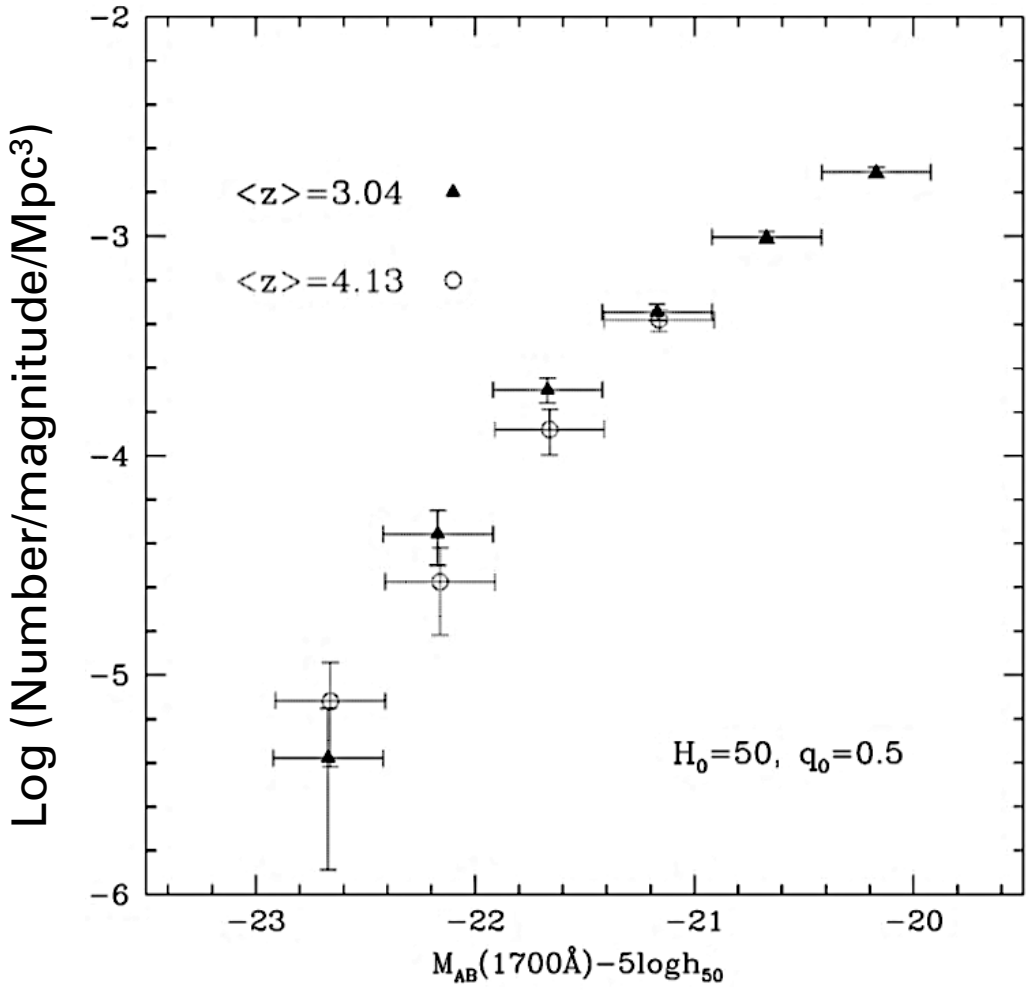
Beyond UV: Rest-frame B-band and Apparent Luminosity Functions of z = 5 — 9 Galaxies

NICHA LEETHOCHAWALIT

NATIONAL ASTRONOMICAL RESEARCH INSTITUTE OF THAILAND

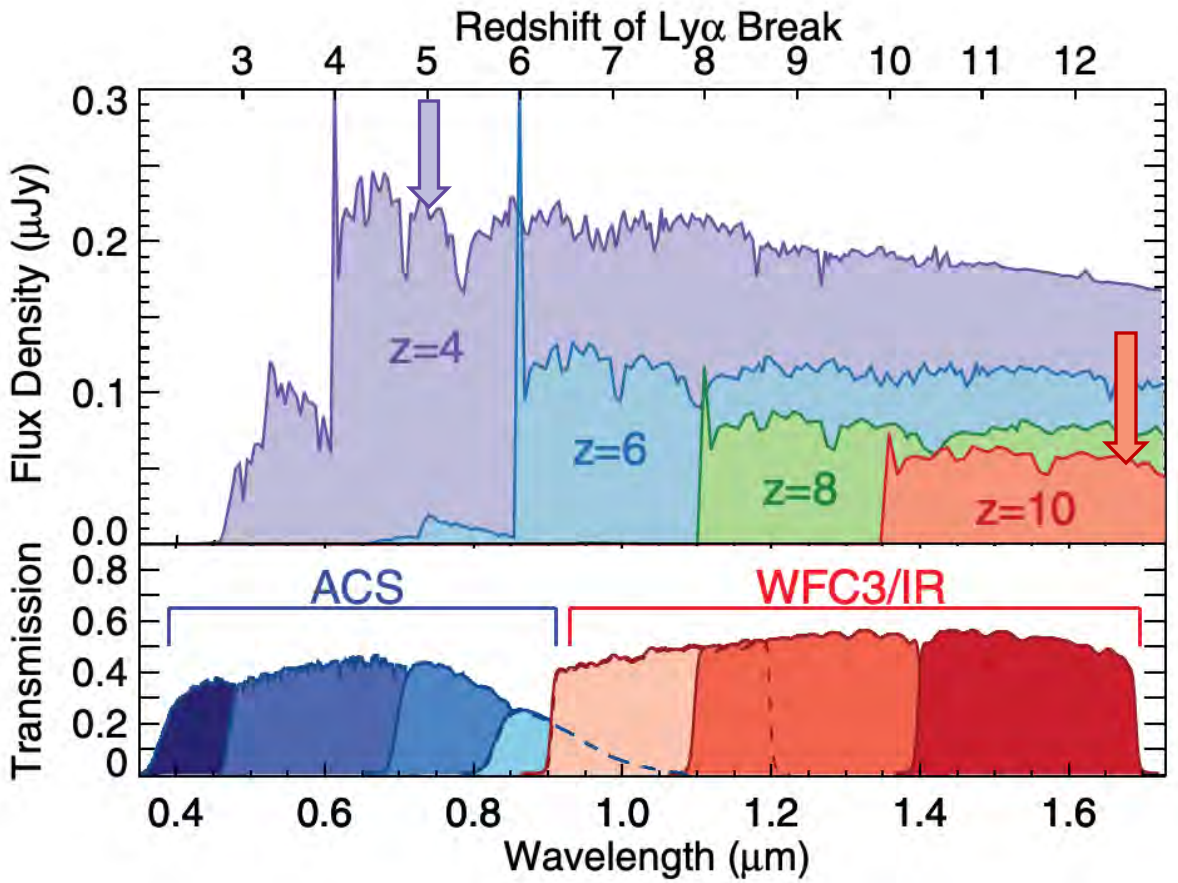
WITH TAKAHIRO MORISHITA (IPAC), TIRAWUT WORRAKITPOONPON (SUT), AND MICHELE TRENTI (U OF MELBOURNE)

Luminosity function (LF) is the volume density of galaxies as a function of their magnitudes



Steidel+1999

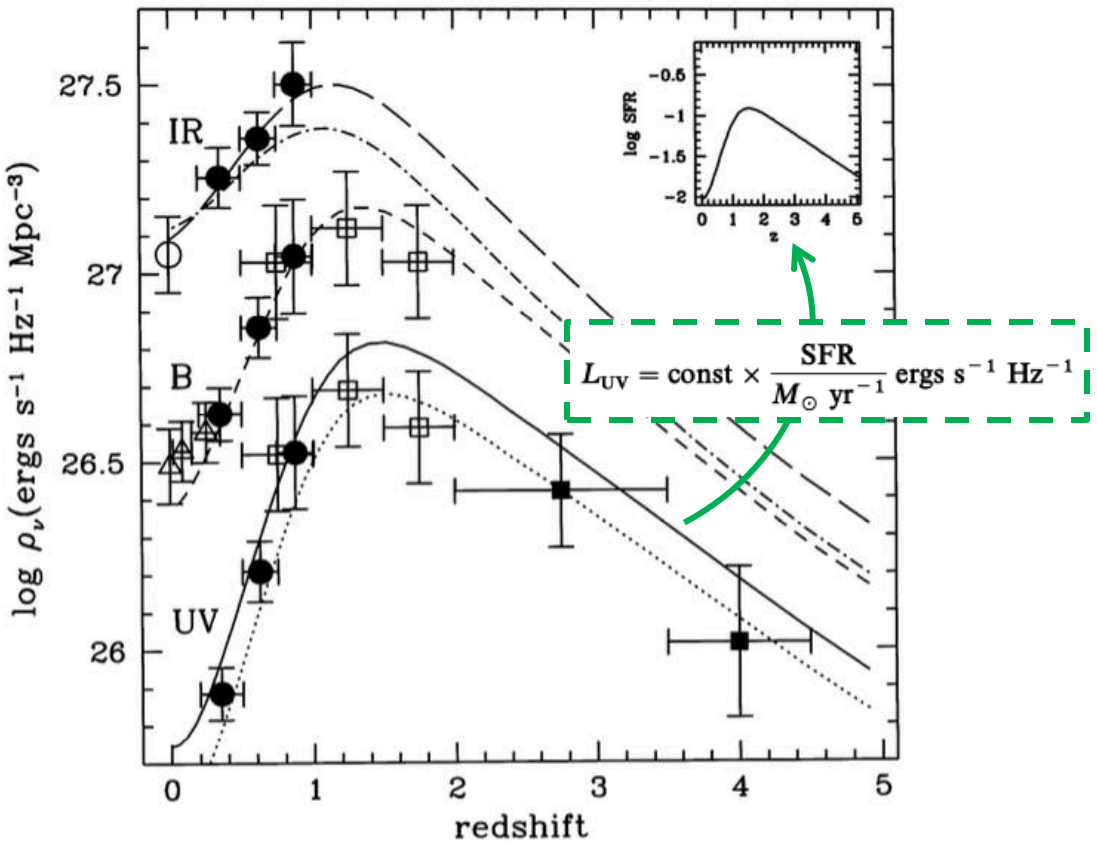
Reasons that LFs in the past focused on UV
1. Availability at high redshifts



