FIRST RESULTS ON THE EARLIEST GALAXIES FROM THE JWST PROGRAMS

Brant Robertson (University of California, Santa Cruz)
Sandro Tacchella (KICC, University of Cambridge)
Benjamin D. Johnson (CfA | Harvard & Smithsonian)

arXiv:2212.04480

K. Hainline, L. Whitler, D. J. Eisenstein, R. Endsley, M. Rieke, D. P. Stark, S. Alberts, A. Dresser, E. Egami, R. Hausen, G. Rieke, I. Shivaei, C. C. Williams, C. N. A. Willmer, S. Arribas, N. Bonaventura, A. Bunker, A. J. Cameron, S. Carniani, S. Charlot, J. Chevallard, M. Curti, E. Curtis-Lake, F. D'Eugenio, P. Jakobsen, T. J. Looser, N. Lützgendorf, R. Maiolino, M. V. Maseda, T. Rawle, H.-W. Rix, R. Smit, H. Übler, C. Willott, J. Witstok, S. Baum, R. Bhatawdekar, K. Boyett, Z. Chen, A. de Graaff, M. Florian, J. M. Helton, R. E. Hviding, Z. Ji, N. Kumari, J. Lyu, E. Nelson, L. Sandles, A. Saxena, K. A. Suess, F. Sun, M. Topping, I. E. B. Wallace and the JADES Collaboration

BRIEF HISTORY OF THE OBSERVABLE UNIVERSE

Robertson, ARAA, 60, 121 (2022)

Brant Robertson (UCSC, brant@ucsc.edu)

BRIEF HISTORY OF THE OBSERVABLE UNIVERSE

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Recombination $z \approx 1100$

BRIEF HISTORY OF THE OBSERVABLE UNIVERSE

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Dark Ages $z \gtrsim 20(?)$

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BRIEF HISTORY OF THE OBSERVABLE UNIVERSE

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First Galaxies $z \sim 15 - 20(?)$

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BRIEF HISTORY OF THE OBSERVABLE UNIVERSE

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Reionization $z \sim 6 - 12(?)$

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BRIEF HISTORY OF THE OBSERVABLE UNIVERSE

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Modern Galaxies Form

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BRIEF HISTORY OF THE OBSERVABLE UNIVERSE

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Present Day

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BRIEF HISTORY OF THE OBSERVABLE UNIVERSE

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BRIEF HISTORY OF THE OBSERVABLE UNIVERSE

Robertson, ARAA, 60, 121 (2022)

Can we find and confirm distant galaxies close to Cosmic Dawn?
What are the properties of the earliest confirmed galaxies?

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JWST SURVEYS OF THE DISTANT UNIVERSE

COSMOS-Web (GO 1727) - COSMOS

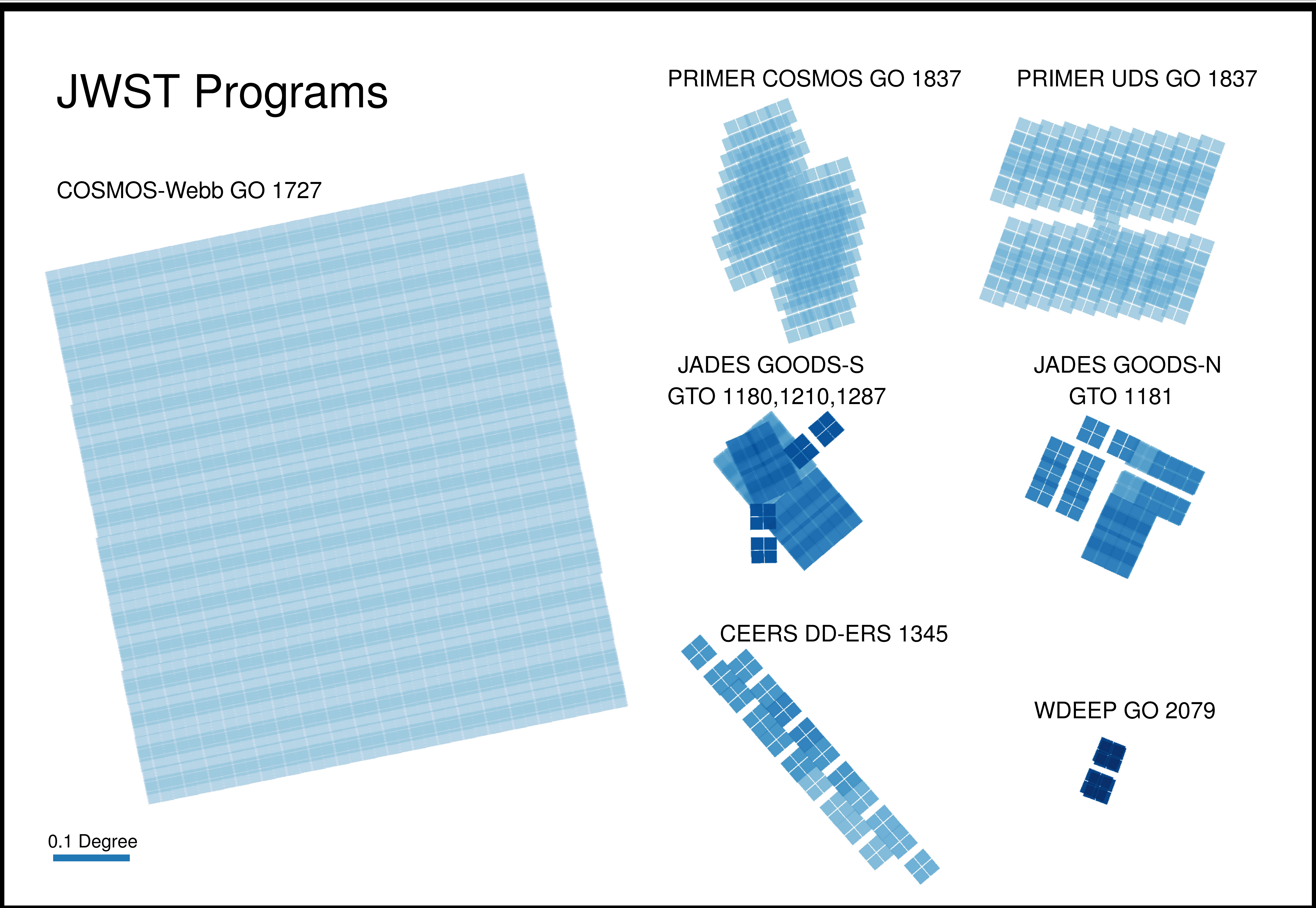
PRIMER (GO 1837) - COSMOS + UDS

CEERS (ERS 1345) - EGS

NGDEEP (GO 2079) - NIRISS on HUDF, NIRCam on UDF Par2

JADES (GTO 1180, 1181, 1210, 1286, 1287) - GOODS N+S

*Pre-launch layouts shown



Robertson, ARAA, 60, 121 (2022)

JWST SURVEYS OF THE DISTANT UNIVERSE

Program	Hours	Target	Area	NIRCam	NIRSpec	NIRISS	MIRI
GLASS DD-ERS 1324 PI Treu	35.1	Abell 2744	~Single pointing w/ parallels	F090W, F115W, F150W, F200W, F277W, F356W, F444W 29-29.4AB Parallel	~0.8-5 micron R~2700 t~17.7 ks	NIRISS R~150 25.5-26.3 AB	-
FRESCO PI Oesch	53.1	GOODS-N GOODS-S	~120 square arcmin	F444W Grism	-	-	-
CEERS DD-ERS 1345 PI Finkelstein	65.7	EGS	~100 square arcmin	F115W, F150W, F200W, F277W, F356W, F410M, F444W t ~ 2.8ks	~0.97-5 micron R~1000 t~2.9 ks; R~100 prism, 26.5AB	-	F1000W, F1280W, F1500W, F1800W, F2100W
UNCOVER PI Labbe	68.2	Abell 2744	~2 NIRCam pointings	(F090W), F115W, F150W, F200W, F2777W, F356W, F444W	R~100 prism t ~ 20 hours	(Imaging) F115W, F150W, F200W, F356W,	-
NGDEEP GO 2079 PI Finkelstein	121.7	HUDF (NIRISS) HUDF Par 2 (NIRCam)	~Single pointing w/ paralles	F115W, F150W, F356W, F444W 30.6-30.9AB	-	F115W, F150W, F200W Grism to f~10^{-18} erg/s/	-
PRIMER GO 1837 PI Dunlop	188.1	COSMOS UDS	144/112 arcmin^2 234/125 arcmin^2	F090W, F115W, F150W, F200W, F277W, F356W, F410M, F444W	-	-	F770W (25.6AB), F1800W
COSMOS-Web GO 1727 PI Kartaltepe, Casey	207.8	COSMOS	0.6 deg^2 / 0.2 deg^2	F115W, F150W, F277W, F444W 27.4-28AB	-	-	F770W (parallel) 24.3-24.5AB

Robertson, ARAA, 60, 121 (2022)

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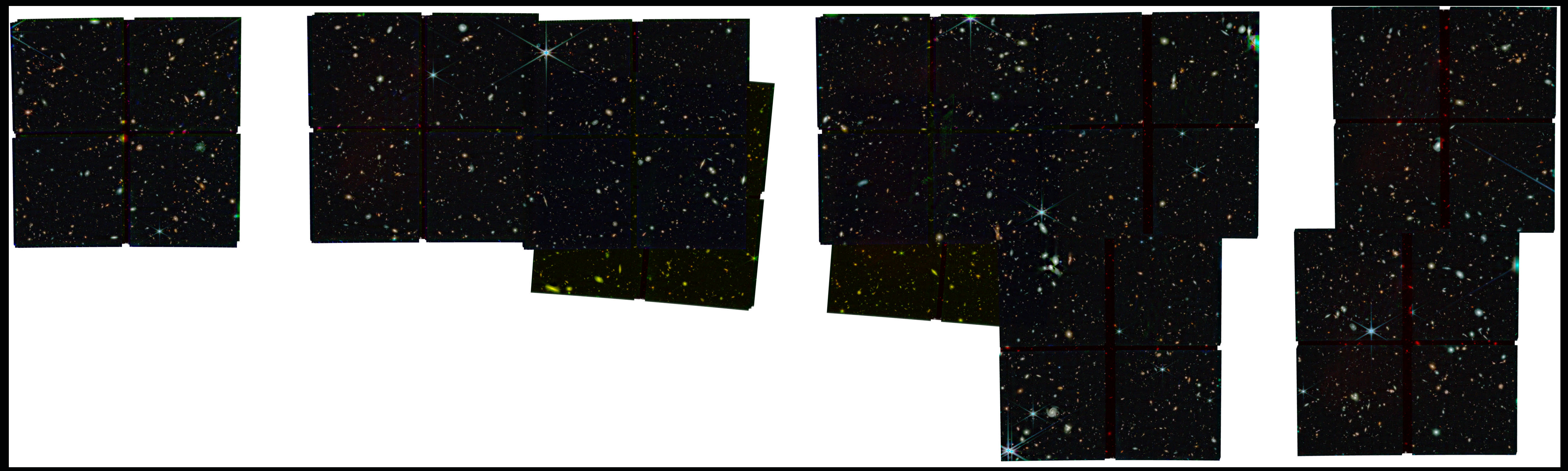
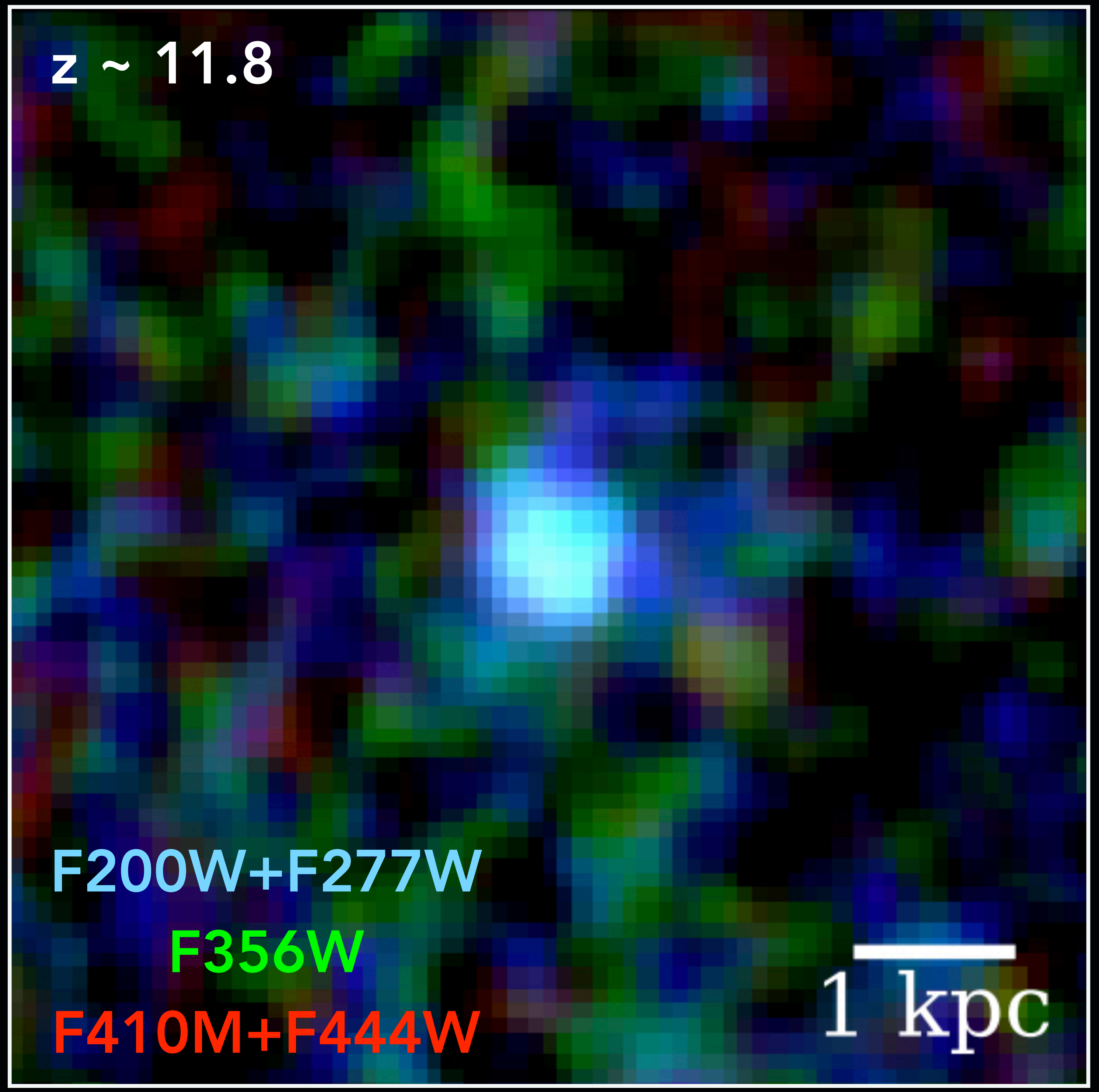
PROGRESS TO DATE

CEERS JWST 1345





Finkelstein et al., arXiv:2207.12474

Wealth of galaxy candidates inferred to lie at z>10 discovered with NIRCam. Detailed spectroscopic properties of galaxies at z<10 being probed with NIRSpec.

