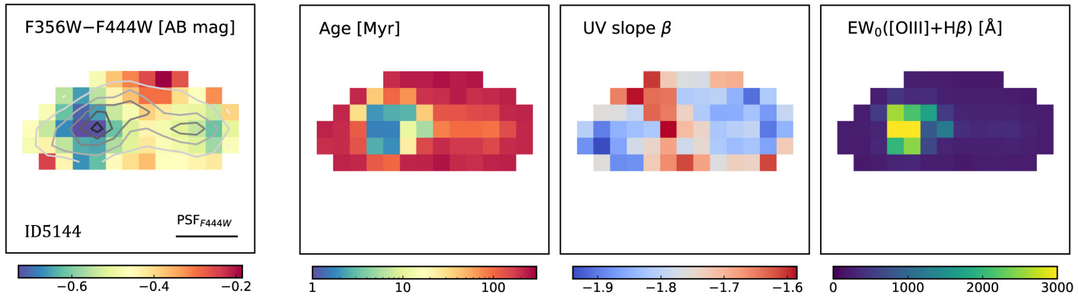
BUT: systematic uncertainties due to strong emission lines

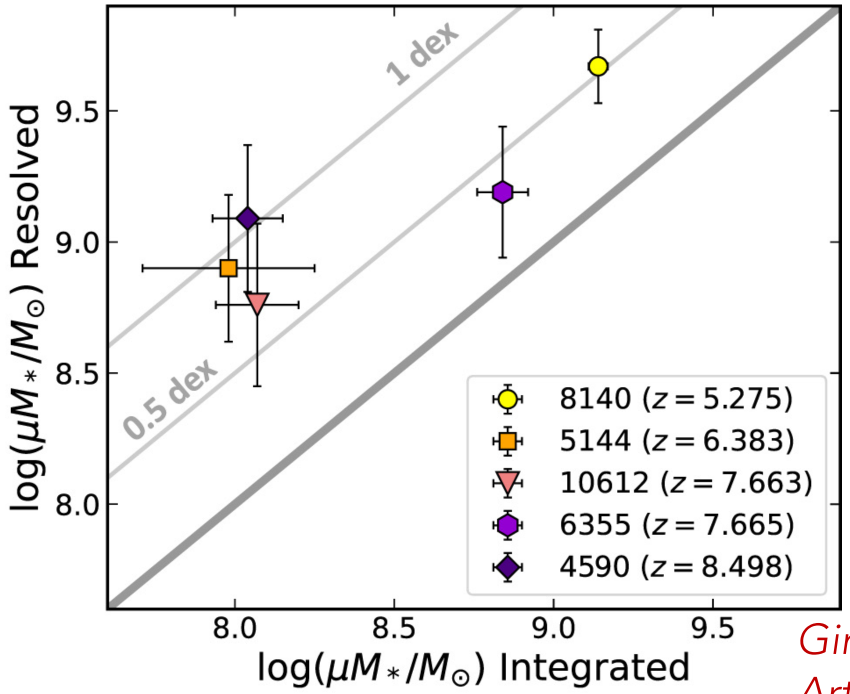
THE NEED FOR SPECTROSCOPIC FOLLOW UP



Santini & GLASS team 23

JWST improves by >10x the accuracy of stellar mass estimates

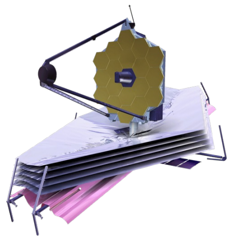




Gimenez-Arteaga+23

#2 BUT: young stellar populations outshine old ones, spatially resolved analysis yields 0.5-1dex higher masses

Take-home messages



- JWST is transforming our view of the earliest epochs of galaxy formation.
- Unexpected detection of bright galaxies at z~10-12 in the GLASS-JWST ERS. High-density of bright z~10 galaxies across the entire A2744 field, possibly indicating an overdensity.
- Evidence of an excess of bright galaxies at very high-redshift confirmed by several surveys, and possible excess of massive galaxies at z~7-10.
- Other 'hints' to an accelerated growth at high-z: M-Z relation, dust, SMBHs
- Several interpretations have been proposed. Is there a conflict with ΛCDM? Some observations can be reconciled (e.g. assuming higher SF efficiency).
- Are we witnessing an 'accelerated' galaxy formation? (Sanders 98) We need detailed predictions of LFs and properties under MOND scenarios (e.g. Wittenburg+23).