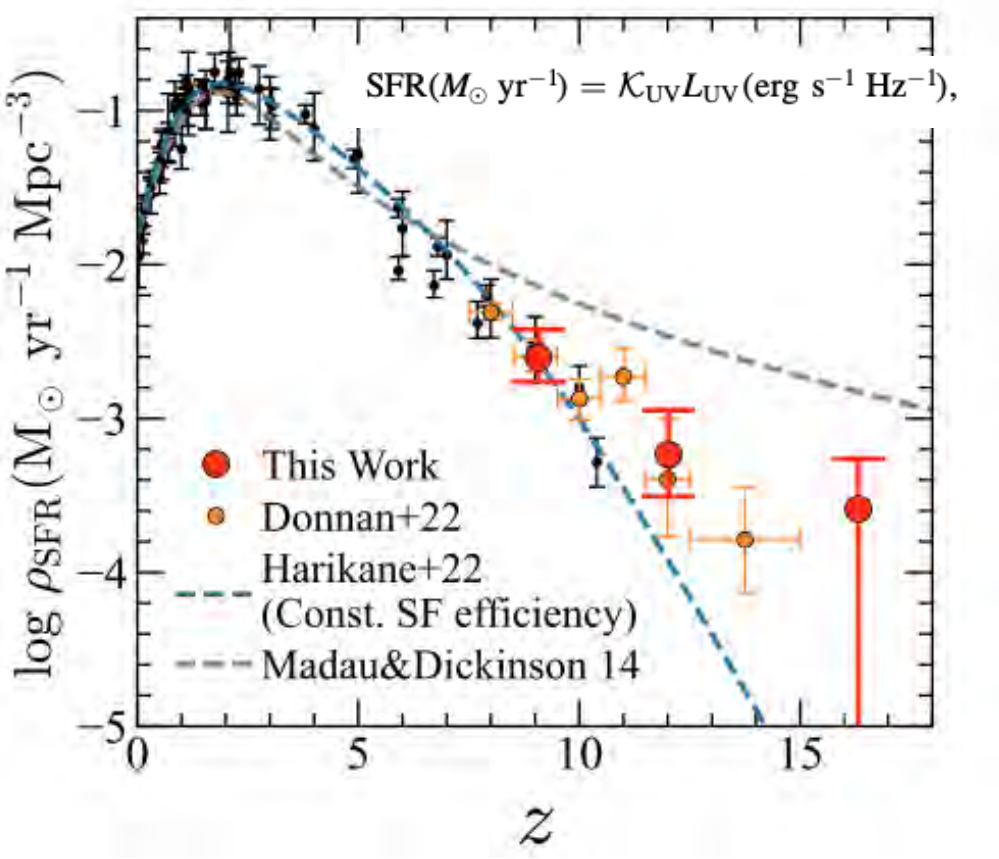
Finkelstein2016

UV LF → 1500 A, or 1700 A rest frame

Reasons that LFs in the past focused on UV
2. To constrain cosmic star formation history