Castellano et al. (2022), Adams et al. arXiv:2207.11217, Finkelstein et al., arXiv:2207.12474, Naidu et al. arXiv:2207.09434, Donnan et al. arXiv:2207.12356, Carnall et al. 2207.08778, Brinchmann et al. 2208.07467, Tacchella et al. 2208.03281, Curti et al. (2022), Trussler et al. 2207.14265, Morishta et al. arXiv:2207.11671, Schaerer et al. (2022), Endsley et al. arXiv:2208.14999, Whitler et al. arXiv:2208.10599, Topping et al. arXiv:2208.01610, Ono et al. arXiv:2208.13582, Rodighiero et al. arXiv:2208.02825, Harikane et al. arXiv:2208.01612, Roberts-Borsani et al. arXiv:2210.15639, + many others!

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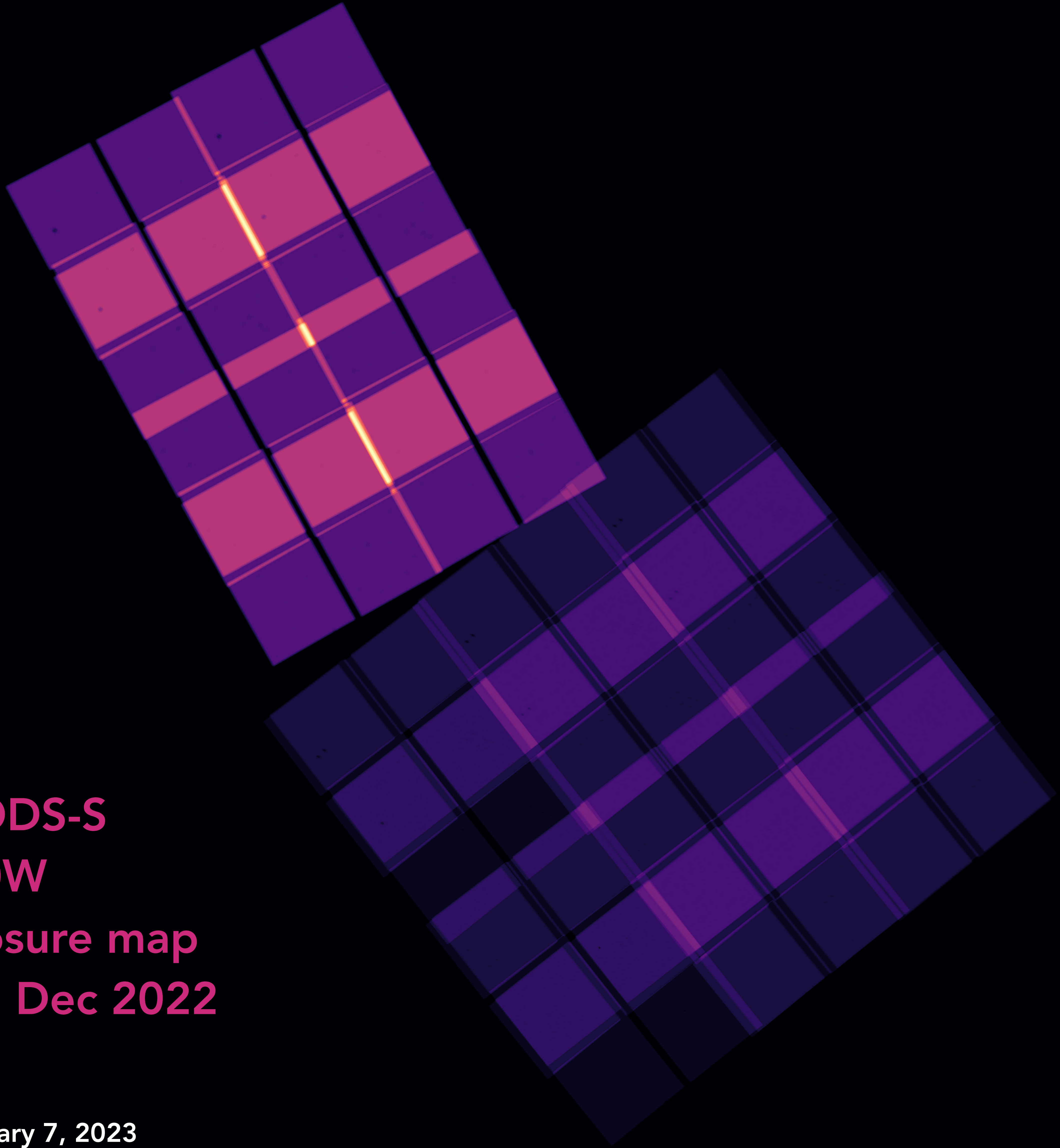
NIRCAM+NIRSPEC GTO PROGRAM IN GOODS-S+N



GOODS-S
F200W
Exposure map
Circa Dec 2022

NIRCam Program 1180 (PI: Eisenstein)

F090W, F115W, F150W, F200W, F277W, F335M, F356W, F410M, F444W imaging acquired late Sept. / early Oct. 2022. More imaging later.

Currently 9.9, 16.8, 9.9, and 6.9 hrs of exposure in F090W, F115W, F150W, F200W. Point-source, 0.15″ radius aperture 5σ depth about 30AB incl. pix covar. on a 0.03″/pix mosaic.

UDF Medium Band program co-located (Program 1963; PI Williams, Maseda, & Tacchella), providing F182M, F210M, F430M, F460M, F480M.

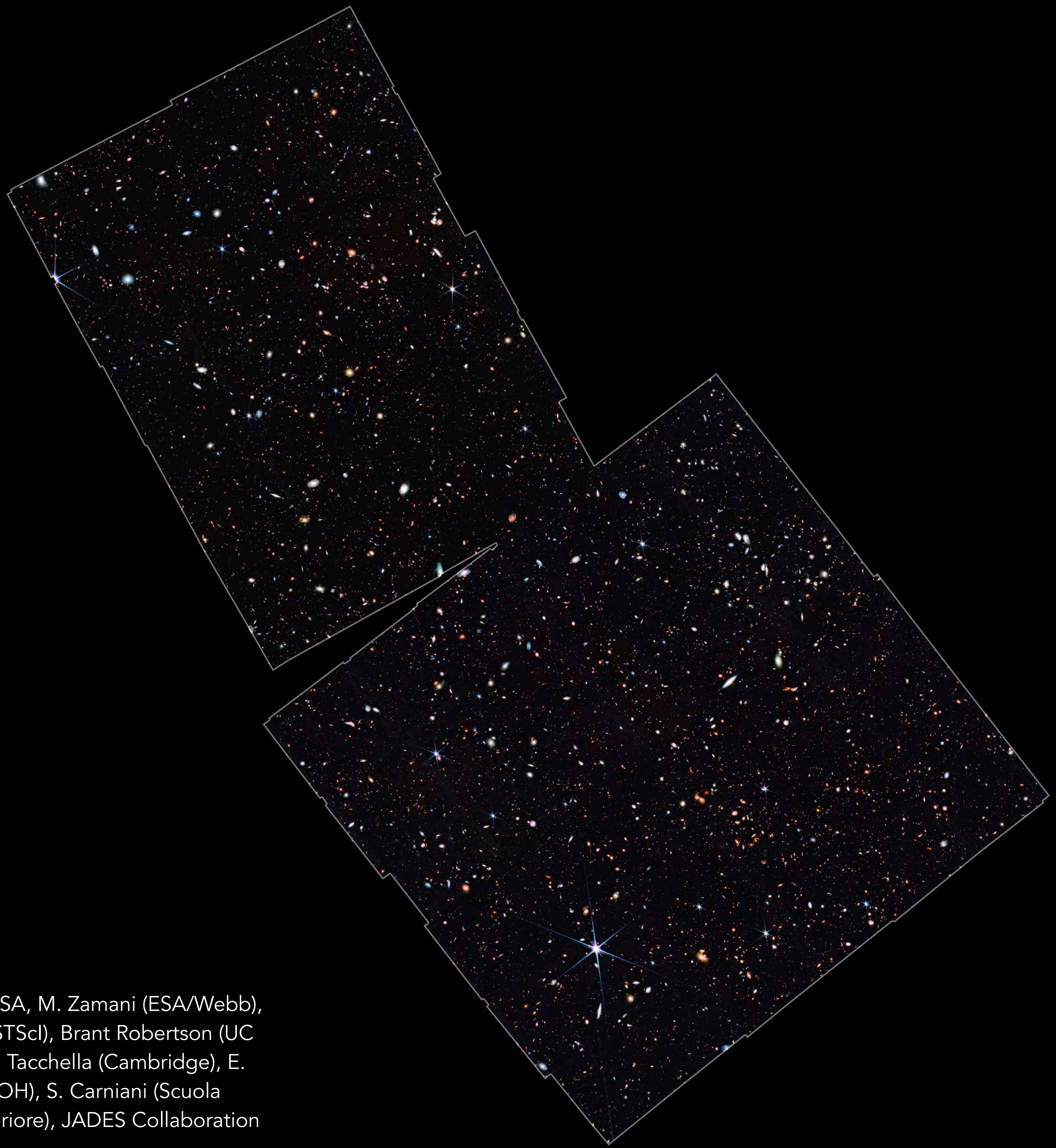
Some regions have all 14 NIRCam bands!

GOODS-N being acquired as we speak…

Brant Robertson (UCSC, brant@ucsc.edu)

NIRCAM IMAGING, OBJECT DETECTION, AND PHOTOMETRY

F115W
F200W
F444W



NASA, ESA, CSA, M. Zamani (ESA/Webb), Leah Hustak (STScI), Brant Robertson (UC Santa Cruz), S. Tacchella (Cambridge), E. Curtis-Lake (UOH), S. Carniani (Scuola Normale Superiore), JADES Collaboration

Custom reduction based mostly on the STScI *jwst* pipeline, including 1/f noise, snowballs, wisp removal, background subtraction.

SNR detection image constructed from inverse-variance stack of F200W, F277W, F335M, F356W, F410M, and F444W.

Photutils-based detection and photometry pipeline to create catalog.

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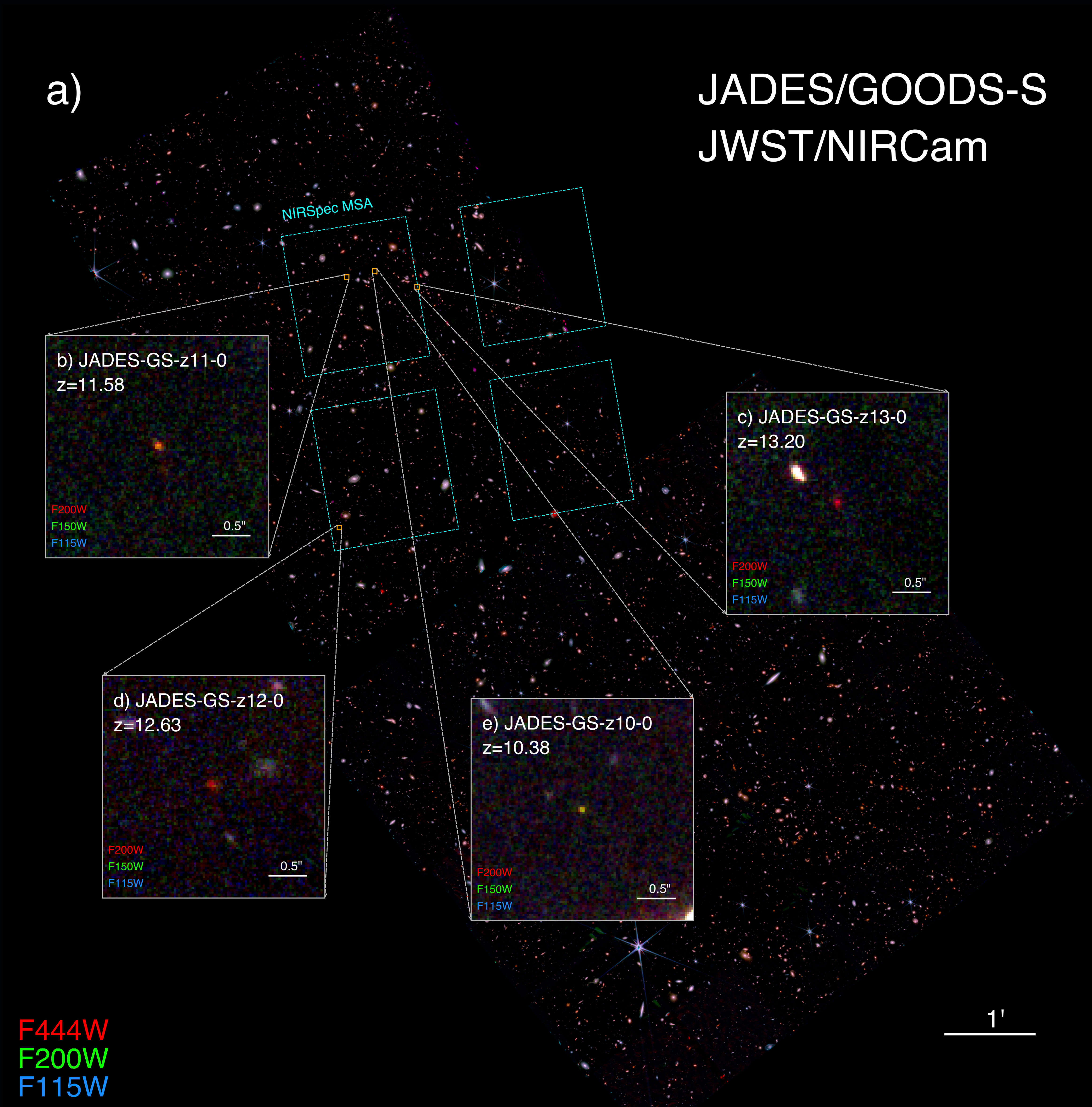
JWST ADVANCED DEEP EXTRAGALACTIC SURVEY (JADES)

DISCOVERY OF EARLIEST GALAXIES WITH CONFIRMED DISTANCES

Robertson et al., submitted



Four high-redshift candidates, confirmed spectroscopically; two were discovered in JADES/NIRCam imaging (Robertson et al., arXiv:2212.04480; Curtis-Lake et al., arXiv:2212.04568). F115W or F150W dropout selections (Hainline et al., ApJ, 892, 125, 2020).

The two lower redshift galaxies (JADES-GS-z10-0 and JADES-GS-z11-0) were discovered with HST as z~10 candidates by Bouwens et al. (2011).

Through UDF12, which had ultra deep Y105 and added J140, Ellis et al. (2013) found $z_{phot} \sim 11.9^{+0.3}_{-0.5}$ for JADES-GS-z11-0. JWST NIRCam UDF Medium Band observations (Program 1963; PI Williams, Maseda, Tacchella) suggest a similar photo-z (Bouwens et al., arXiv:2211.02607).