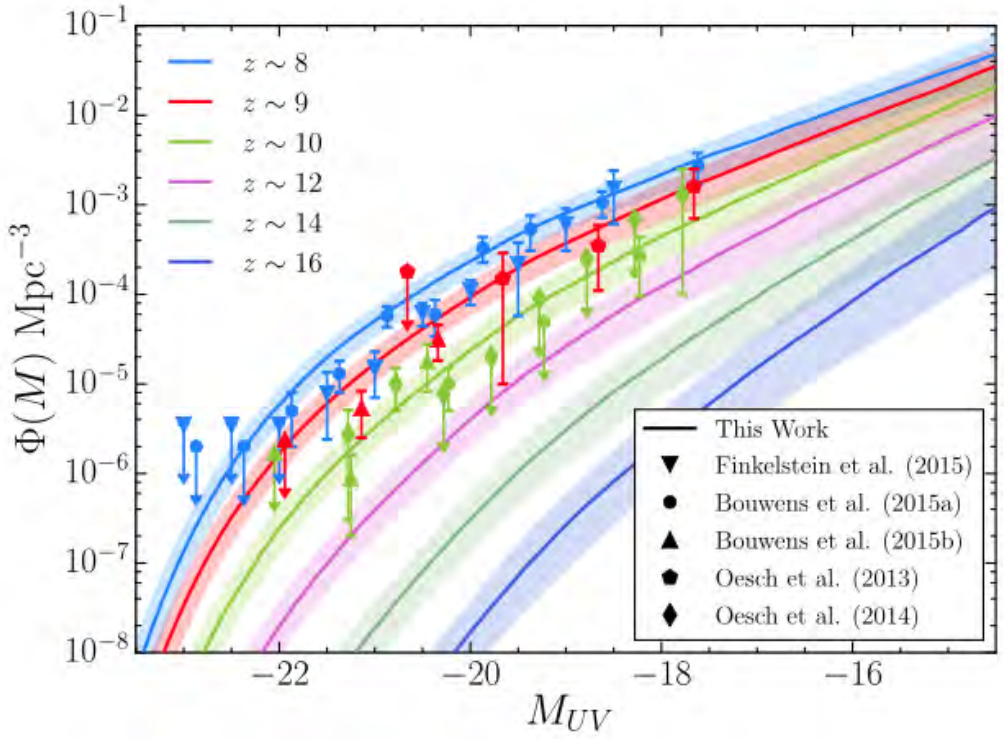


Madau, Pozzeti & Dickinson 1998



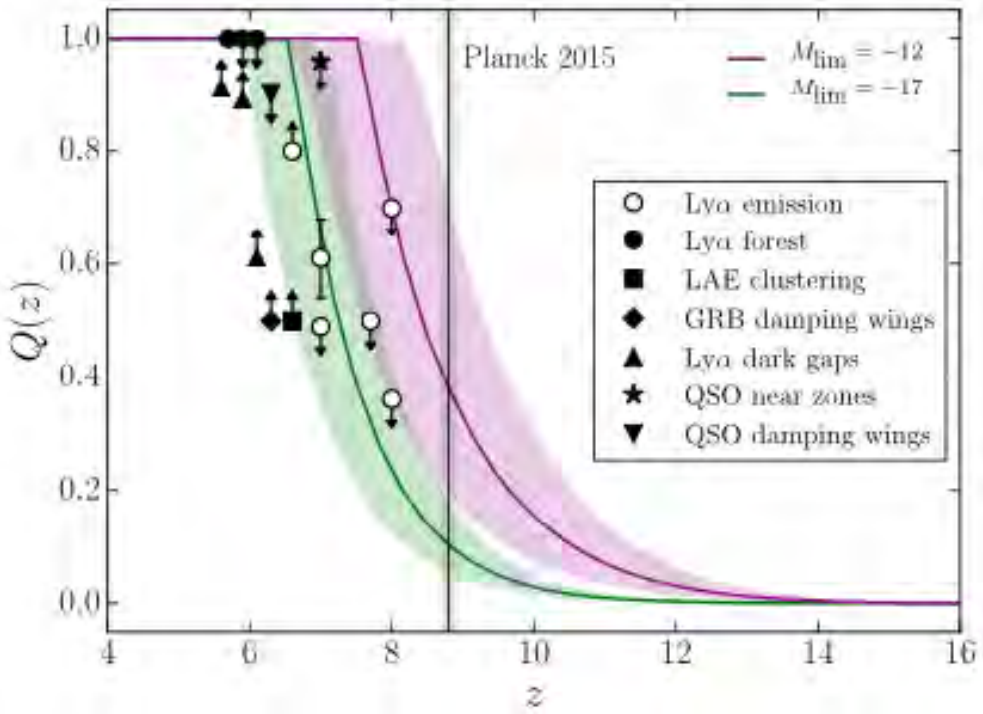
Harikane+2023

Later on, UVLF is used to constrain the reionization



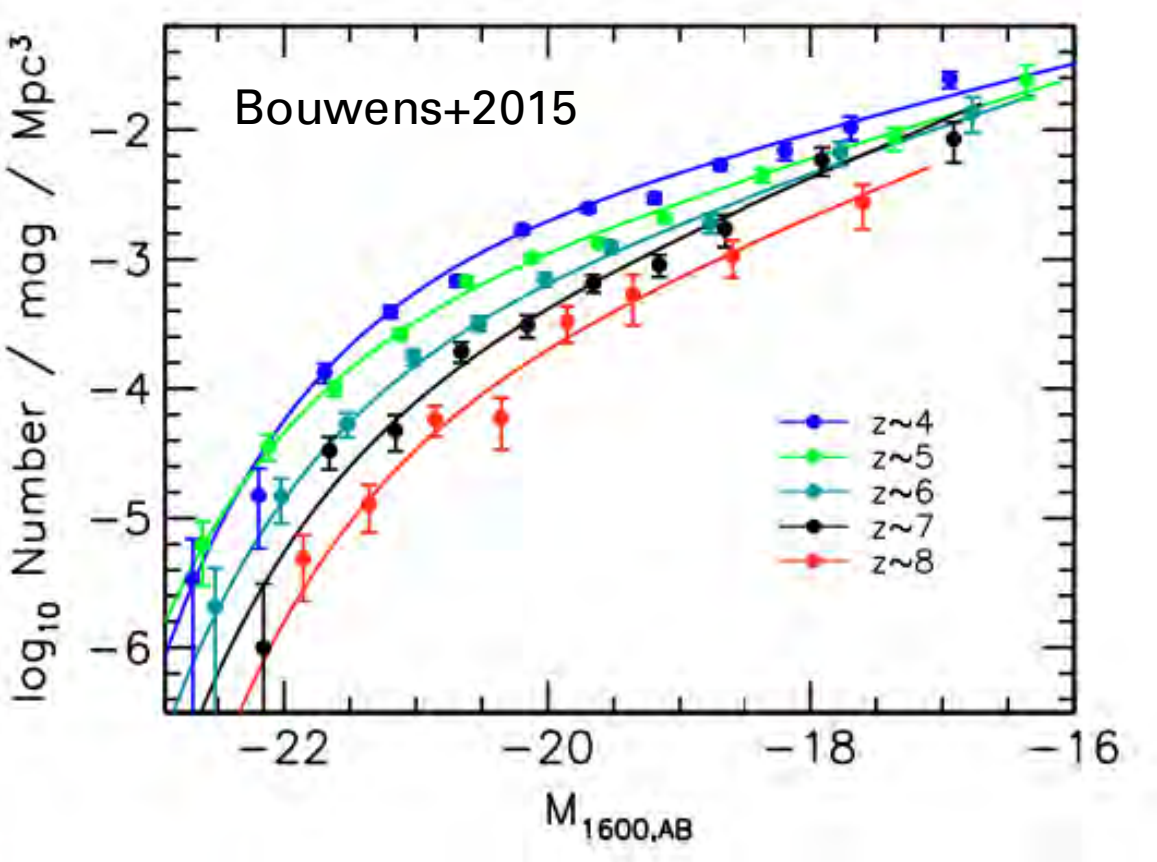
f_{esc} x ξ_{ion}

Galaxies can provide enough photons to fully reionize the universe



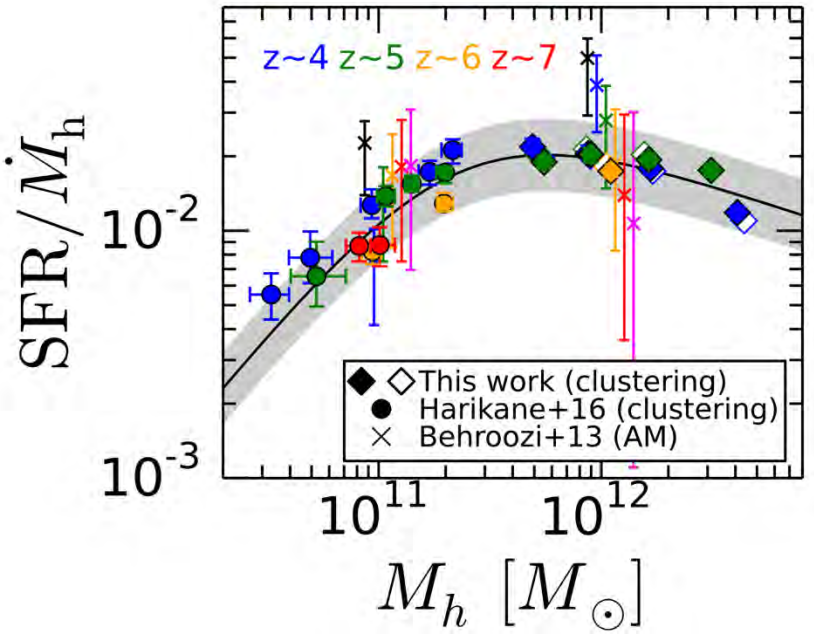
Mason+2015

The cencus of UV LFs until ~2020 was (overall) smooth and monotonic evolution



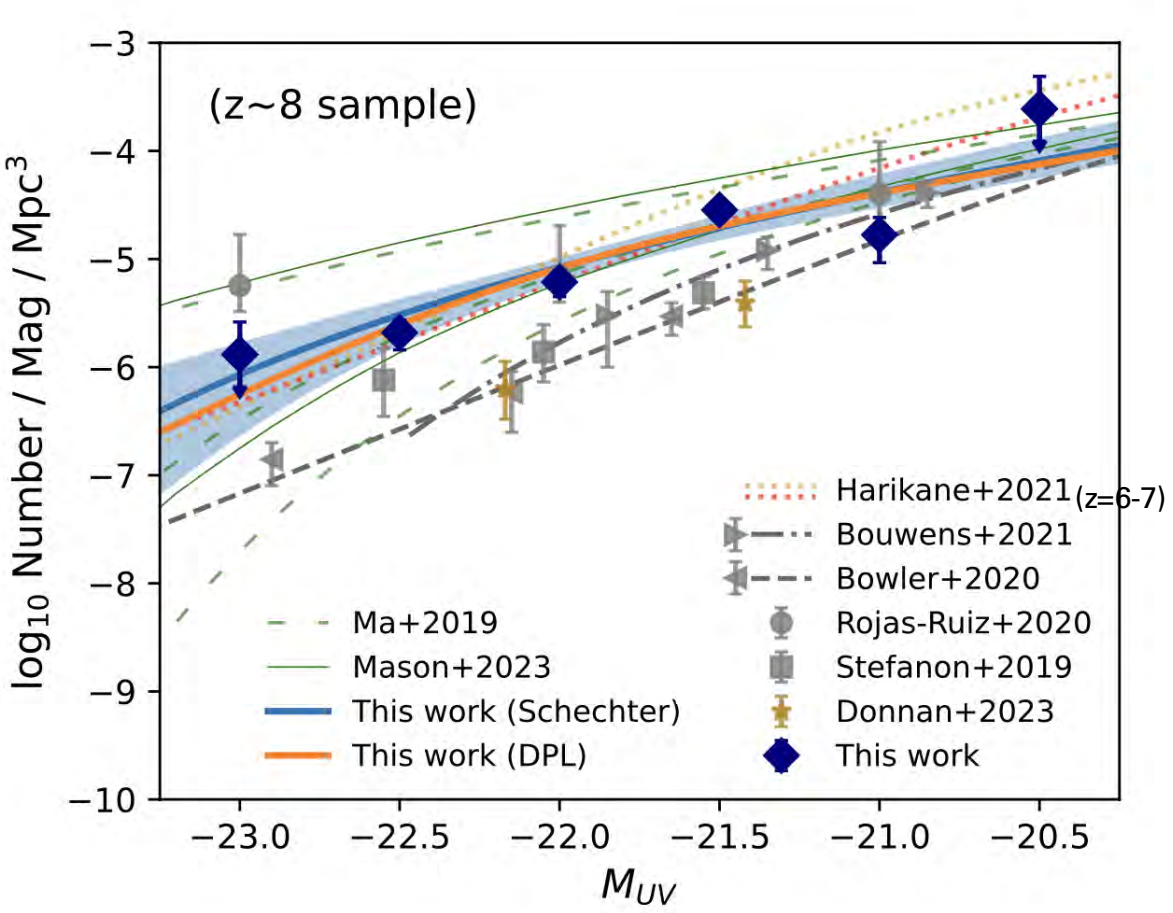
See also: Bouwens+2021

The observed evolution of UVLF can be explained by the evolution of halo mass function with constant star formation efficiency model



Harikane+2018a – star formation efficiency doesn't depend on redshift

Previous results large-area survey suggest a possible bright-end excess at z>6



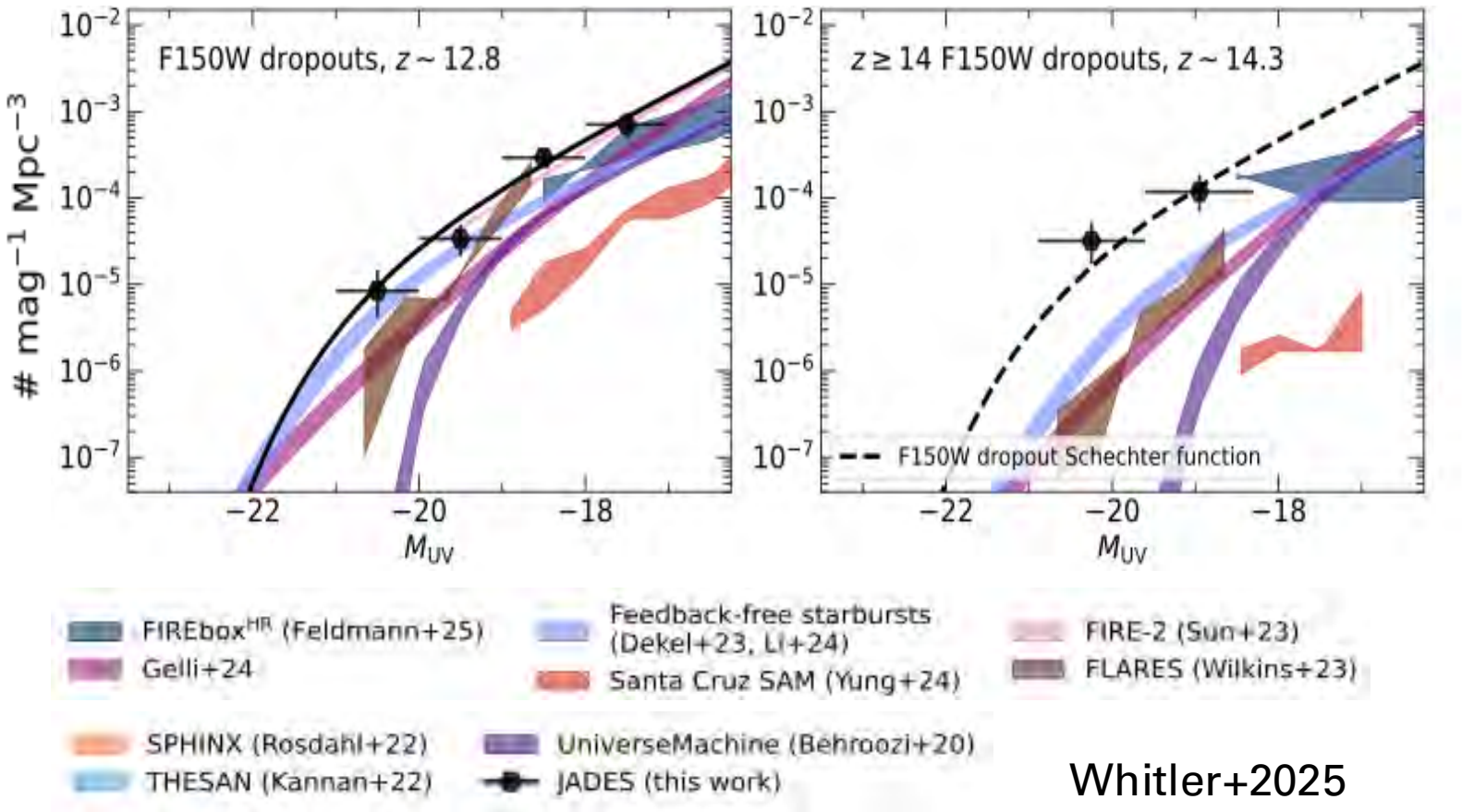
Leethochawalit+2023b

- From 0.4 deg^2 compilation of all HST parallel data (SuperBoRG)
- Consistent with AGN+Galaxies UVLF at lower redshifts (z=6-7)
- Explainations: AGN, dust, or scatter in the UV-halo mass relation

Also
Bowler+2014,15,17,20 & Stefanon+2017,19 (UltraVISTA)
Ono+2018, Harikane+2022 (HSC)

Morishita+2018 (HST parallel)
Finkelstein+2022 (HST CANDELS)
etc

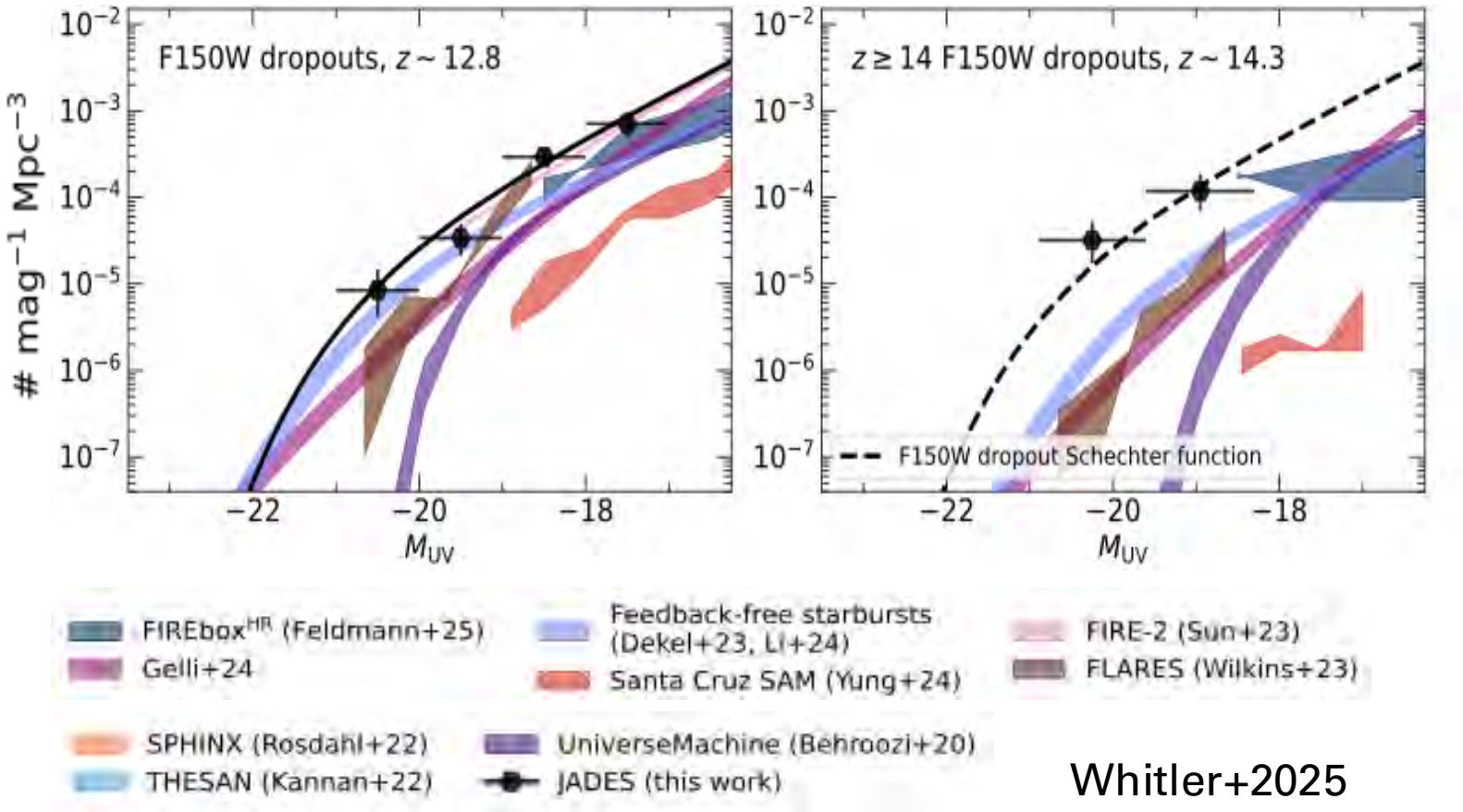
JWST: Galaxy number densities at $z \geq 10$ are larger than predictions



Whitler+2025

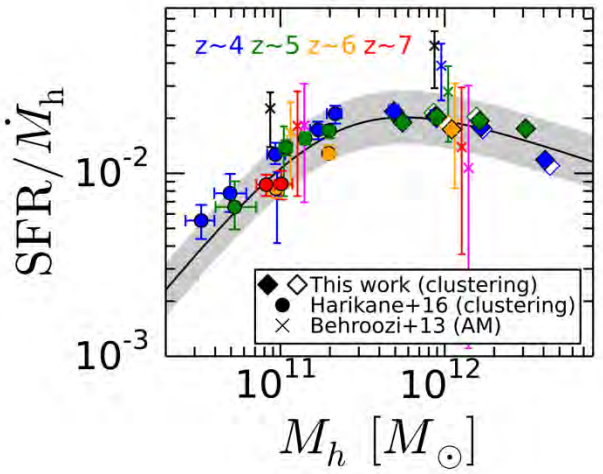
Also:
Castellano+2022, Bouwens+2023, Harikane+2023, McLeod+202, Adams+2024,Donna+2024,Finkelstein+2024, etc.

JWST: Galaxy number densities at $z \geq 10$ are larger than predictions

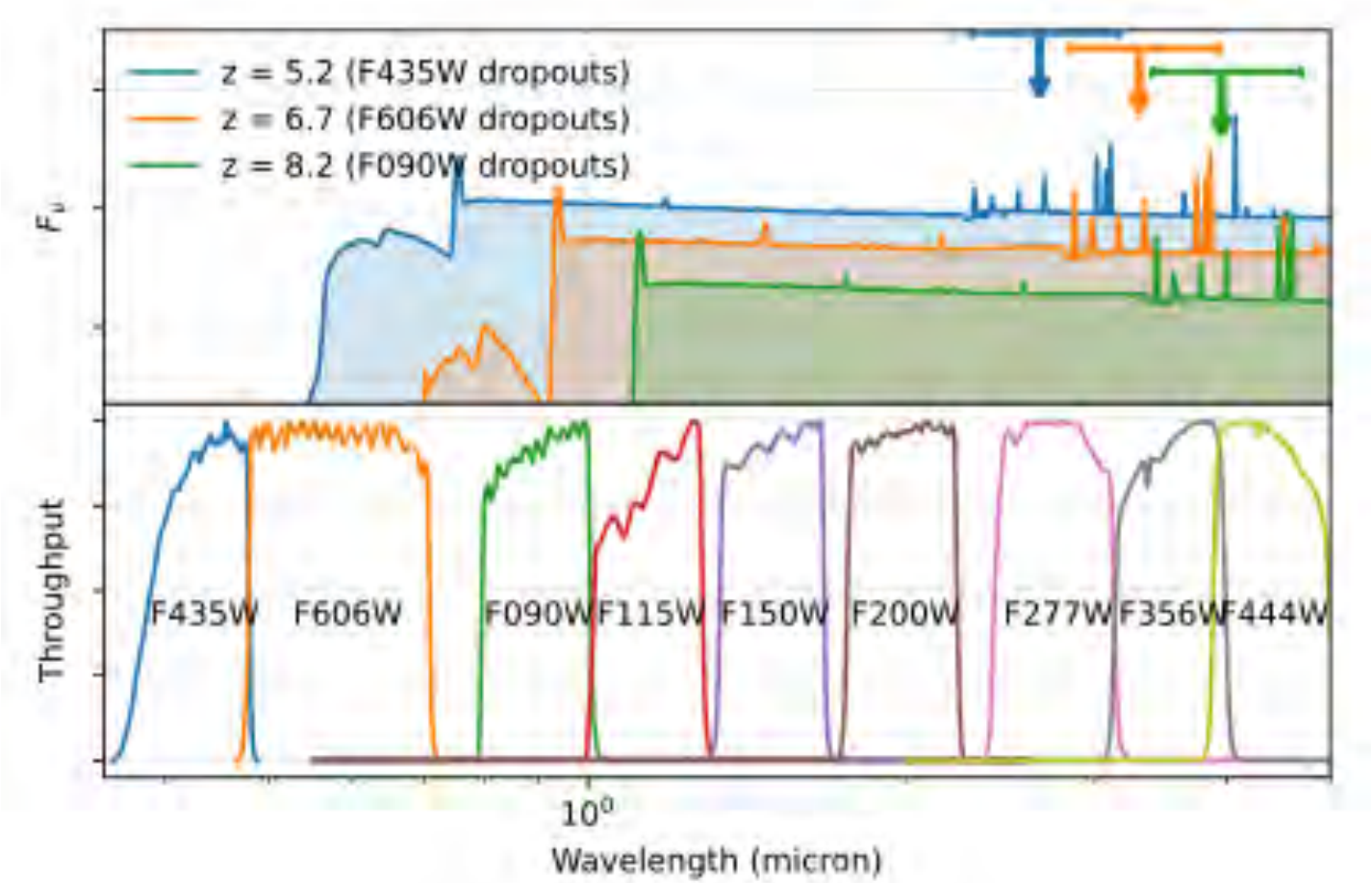


Whitler+2025

- Larger star-formation efficiency at higher redshifts
- Top-heavy IMF
- Less dust obsurcation



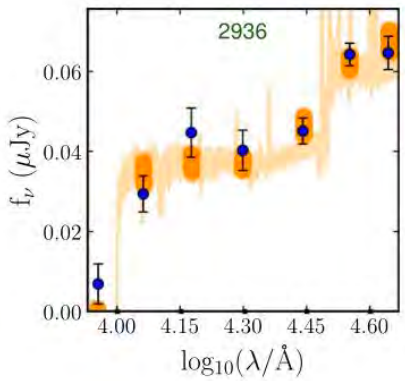
With JWST, we can go beyond UVLF

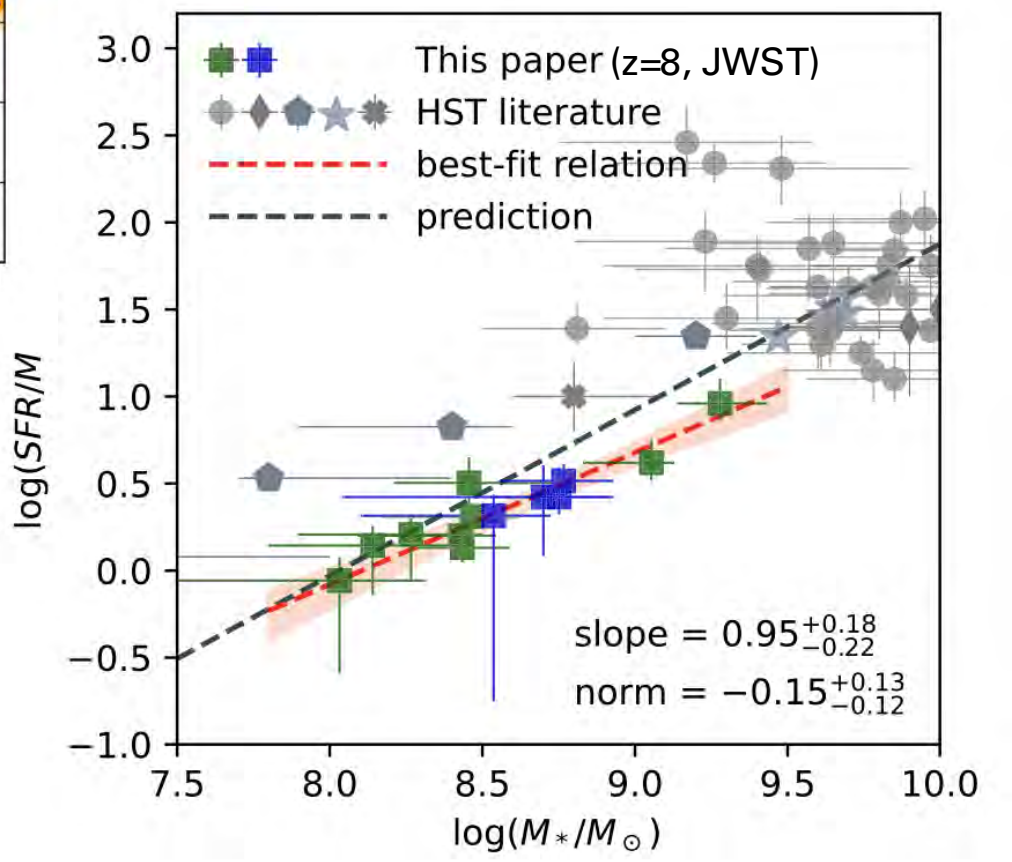


- Thousands of galaxies in NIRCam

- UV α SFR (young stars)
- Redder opt bands
  → Older stars (integrated star formation history, stellar mass)
  → Less sensitive to dust