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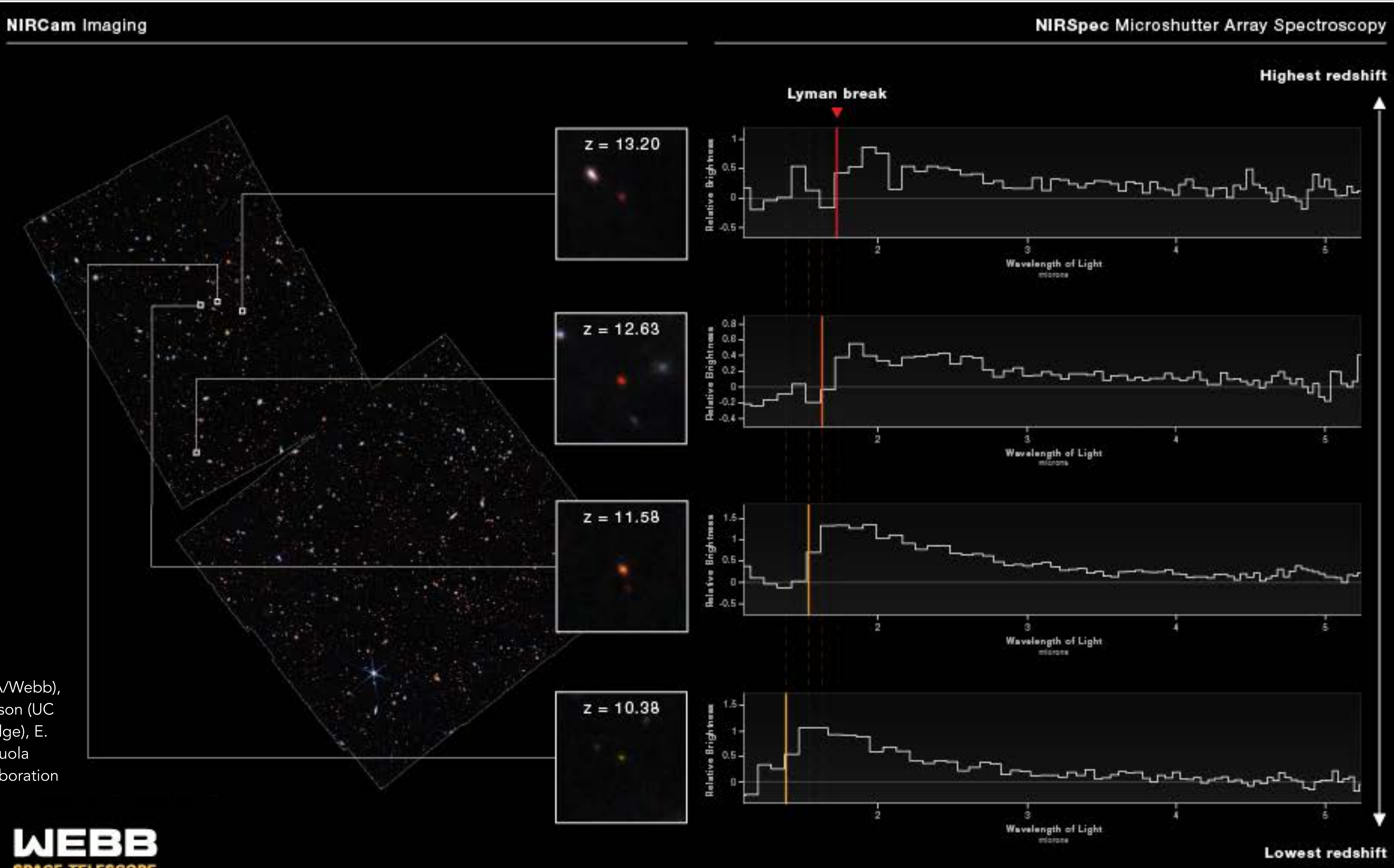
JWST ADVANCED DEEP EXTRAGALACTIC SURVEY (JADES)

WEBB SPECTRA REACH NEW MILESTONE IN REDSHIFT FRONTIER



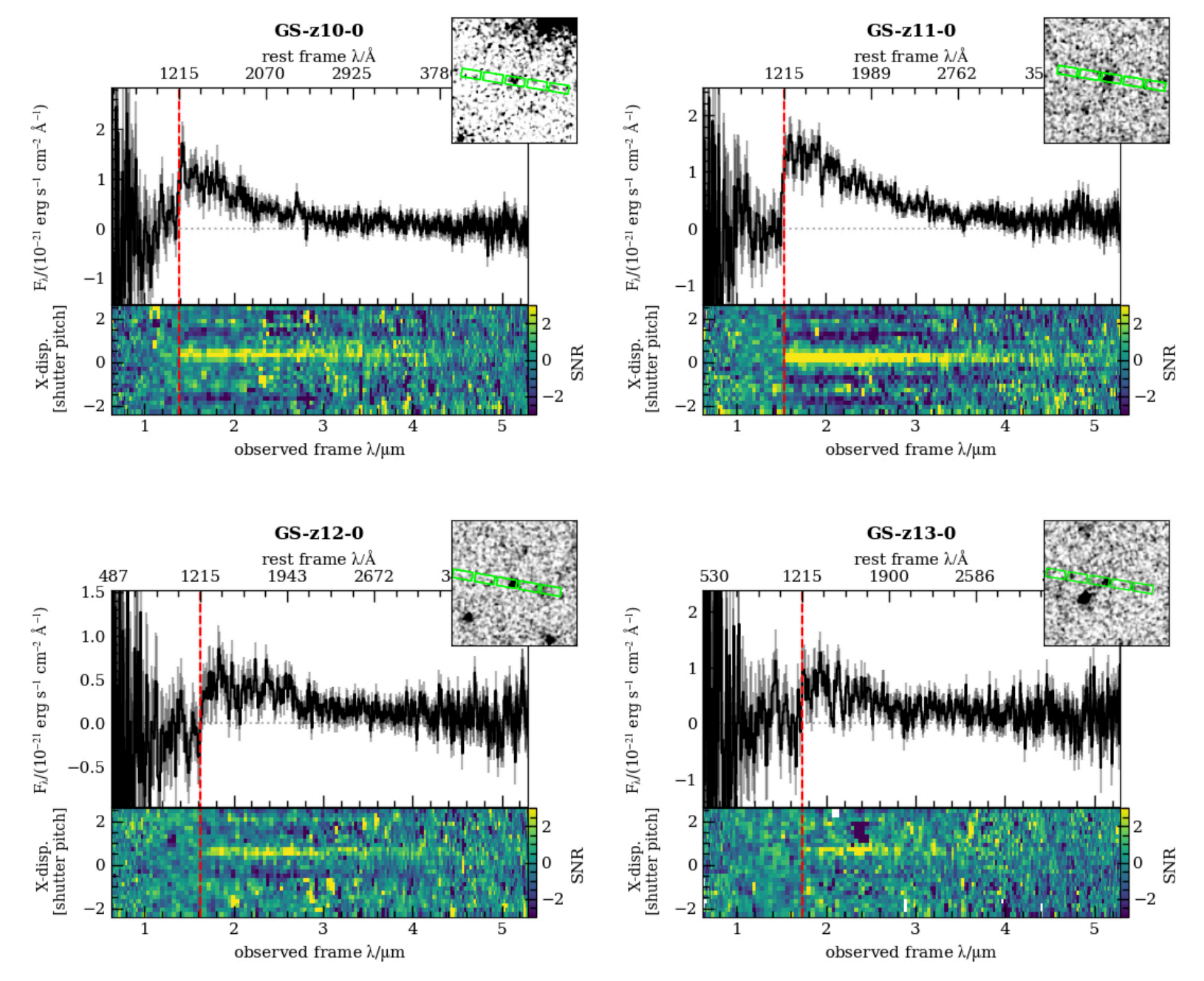
See Emma Curtis-Lake's paper arXiv:2212.04568 for the spectral analysis!

NASA, ESA, CSA, M. Zamani (ESA/Webb), Leah Hustak (STScI), Brant Robertson (UC Santa Cruz), S. Tacchella (Cambridge), E. Curtis-Lake (UOH), S. Carniani (Scuola Normale Superiore), JADES Collaboration

WEBB SPACE TELESCOPE

Brant Robertson (UCSC, brant@ucsc.edu)

WEBB SPECTRA REACH NEW MILESTONE IN REDSHIFT FRONTIER



See Emma Curtis-Lake's paper arXiv:2212.04568 for the spectral analysis!

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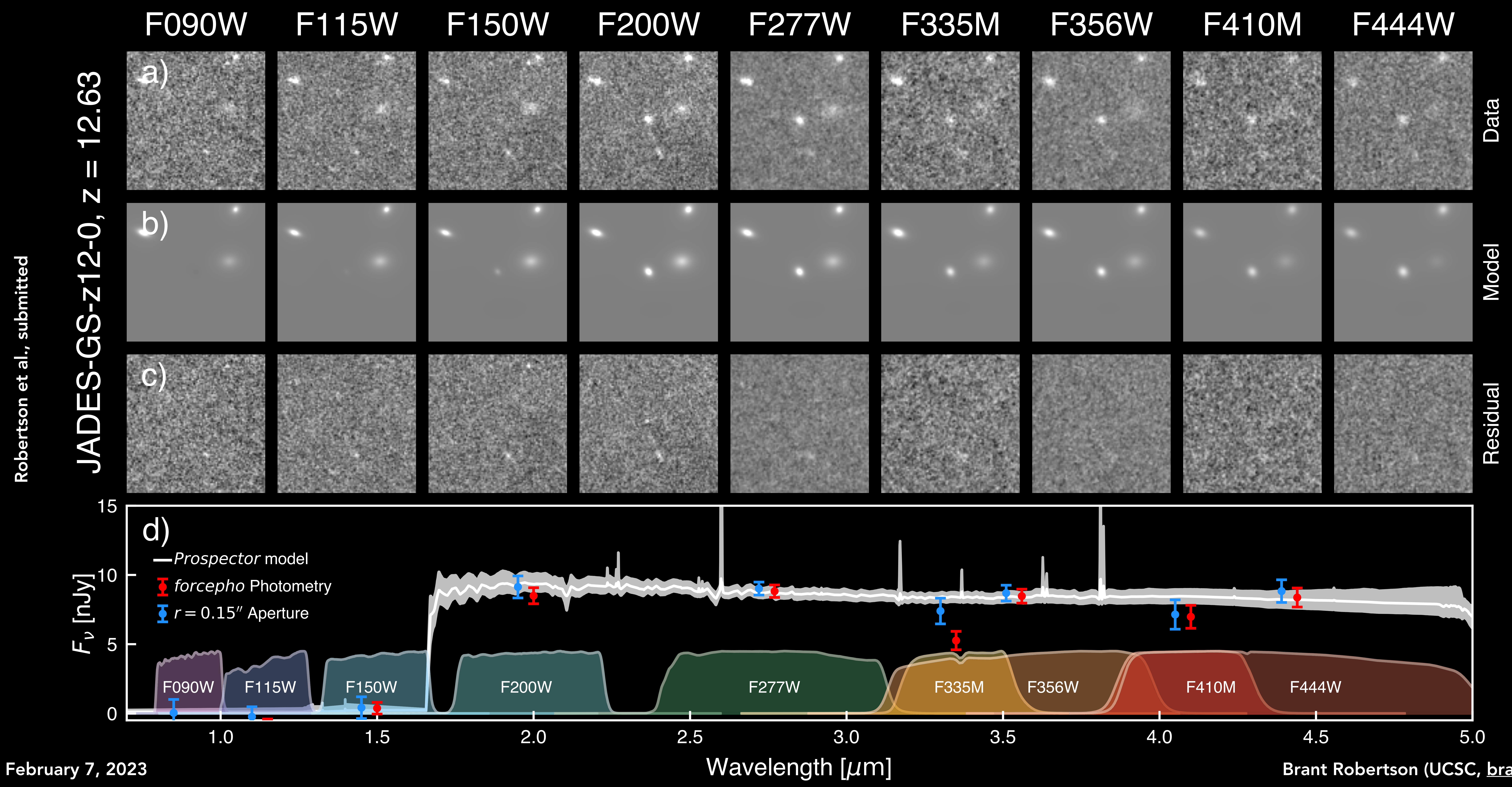
JWST ADVANCED DEEP EXTRAGALACTIC SURVEY (JADES)

PHOTOMETRIC FORWARD MODELING WITH forcepho



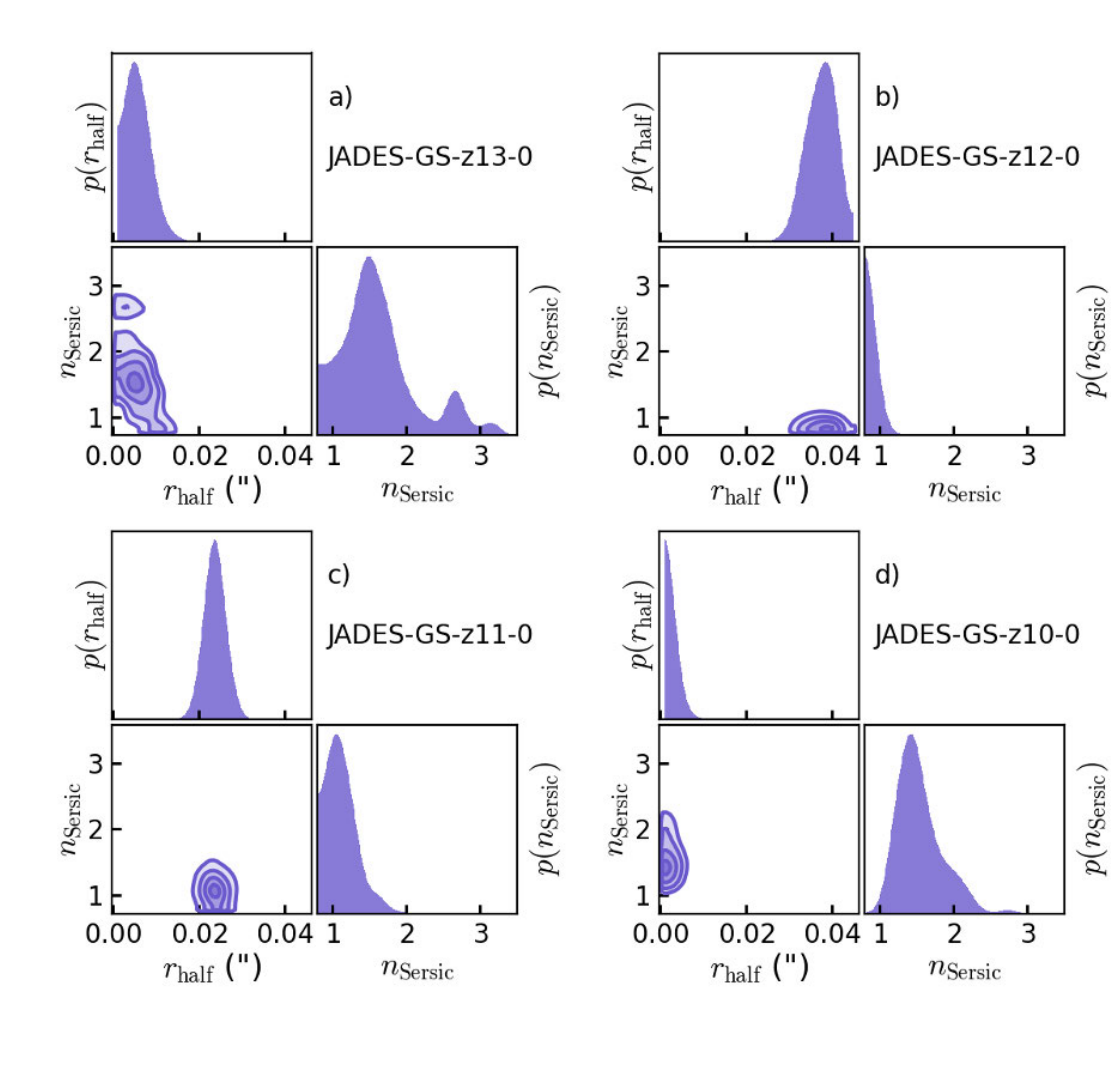
Brant Robertson (UCSC, brant@ucsc.edu)

STRUCTURAL CONSTRAINTS ON DISTANT GALAXIES

forcepho (B. D. Johnson et al., in prep.) allows us to forward model the surface brightness profile of each object, accounting for possible covariances with other neighboring sources.