With JWST, we can go beyond UVLF





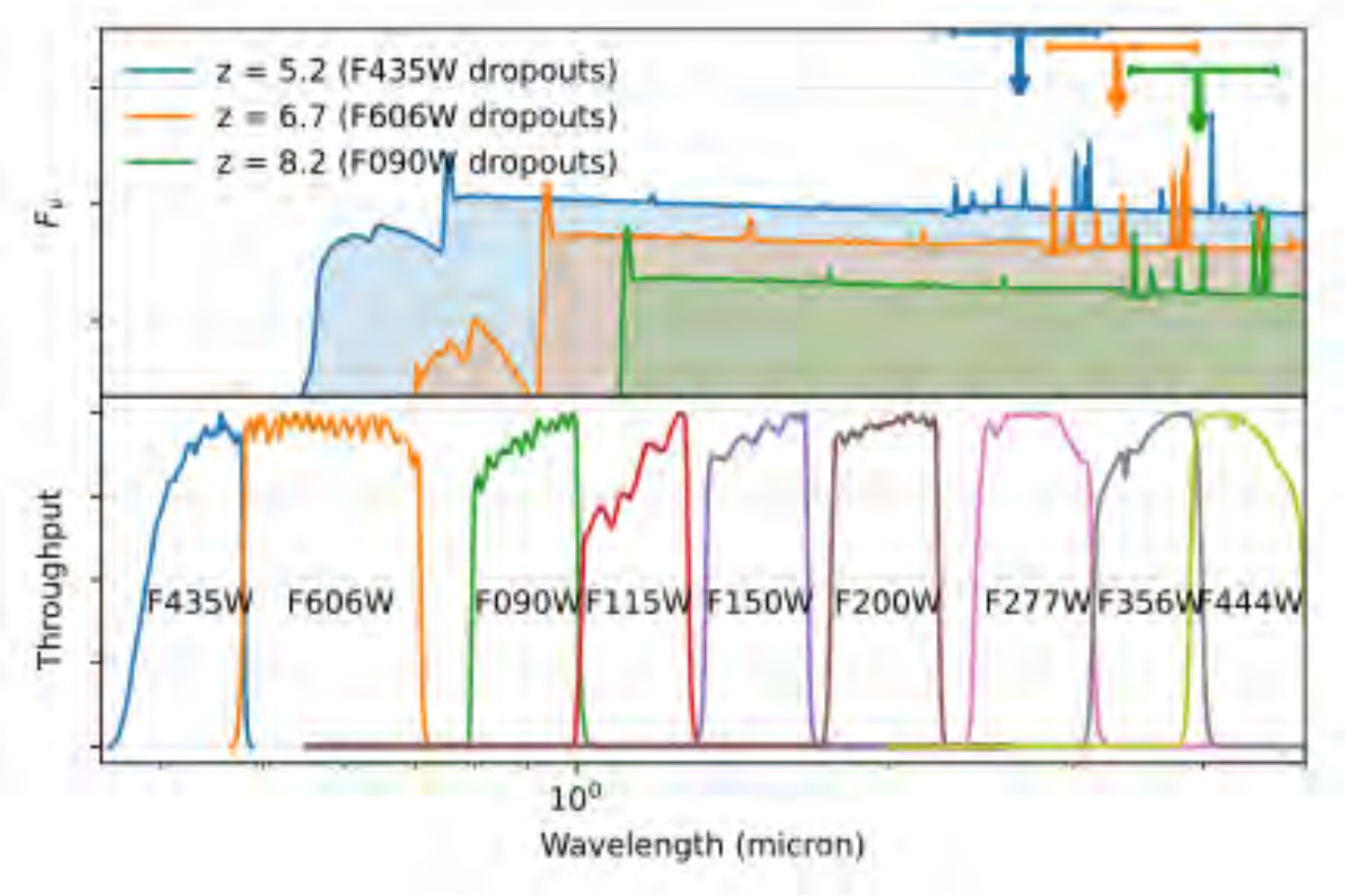
Leethochawalit+2023a

- Thousands of galaxies in NIRCam

- UV α SFR (young stars)
- Redder opt bands
  → Older stars (integrated star formation history, stellar mass)
  → Less sensitive to dust

- LFs be compared to simulations ‘directly’
- Less dependent on SED fitting

Data and galaxy selection



Data and galaxy selection

F435W dropouts
z=4.8-5.7

F606W dropouts
z=6.4-7.1

F090W dropouts
z=7.3-8.9

JADES (Rieke+2023, ~64 arcmin^2)

First Cycle (Morishita+2024, ~ 290 arcmin^2)

PRIMER-UDS, J1235, NEP, PAR1199, JADES-GDs, and CEERS

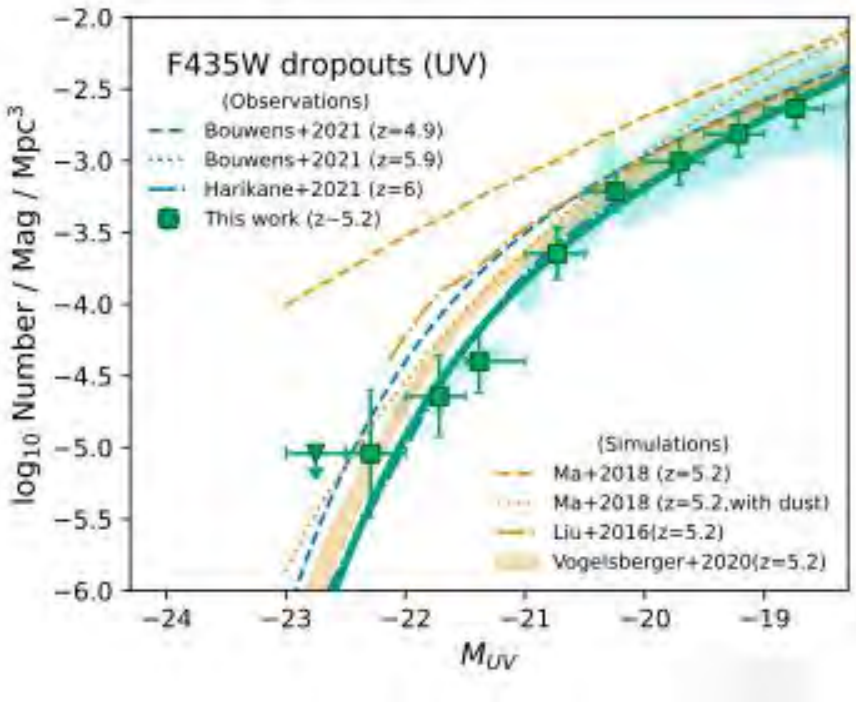
Non-detection + Detection + Photometric redshift criteria

1380 candidates

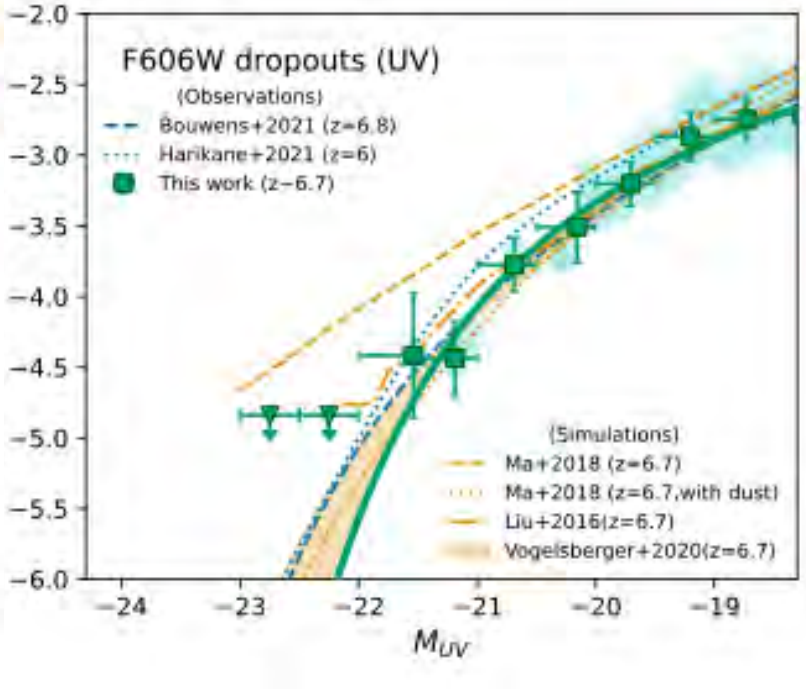
696 candidates

406 candidates

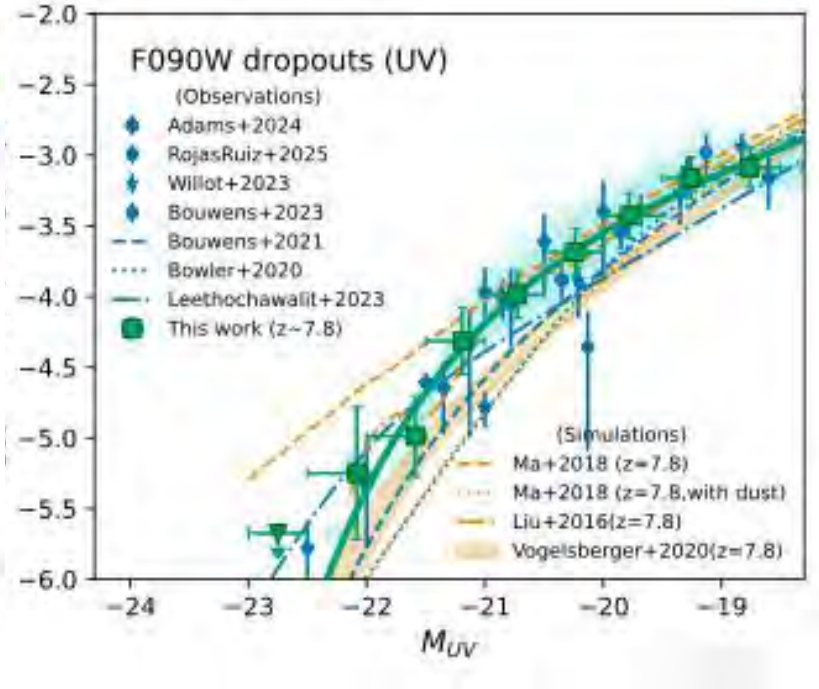
UV LFs are consistent with current observations



z=5.2



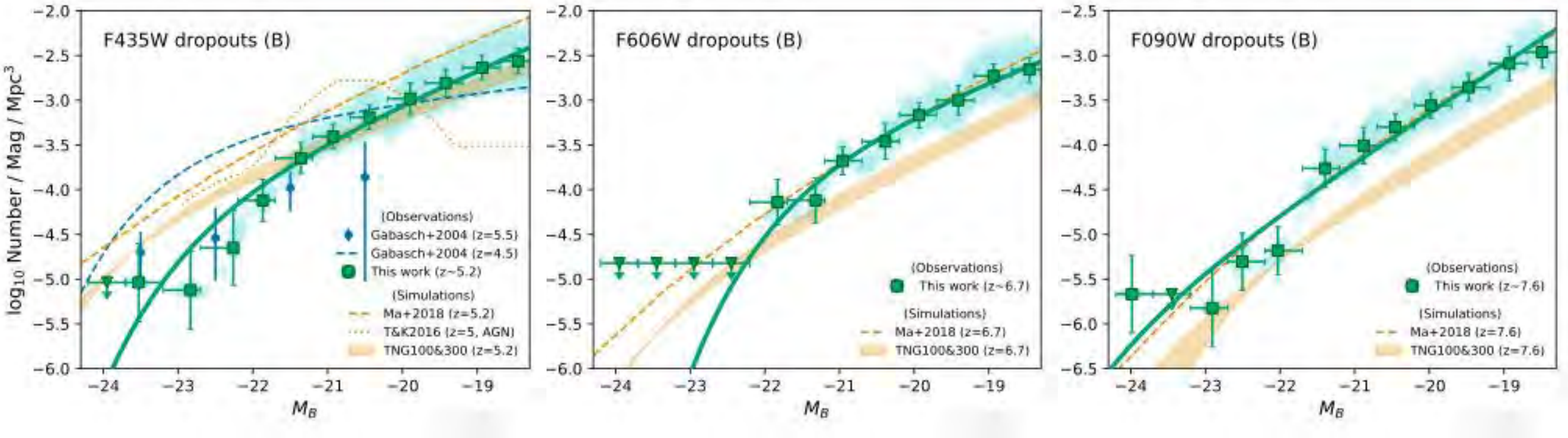
z=6.7



z=7.8

Leethochawalit+, submitted to ApJ

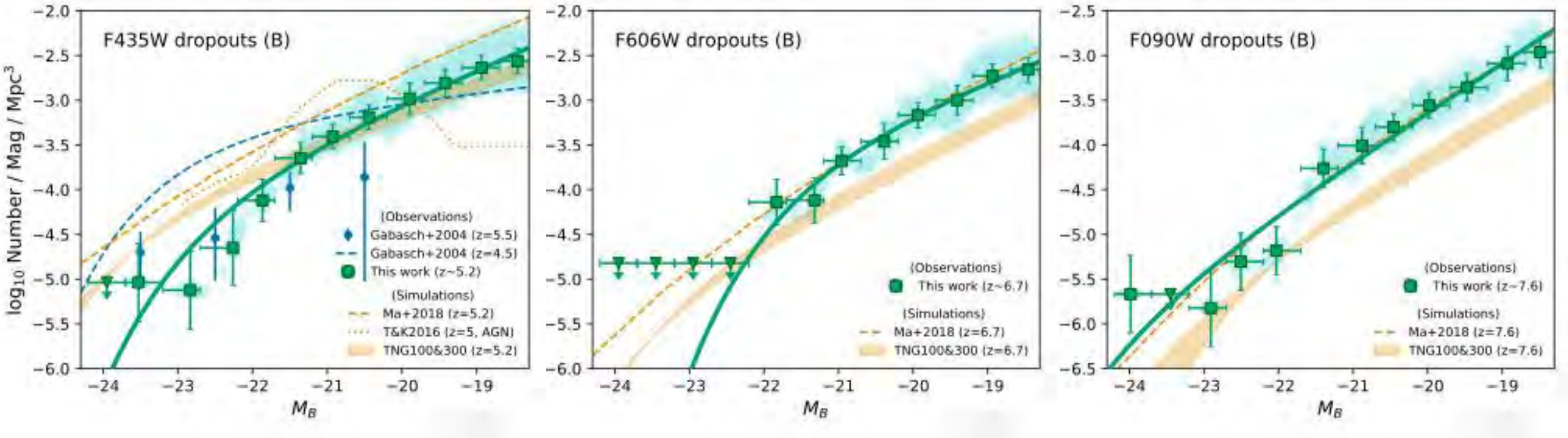
B-band LFs at z~5 are consistent with previous observations. First measurements at z > 5



z=5.2 z=6.7 z=7.8

Leethochawalit+, submitted to ApJ

When compared to simulations, FIRE-2 overpredicts B-band LF at z~5, while TNG underpredicts at higher z



z=5.2 z=6.7 z=7.8

Leethochawalit+, submitted to ApJ

When compared to simulations, FIRE-2 overpredicts B-band LF at z~5, while TNG underpredicts at higher z

Binary model:

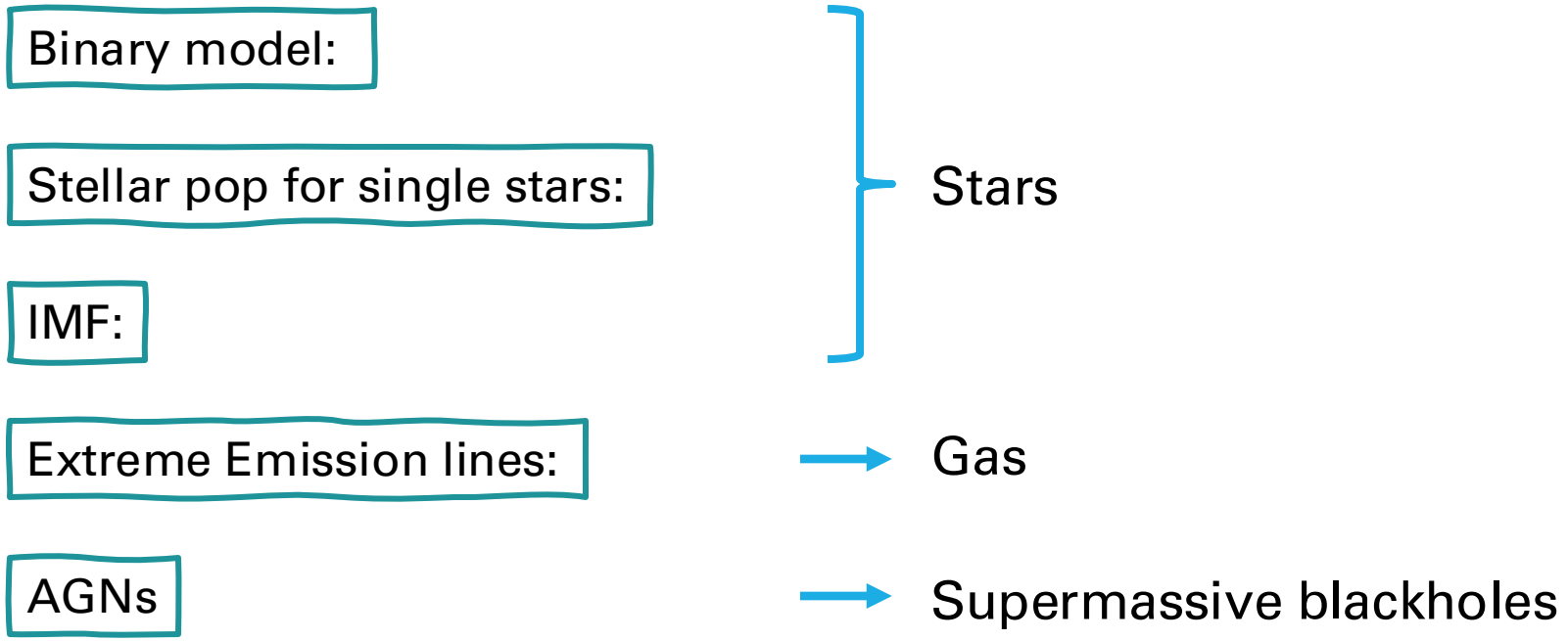
Stellar pop for single stars:

IMF:

Extreme Emission lines:

AGNs

When compared to simulations, FIRE-2 overpredicts B-band LF at z~5, while TNG underpredicts at higher z



When compared to simulations, FIRE-2 overpredicts B-band LF at z~5, while TNG underpredicts at higher z

	FIRE2	TNG	Implication
Binary model:	Yes	No	
Stellar pop for single stars:	BPASSv2.0	BC03	
IMF:	Chabrier 2003	Kroupa 2001	
Extreme Emission lines:			
AGNs			

When compared to simulations, FIRE-2 overpredicts B-band LF at z~5, while TNG underpredicts at higher z

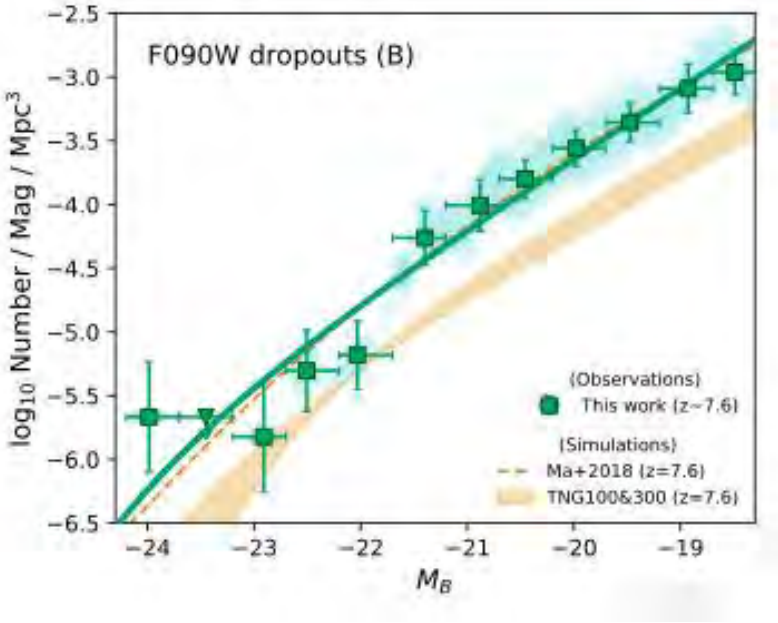
	FIRE2	TNG	Implication
Binary model:	Yes	No	
Stellar pop for single stars:	BPASSv2.0	BC03	
IMF:	Chabrier 2003	Kroupa 2001	Not the cause
Extreme Emission lines:			
AGNs			

Binaries become especially important at high-z

	FIRE2	TNG	Implication
Binary model:	Yes	No	• Binary models are neccesary esp z≥7 • Need better constraints for lower mass stars

Facts:

- In MW and Magellanic Clouds
  → F, G, K stars 40% binaries
  → O, B stars 80% binaries (Sana+2014, Frost2025)
- Multiplicity of stars increase with decreasing metallicity (Bate+2019)
- BPASS is optimized for young populations, not constrained well for lower-mass stars (Eldridge+2017)

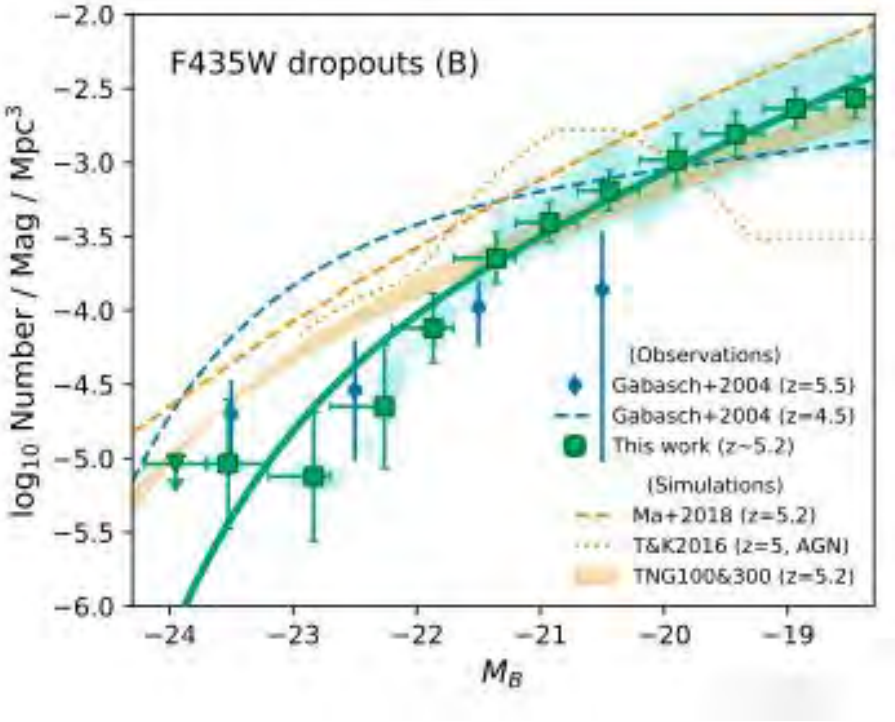


BPASS stellar pop is redder than BC03 at (older) age → over-predict at lower z (?)