These objects are small! JADES-GS-z10-0 and JADES-GS-z13-0 are unresolved. Other objects are 0.02-0.04” in half-light radius.

Sérsic indices are *n < 2.*

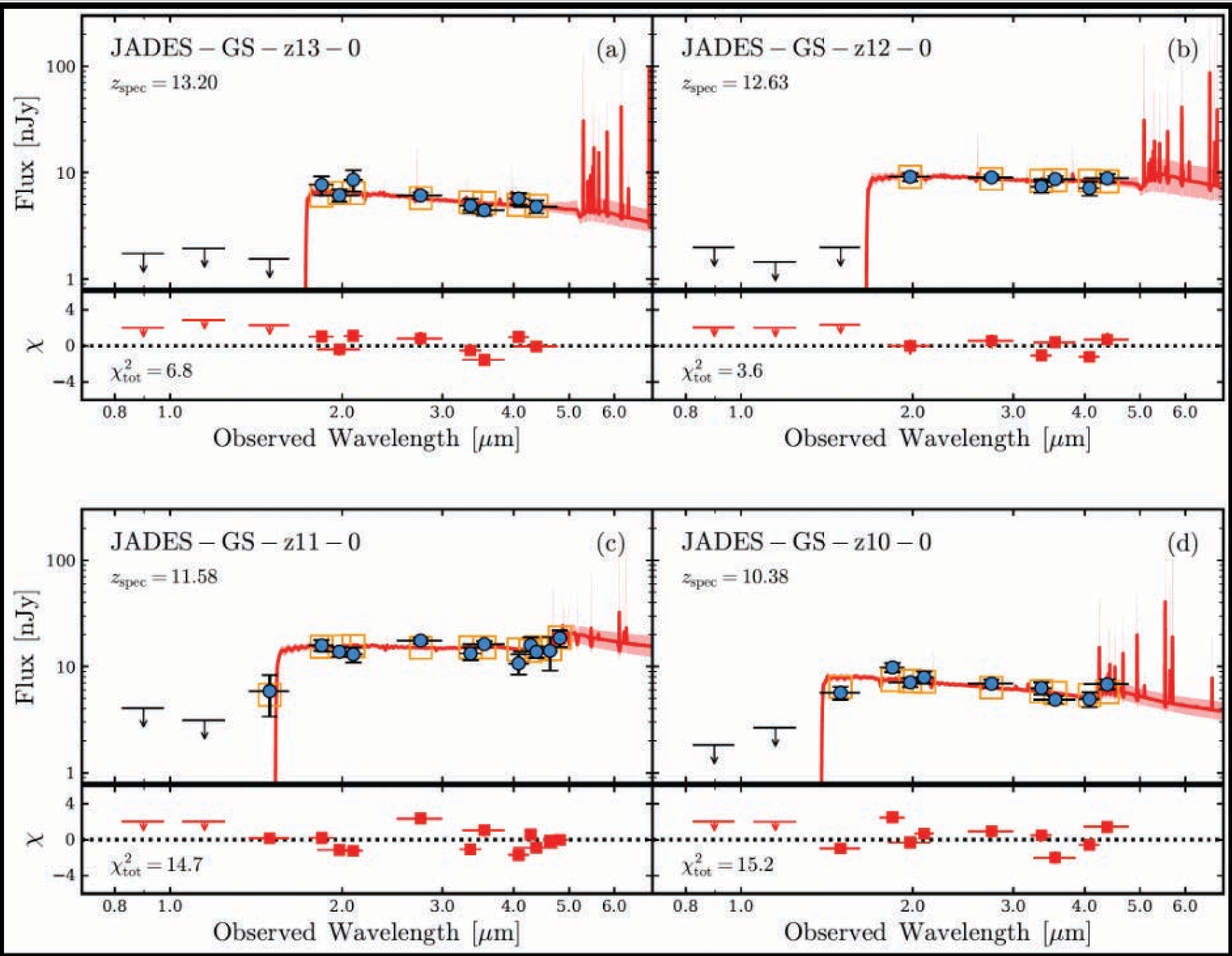


Robertson et al., submitted

Brant Robertson (UCSC, brant@ucsc.edu)

STELLAR POPULATION MODELS OF PHOTOMETRY

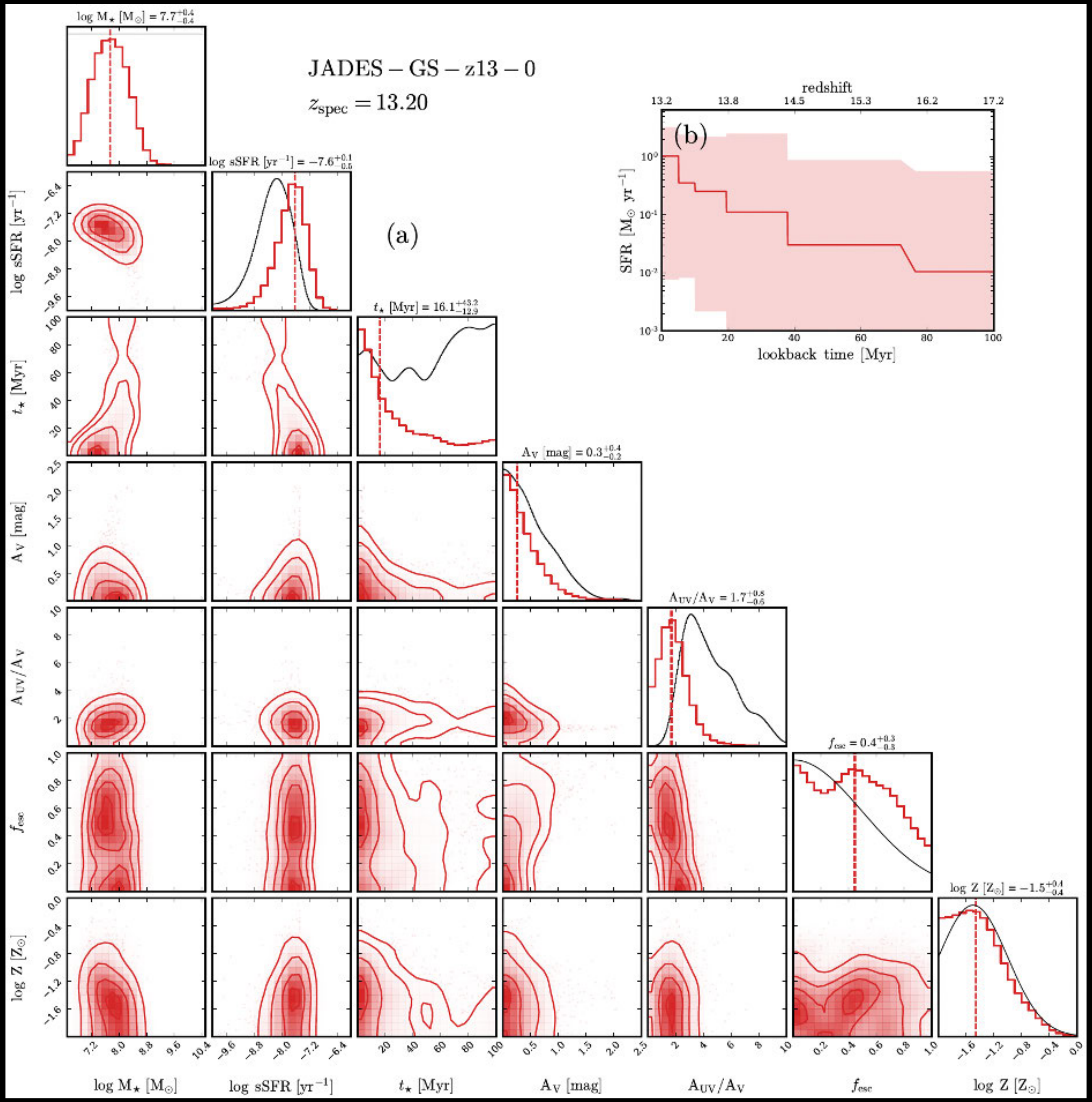
Using *Prospector* (B. D. Johnson et al. 2021) we can model the stellar populations by fitting to the photometry while keeping the redshift fixed at the measured spectroscopic value.

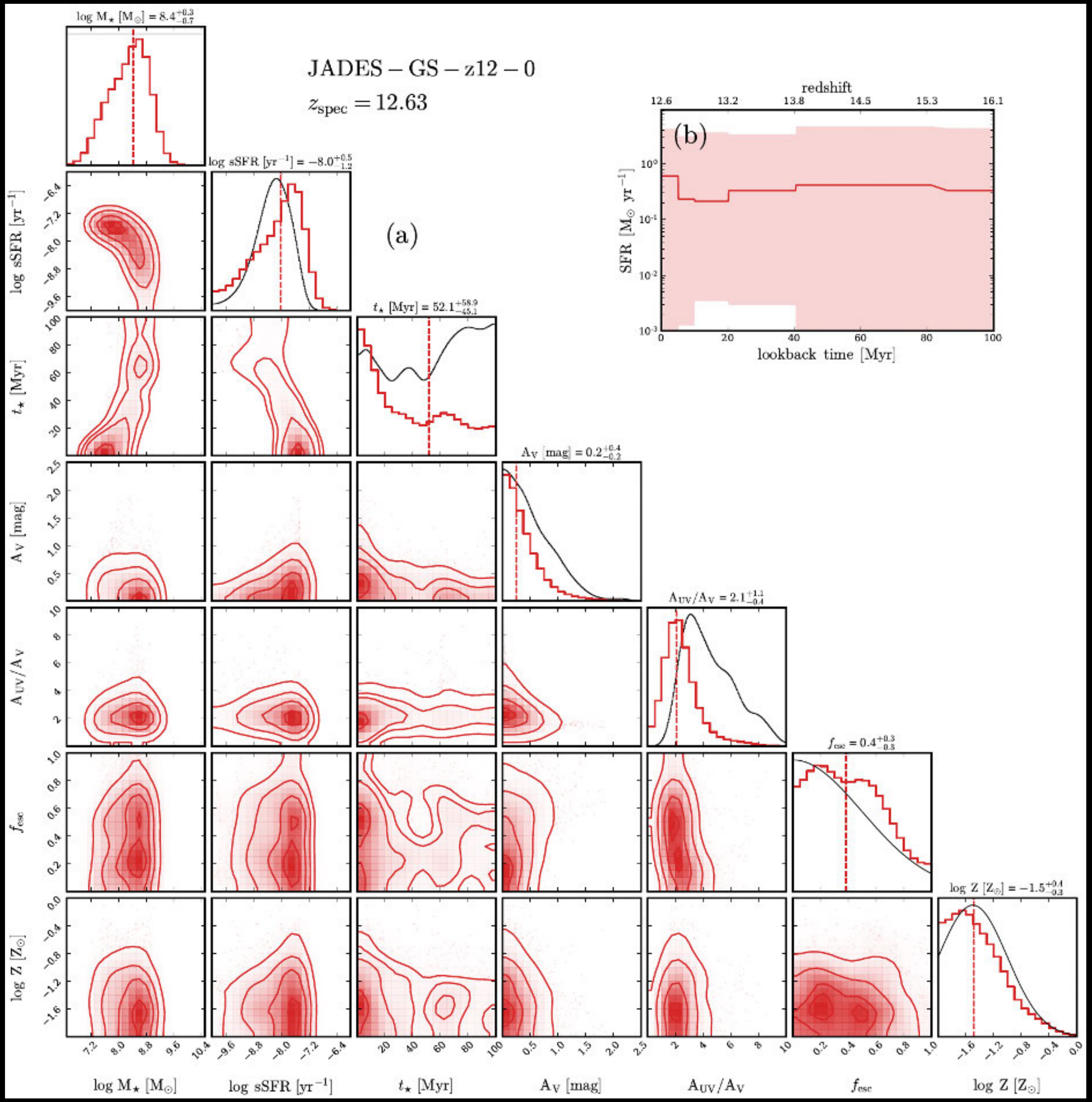


Robertson et al., submitted

JWST ADVANCED DEEP EXTRAGALACTIC SURVEY (JADES)

STELLAR POPULATION CONSTRAINTS AT z > 12.5





Robertson et al., submitted

JWST ADVANCED DEEP EXTRAGALACTIC SURVEY (JADES)

STELLAR POPULATION CONSTRAINTS AT 10.4 < z < 13.2

Marginal posterior distributions show that stellar masses are $M_\star \approx 10^8 - 10^9 M_\odot$, solar masses, $SFR \approx 1 M_\odot/\mathrm{yr}$, and half stellar mass ages of $t_\star \lesssim 100$ Myr.