	FIRE2	TNG	Implication
Stellar pop for single stars:	BPASSv2.0	BC03	Can contribute

BPASS model for stellar populations with age > a few hundred Myr are significantly redder than those of BC03, due to different treatment of AGB (Eldridge+2017)

At lower age, they are similar



When compared to simulations, B-band LFs at z~5 are more consistent with TNG, at high-z are more consistent with FIRE2

	FIRE2	TNG	Implication
Binary model:	Yes	No	• Binary models are neccesary esp z≥7 • Need better constraints for lower mass stars
Stellar pop for single stars:	BPASSv2.0	BC03	Can contribute
IMF:	Chabrier 2003	Kroupa 2001	Not the cause
Extreme Emission lines:			
AGNs			

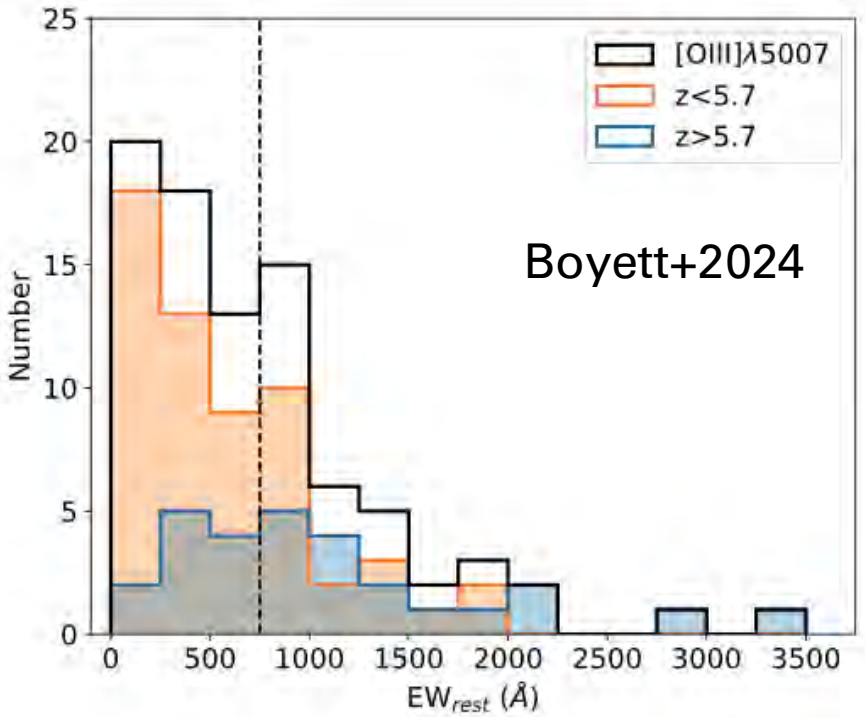
Extreme emission lines in high-z galaxies cannot explain all excess in the abundance (relative to TNG)

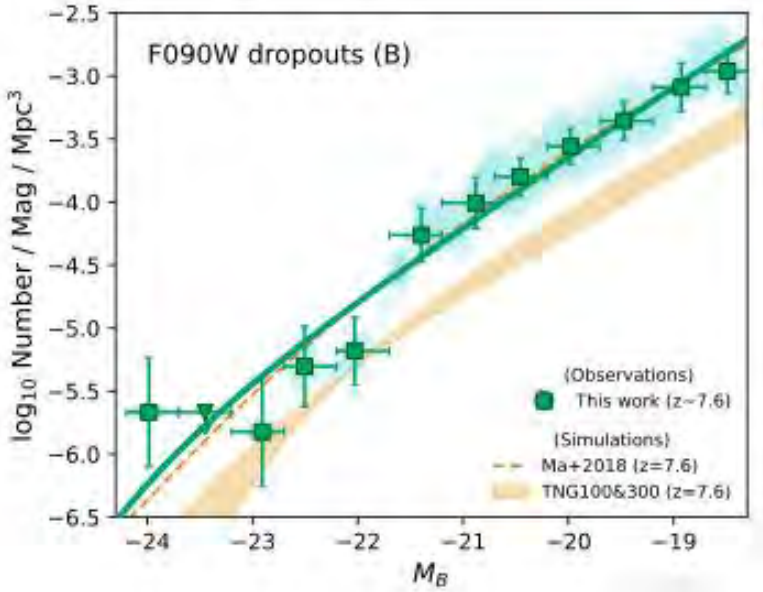
FIRE2 | TNG | Implication

Extreme Emission lines:

EM not included

Can contribute but cannot account for all discrepancy





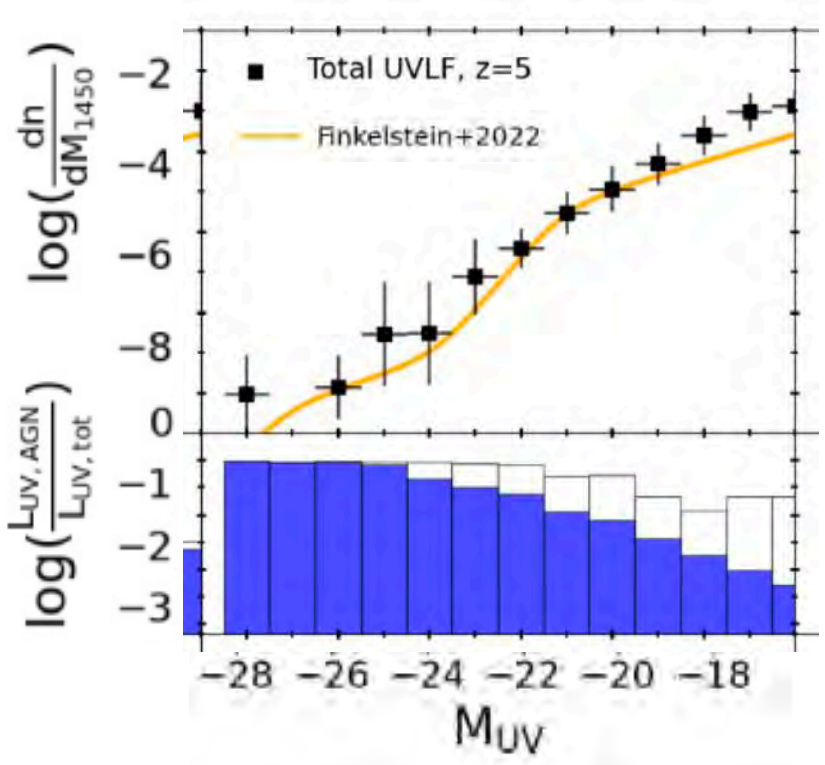
EW=500-3000A x Bband filter → 0.1-0.6 mag

When compared to simulations, B-band LFs at z~5 are more consistent with TNG, at high-z are more consistent with FIRE2

	FIRE2	TNG	Implication
Binary model:	Yes	No	• Binary models are neccesary esp z≥7 • Need better constraints for lower mass stars
Stellar pop for single stars:	BPASSv2.0	BC03	Can contribute
IMF:	Chabrier 2003	Kroupa 2001	Not the cause
Extreme Emission lines:	EM not included		Can contribute 10-50% (lift the normalization)
AGNs			

When compared to simulations, B-band LFs at z~5 are more consistent with TNG, at high-z are more consistent with FIRE2

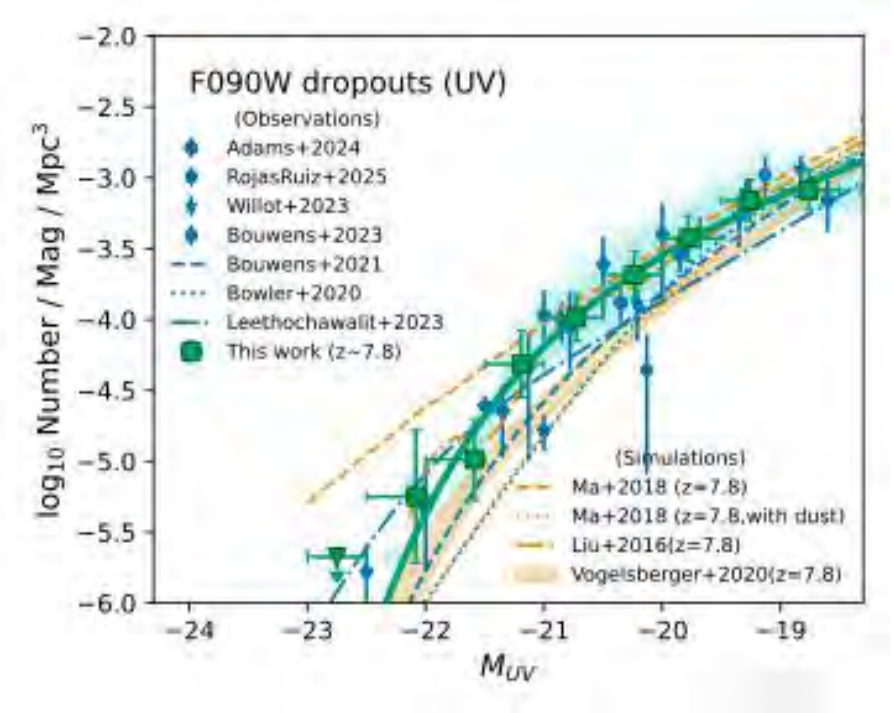
	FIRE2	TNG	Implication
AGNs	Yes (feedback)	No	simulation SAM w/ Pop III and AGNs

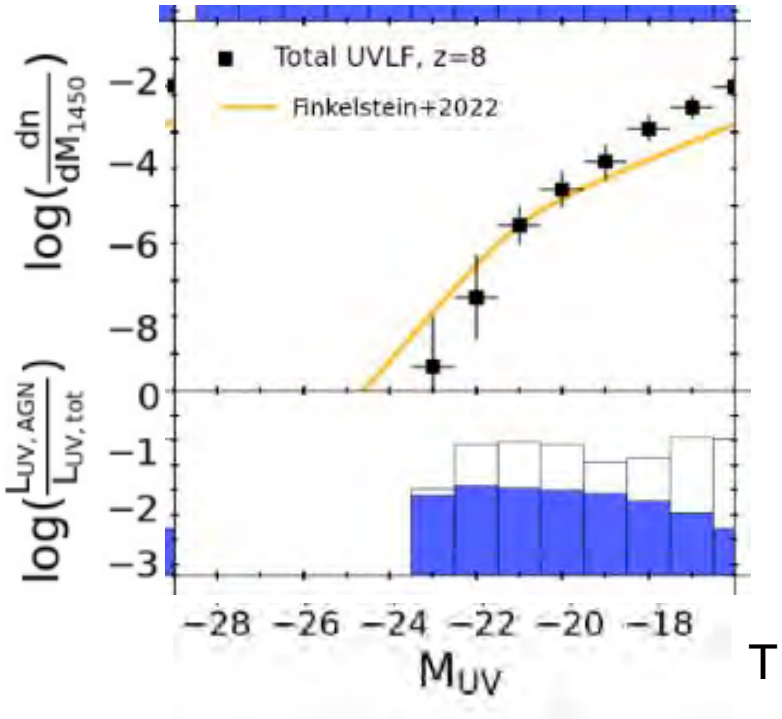


Trinca+2024

When compared to simulations, B-band LFs at z~5 are more consistent with TNG, at high-z are more consistent with FIRE2

	FIRE2	TNG	Implication
AGNs	Yes (feedback)	No	





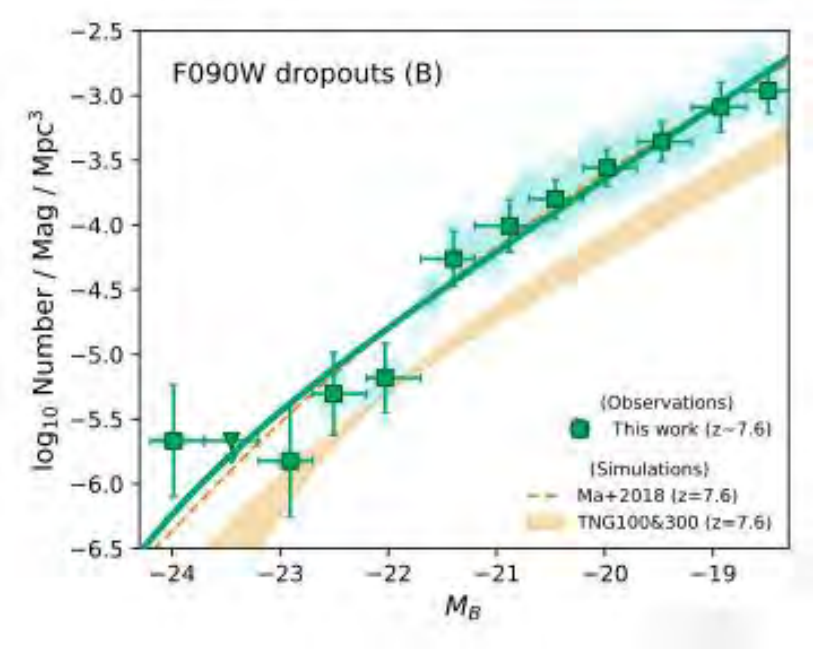
simulation SAM w/ Pop III and AGNs

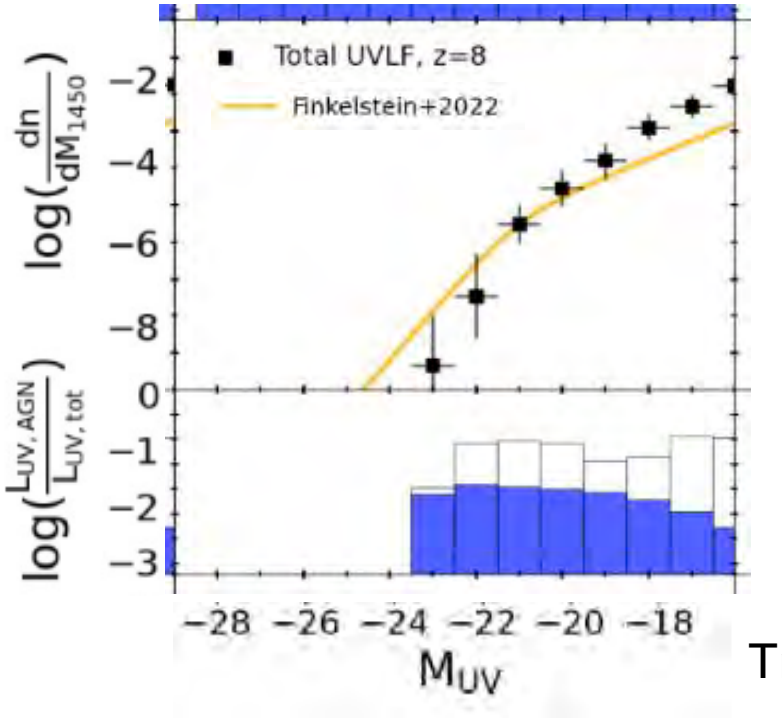
AGN contribute at most 30% in UV

Trinca+2024

When compared to simulations, B-band LFs at z~5 are more consistent with TNG, at high-z are more consistent with FIRE2

	FIRE2	TNG	Implication
AGNs	Yes (feedback)	No	Possible to contribute 60% at the bright end





simulation SAM w/ Pop III and AGN

AGN contribute at most 30% in UV

$\frac{L_{\rm bol}}{L_{\rm B}} = 5.13$ $L_\nu \propto \nu^{-0.44}$

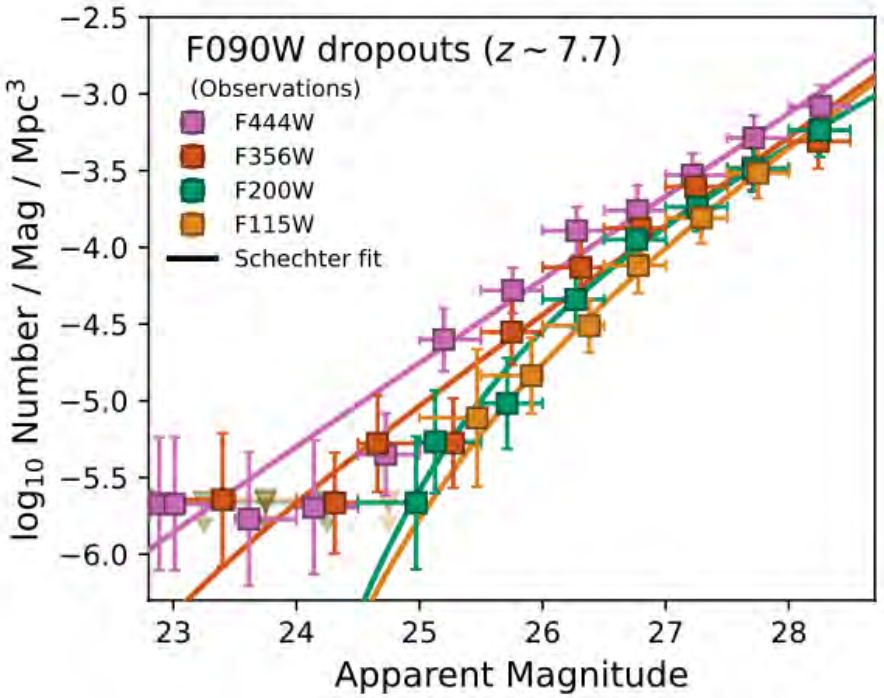
Could be up to 60% in the B-band!

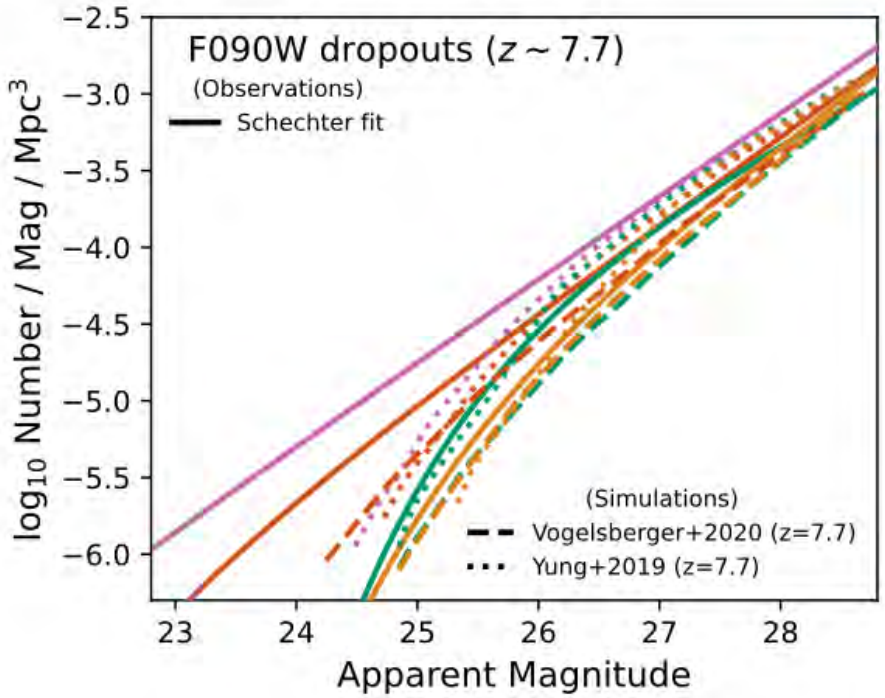
Trinca+2024

When compared to simulations, B-band LFs at z~5 are more consistent with TNG, at high-z are more consistent with FIRE2

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Binary model:	Yes	No	• Binary models are neccesary esp z≥7 • Need better constraints for lower mass stars
Stellar pop for single stars:	BPASSv2.0	BC03	Can contribute
IMF:	Chabrier 2003	Kroupa 2001	Not the cause
Extreme Emission lines:	EM not included		Can contribute 10-50% (lift the normalization)
AGNs	Yes (feedback)	No	Possible to contribute 60% at the bright-most bin

We also provide luminosity functions in observed NIRCam bands to be directly compared with simulations





Less dependent on redshift estimation (distance modulus to convert m to M)

Conclusion

- First B-band LFs and observed NIRCam LFs at $z > 6$
- No simulations predict all observed trends: z=5 aligns with TNG, z>5 aligns with FIRE-2
- Extreme emission lines could account at most half (or the normalization)
- Other factors include binaries and stellar population models
- Bright end could be signature of AGNs (as it is brighter in B-band than UV)