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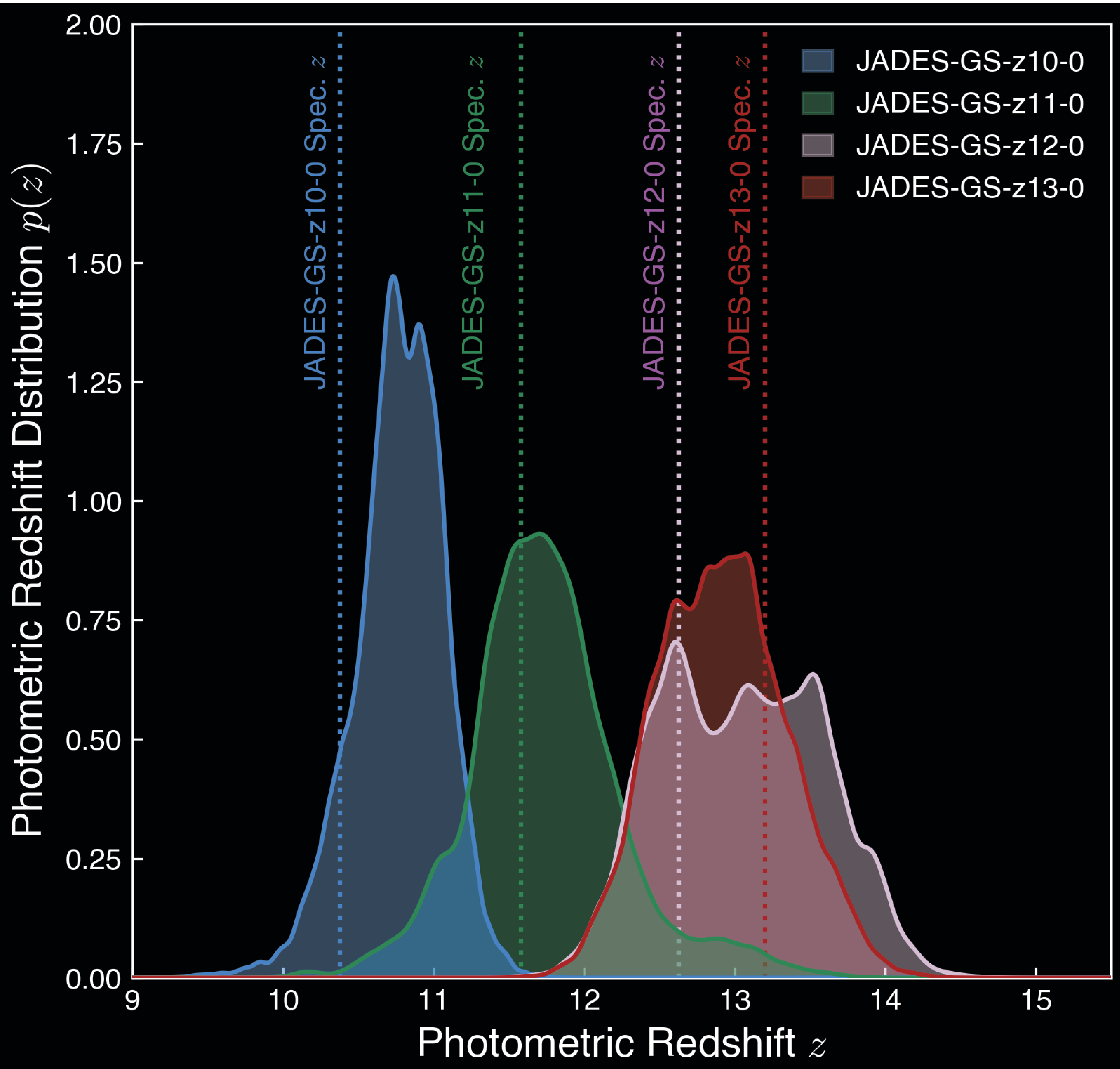
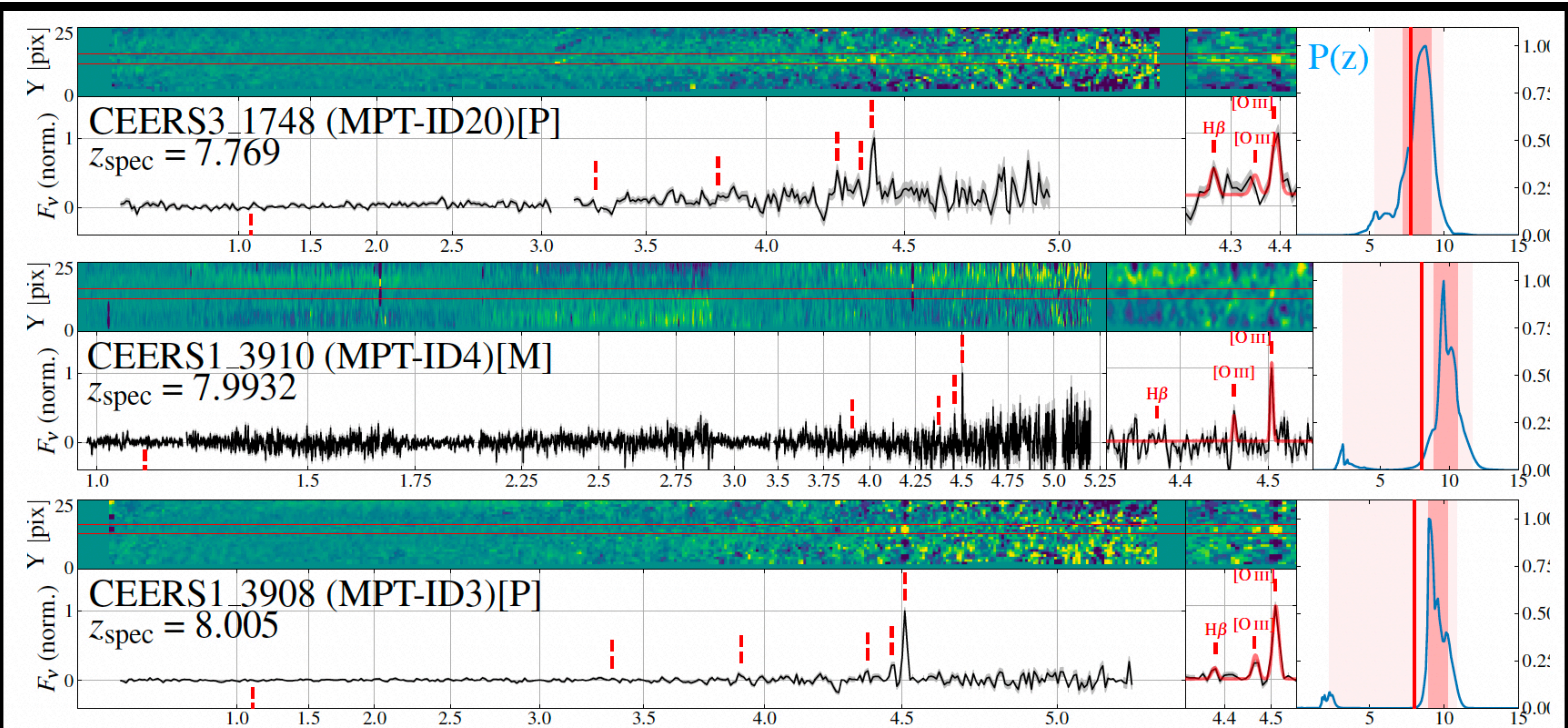
JWST ADVANCED DEEP EXTRAGALACTIC SURVEY (JADES)

PHOTOMETRIC REDSHIFT DISTRIBUTIONS



Robertson et al., submitted

PHOTOMETRIC REDSHIFT DISTRIBUTIONS FROM CEERS (FUJIMOTO ET AL. 2023)

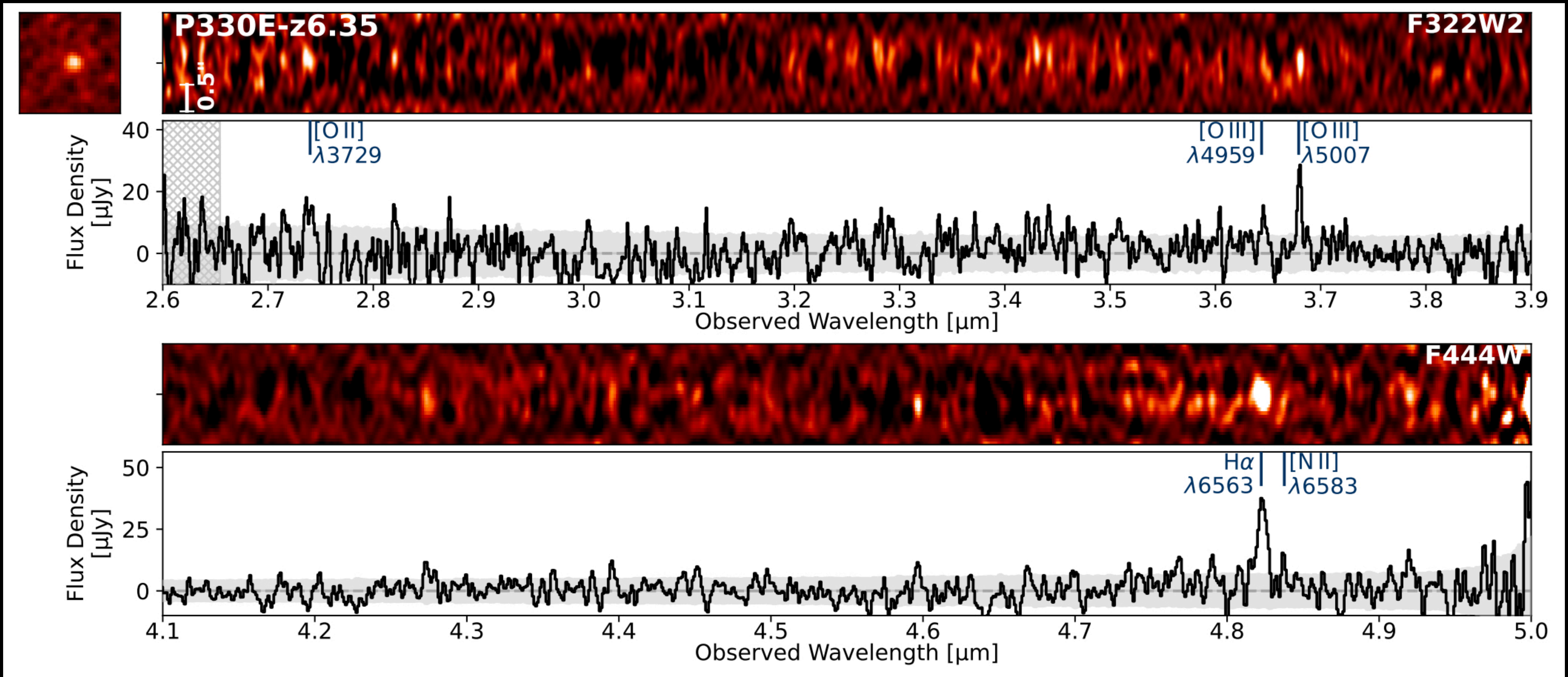


Fujimoto et al., arXiv:2301.09482

PHOTOMETRIC REDSHIFT DISTRIBUTIONS FROM CEERS (FUJIMOTO ET AL. 2023)

Fujimoto et al., arXiv:2301.09482

FIRST NIRCAM GRISM DETECTIONS z>6.35 (SUN ET AL., arXiv:2209.03374)



arXiv:2209.03374

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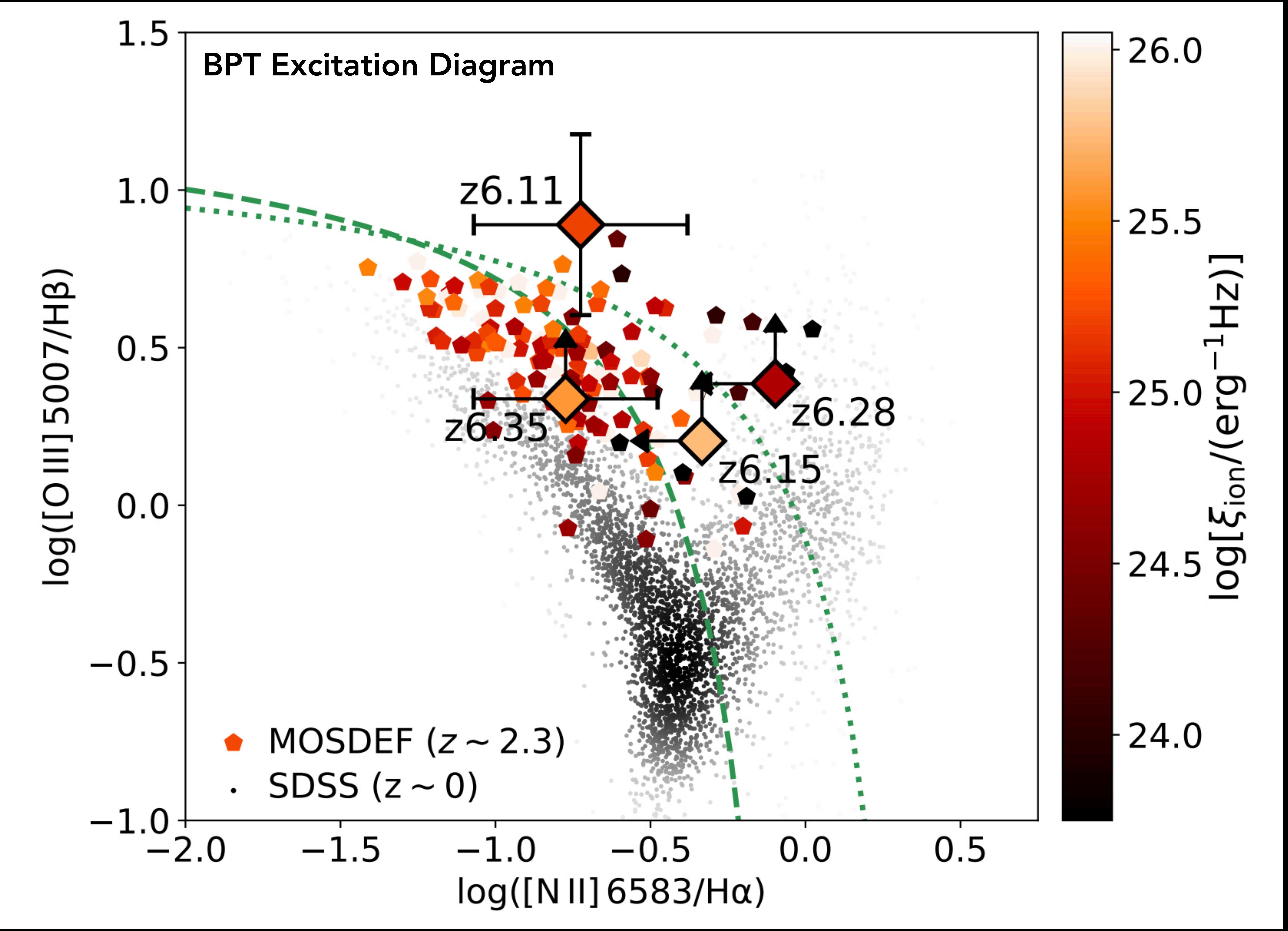
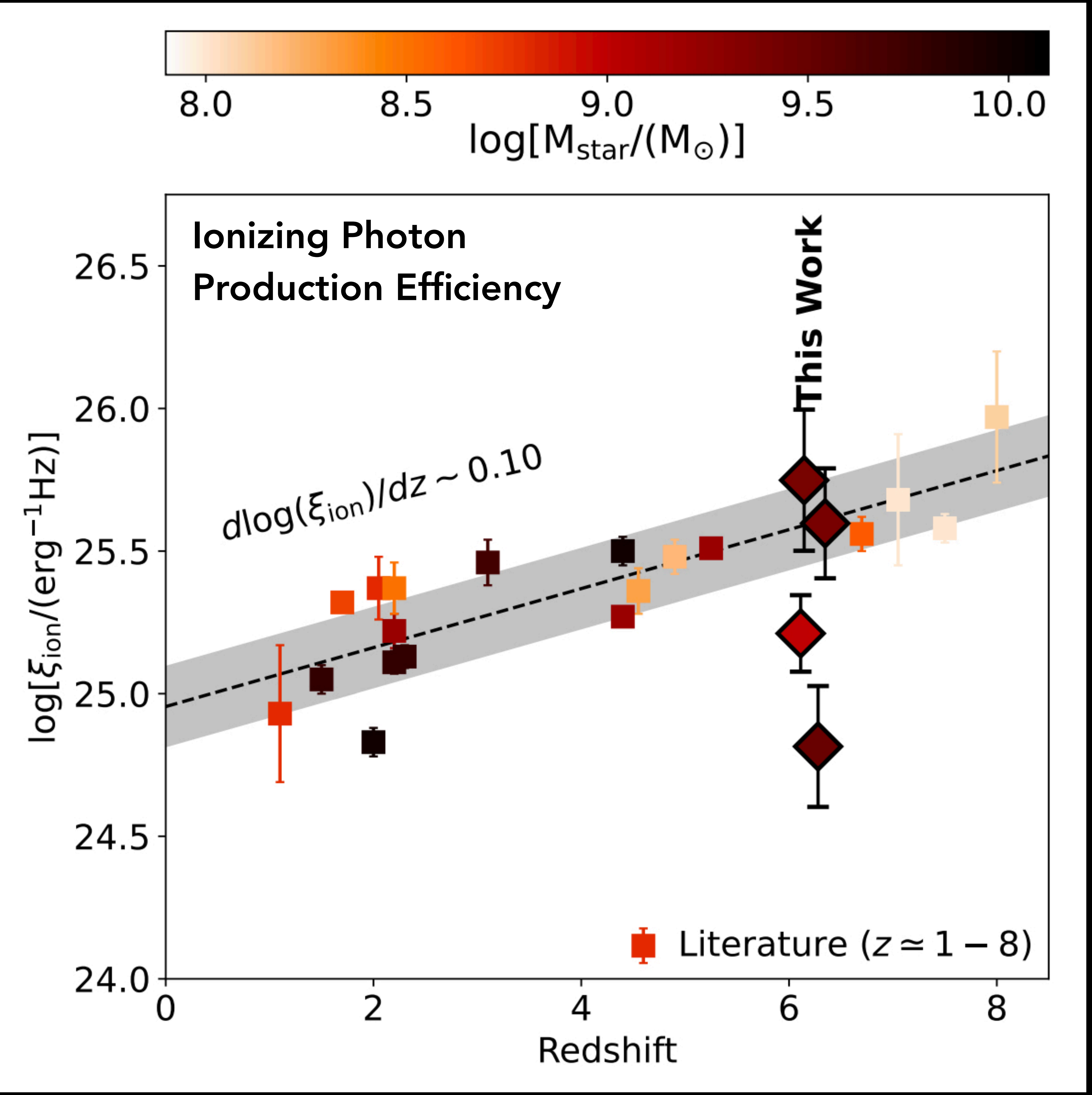
FIRST NIRCAM GRISM DETECTIONS z>6.35 (SUN ET AL., arXiv:2209.03374)





arXiv:2209.03374

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STELLAR POPULATIONS AT Z~8.5 (TACCHELLA ET AL., arXiv:2208.03281)

SMACS-0273

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STELLAR POPULATIONS AT Z~8.5 (TACCHELLA ET AL., arXiv:2208.03281)

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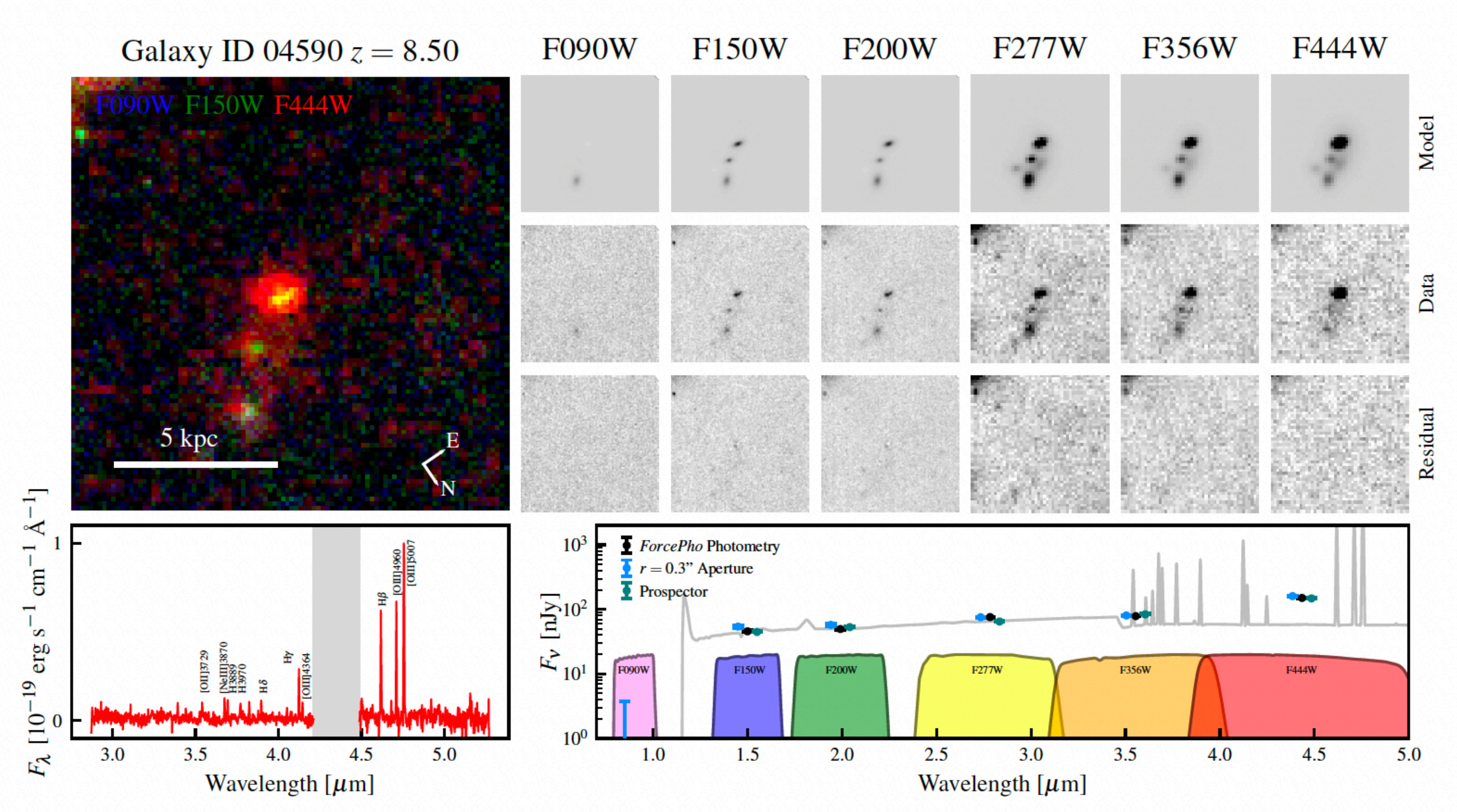

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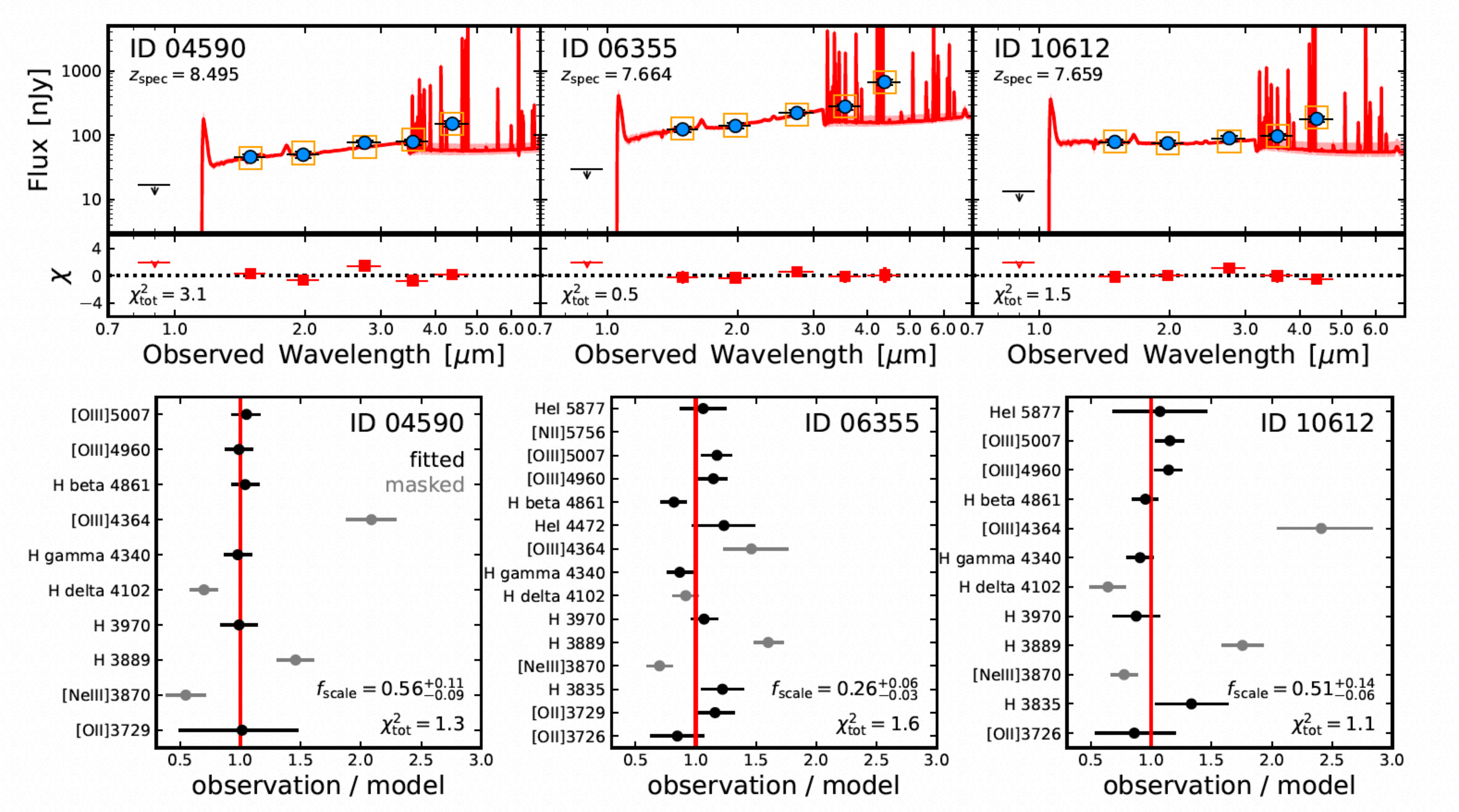
STELLAR POPULATIONS AT Z~8.5 (TACCHELLA ET AL., arXiv:2208.03281)



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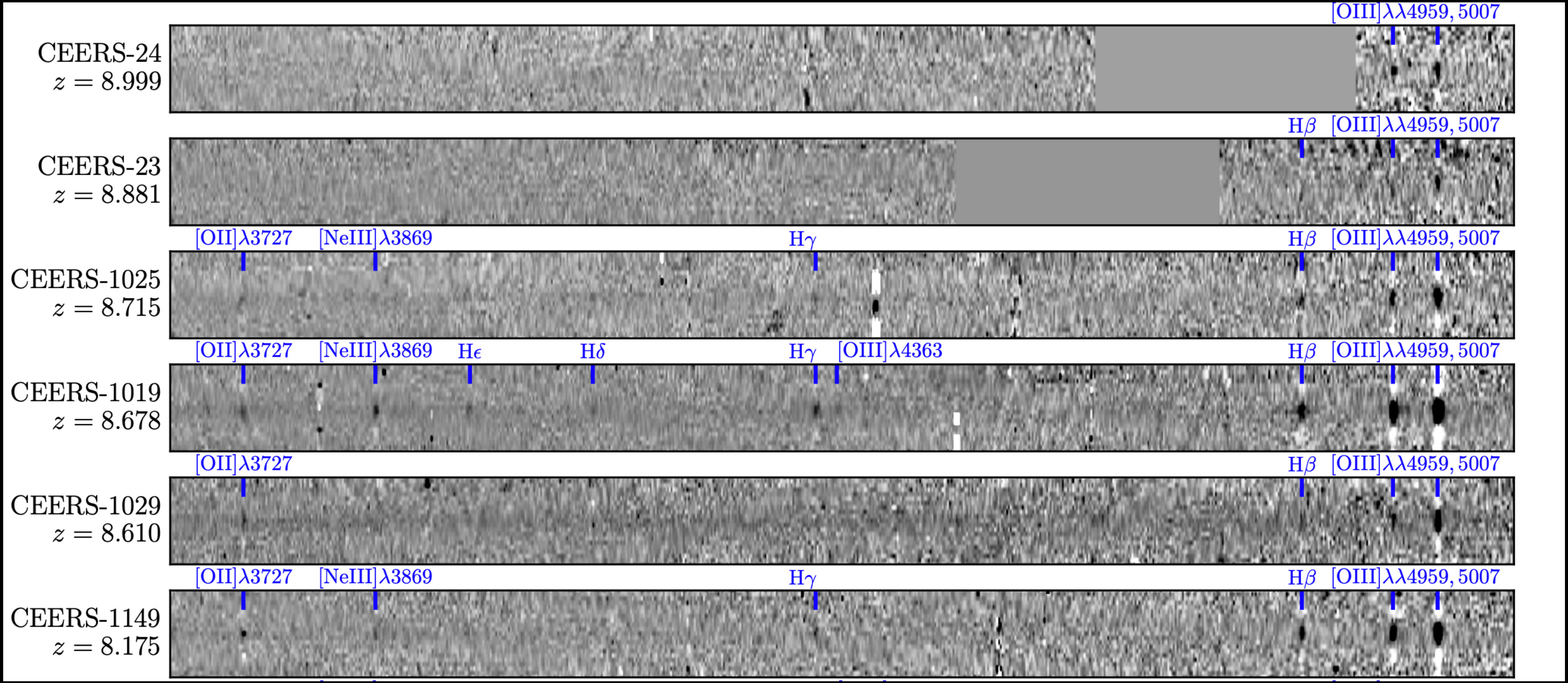
EMISSION SPECTRA AT Z~8 (TANG ET AL., arXiv:2301.07072)



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EMISSION SPECTRA AT Z~8 (TANG ET AL., arXiv:2301.07072)

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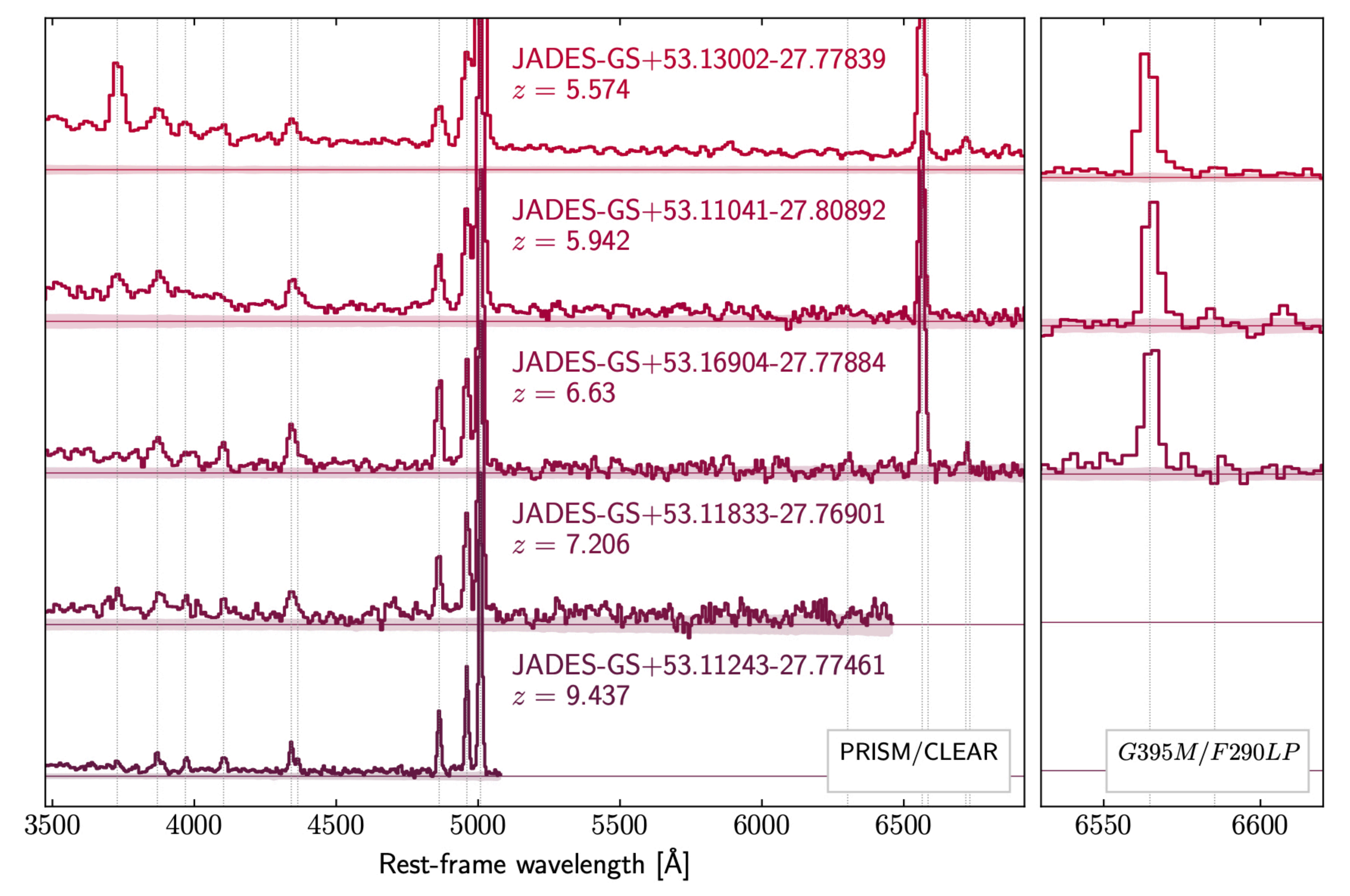
ISM PROPERTIES TO Z~9 (ALEX CAMERON ET AL, arXiv THIS WEEK)



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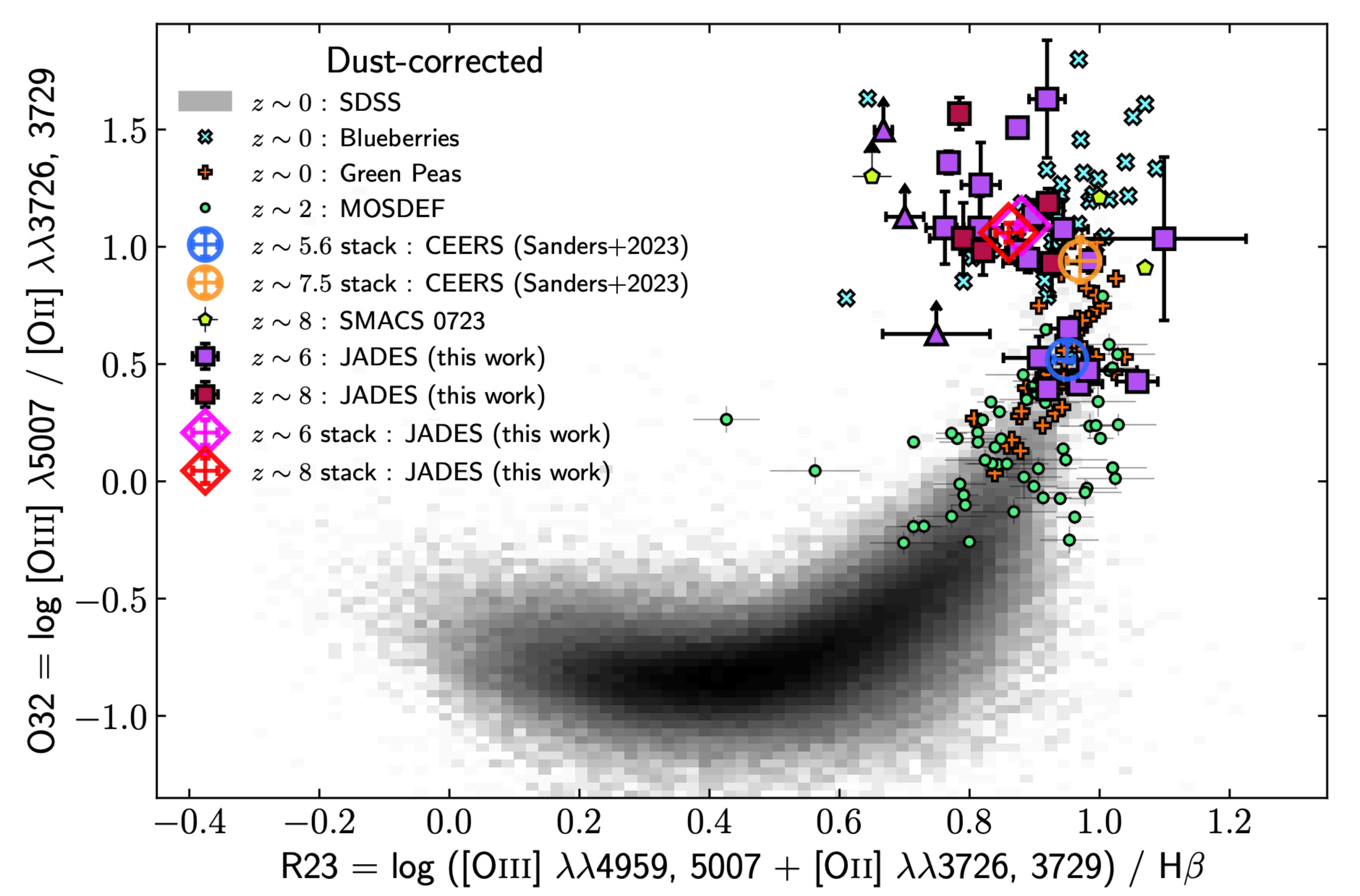
ISM PROPERTIES TO Z~9 (ALEX CAMERON ET AL, arXiv THIS WEEK)



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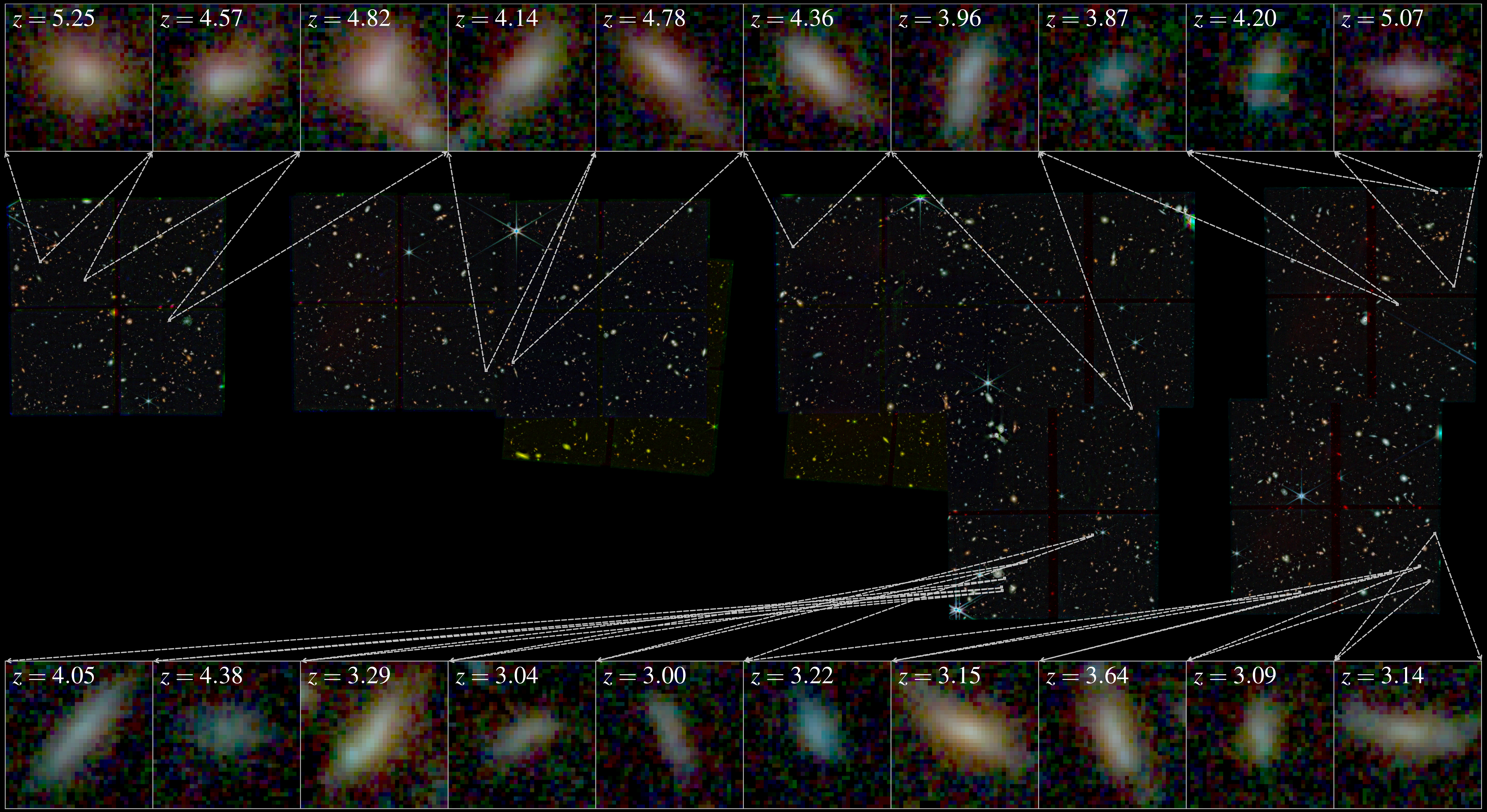
FIRST AI/ML ANALYSIS OF JWST IMAGES: DISKS IN THE EARLY UNIVERSE (z>2)



Robertson et al., ApJL, 942, 42 (2023)

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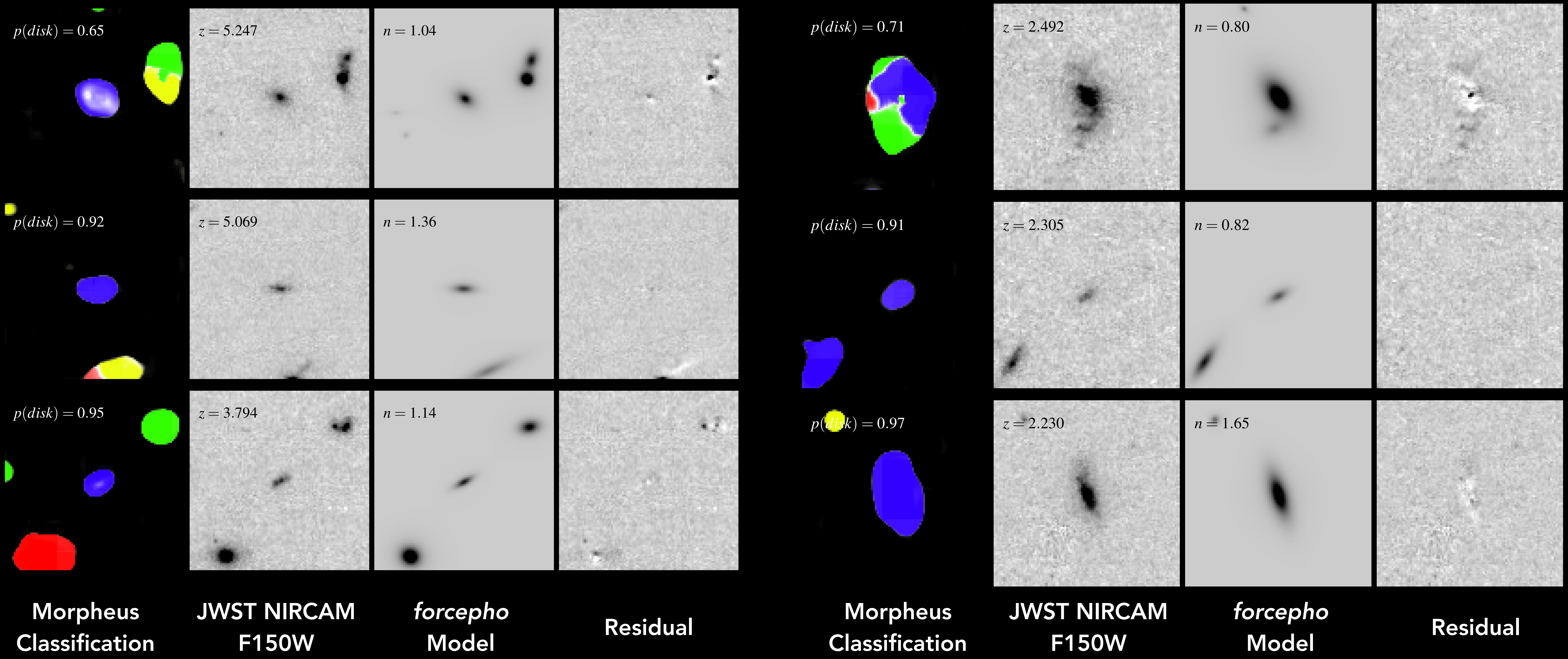
FIRST AI/ML ANALYSIS OF JWST IMAGES: DISKS IN THE EARLY UNIVERSE (z>2)

Robertson et al., ApJL, 942, 42 (2023)



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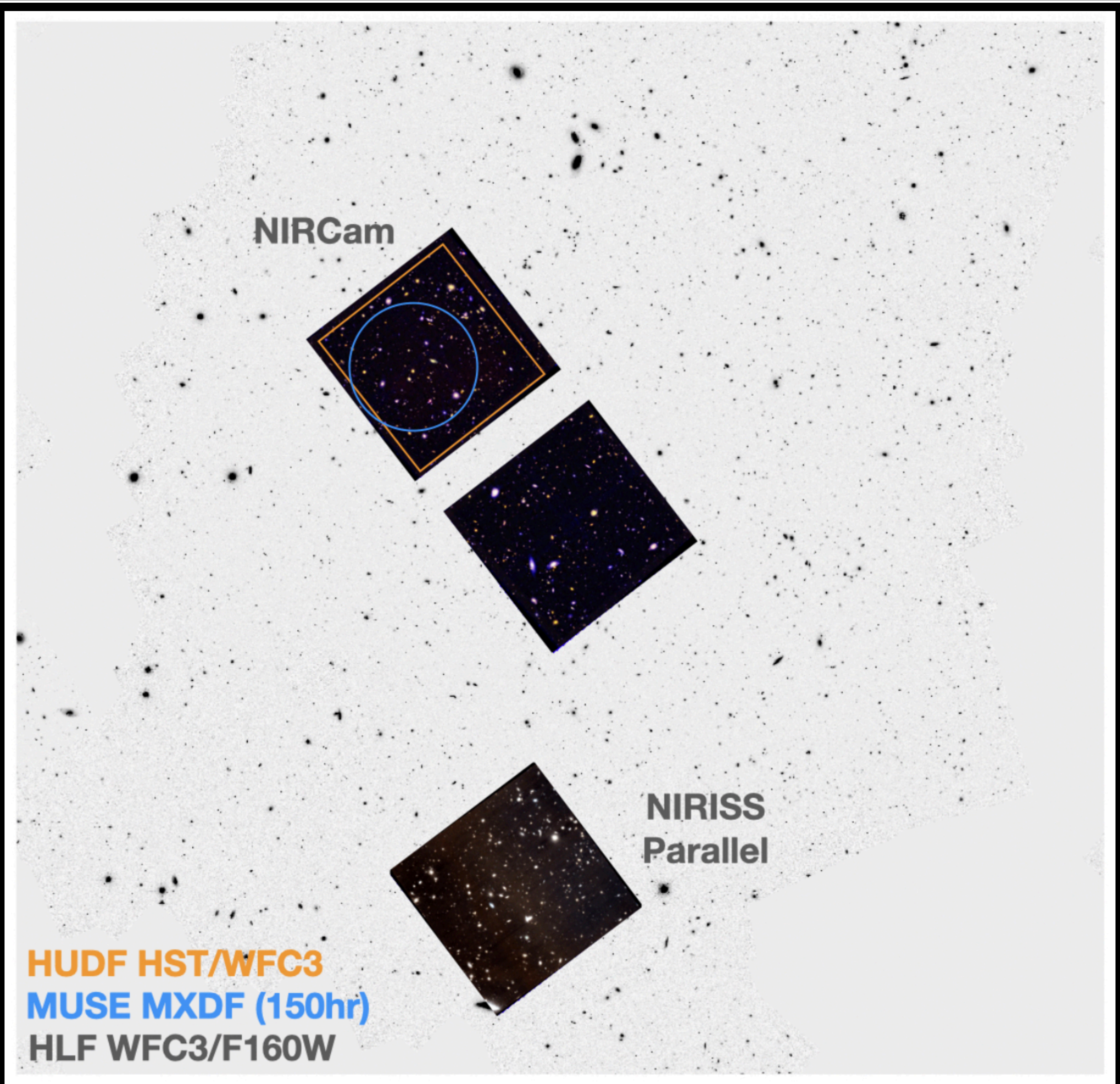
ULTRADEEP FIELD JWST/NIRCAM MEDIUM BAND SURVEY



Williams, Tacchella, Maseda, Robertson al., arXiv:2301.09780

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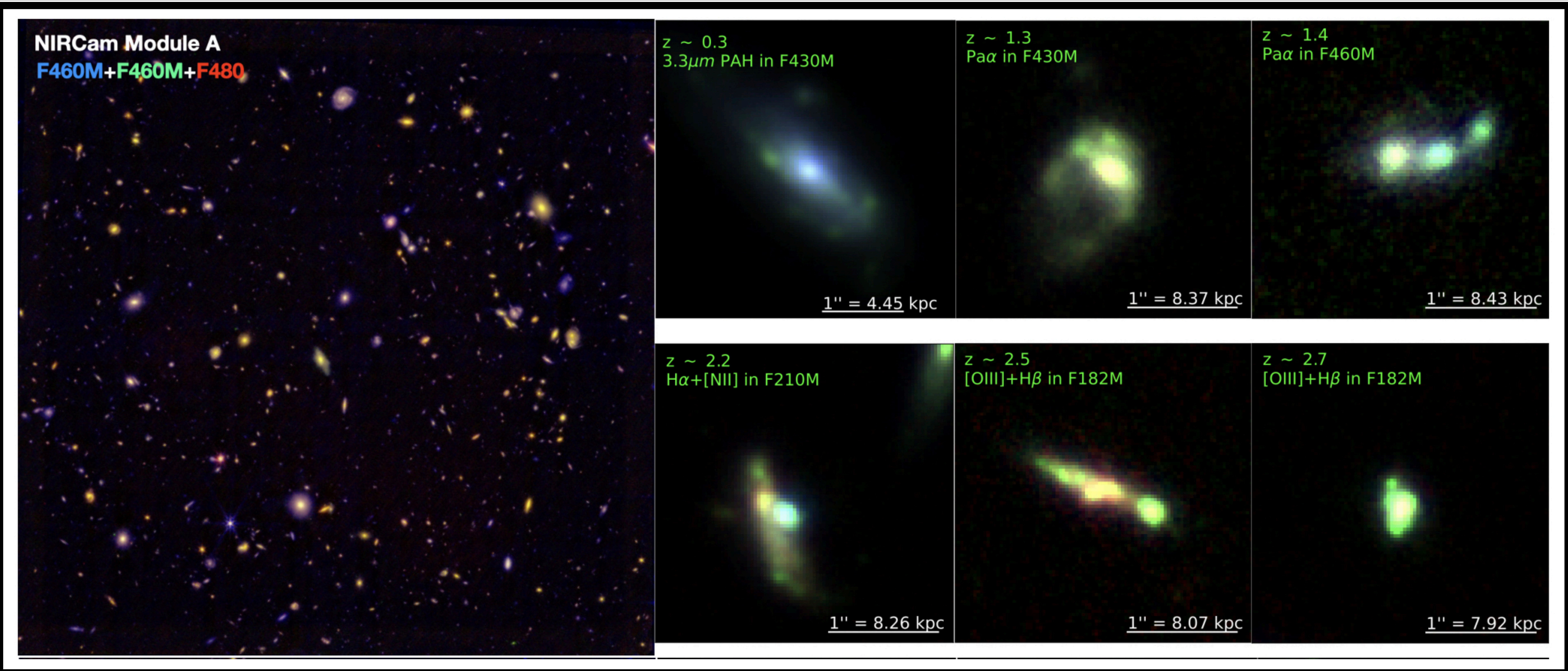
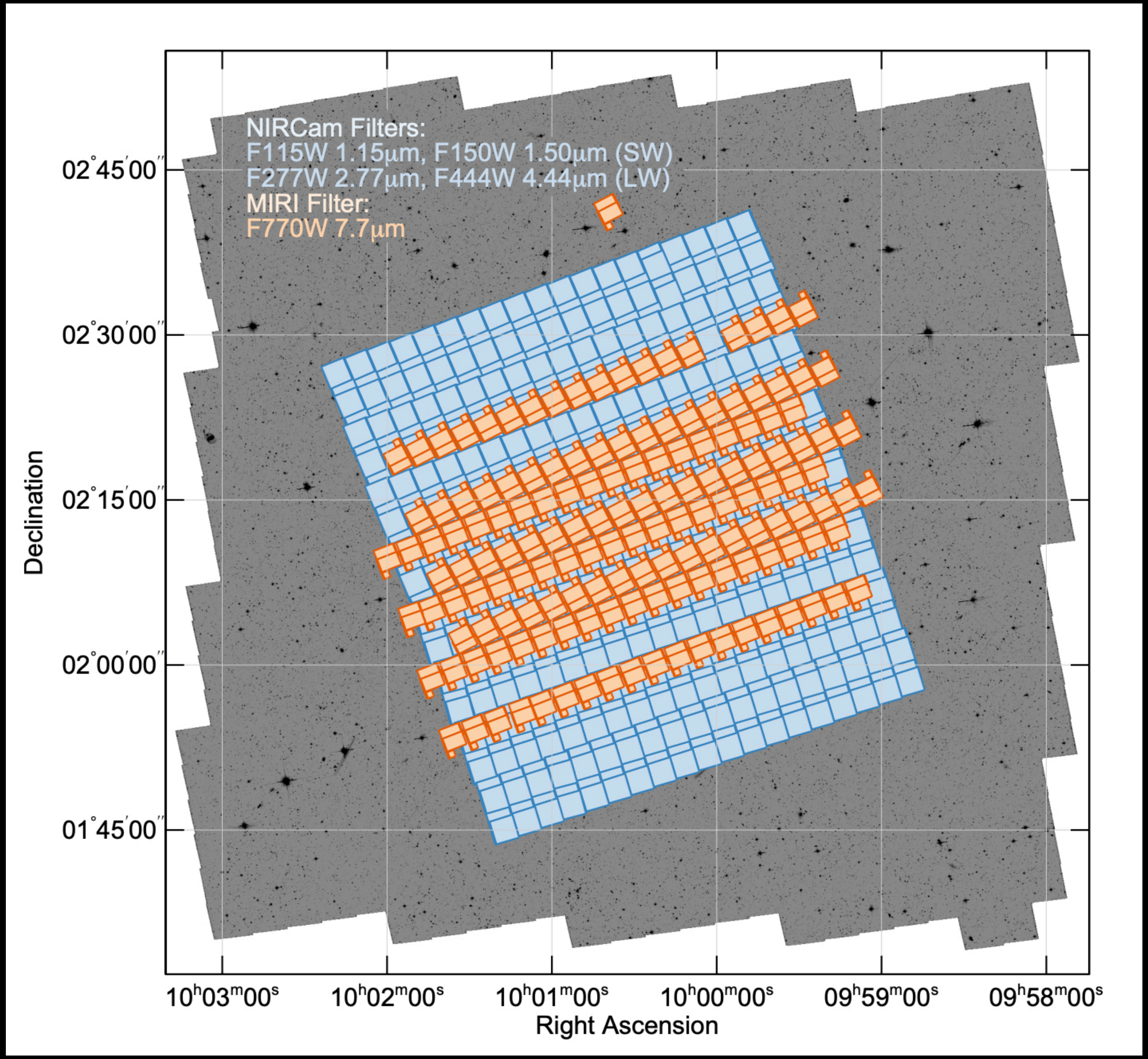
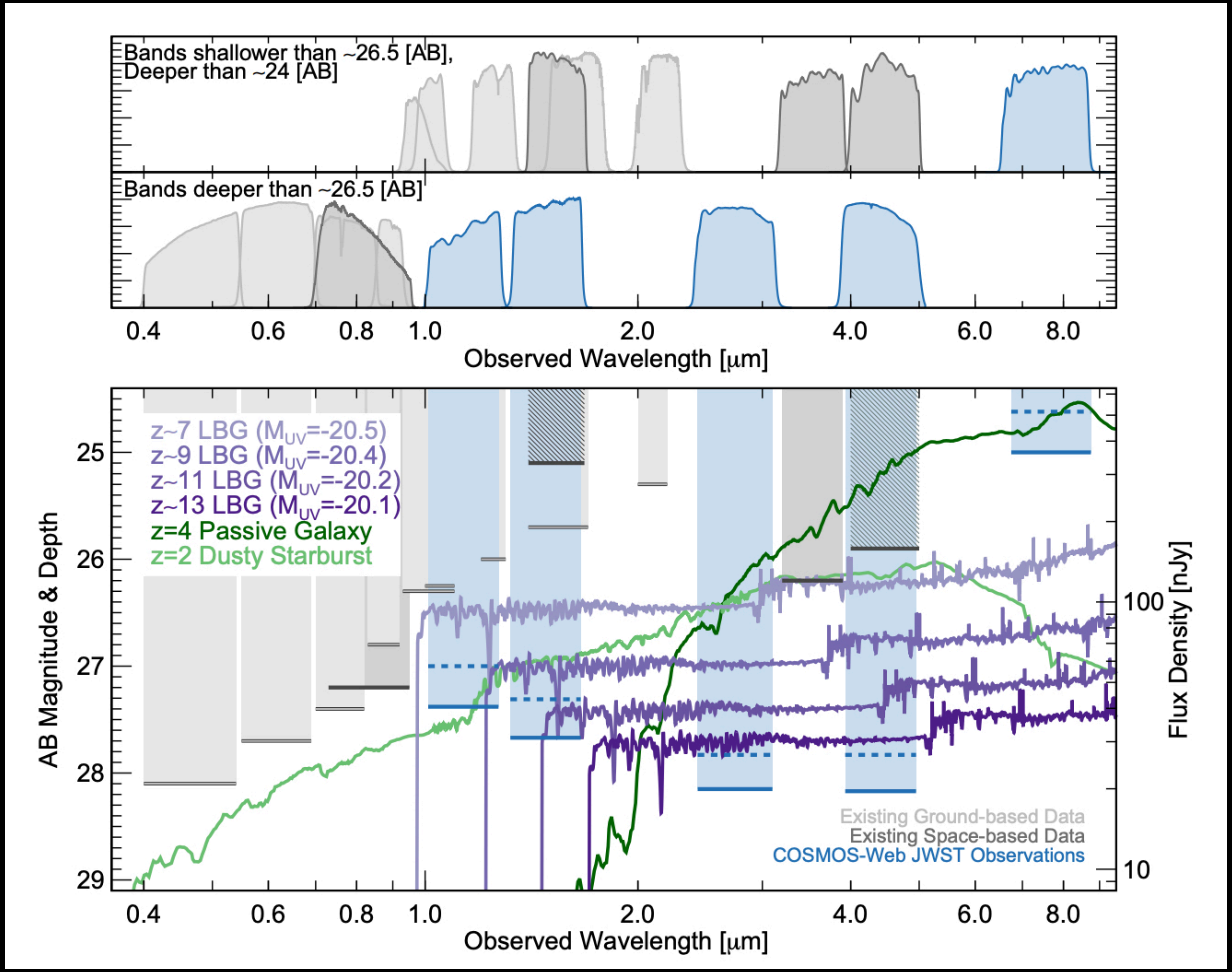
ULTRADEEP FIELD JWST/NIRCAM MEDIUM BAND SURVEY



Williams, Tacchella, Maseda, Robertson al., arXiv:2301.09780

COSMOS-WEB: LARGEST CYCLE 1 GO PROGRAM

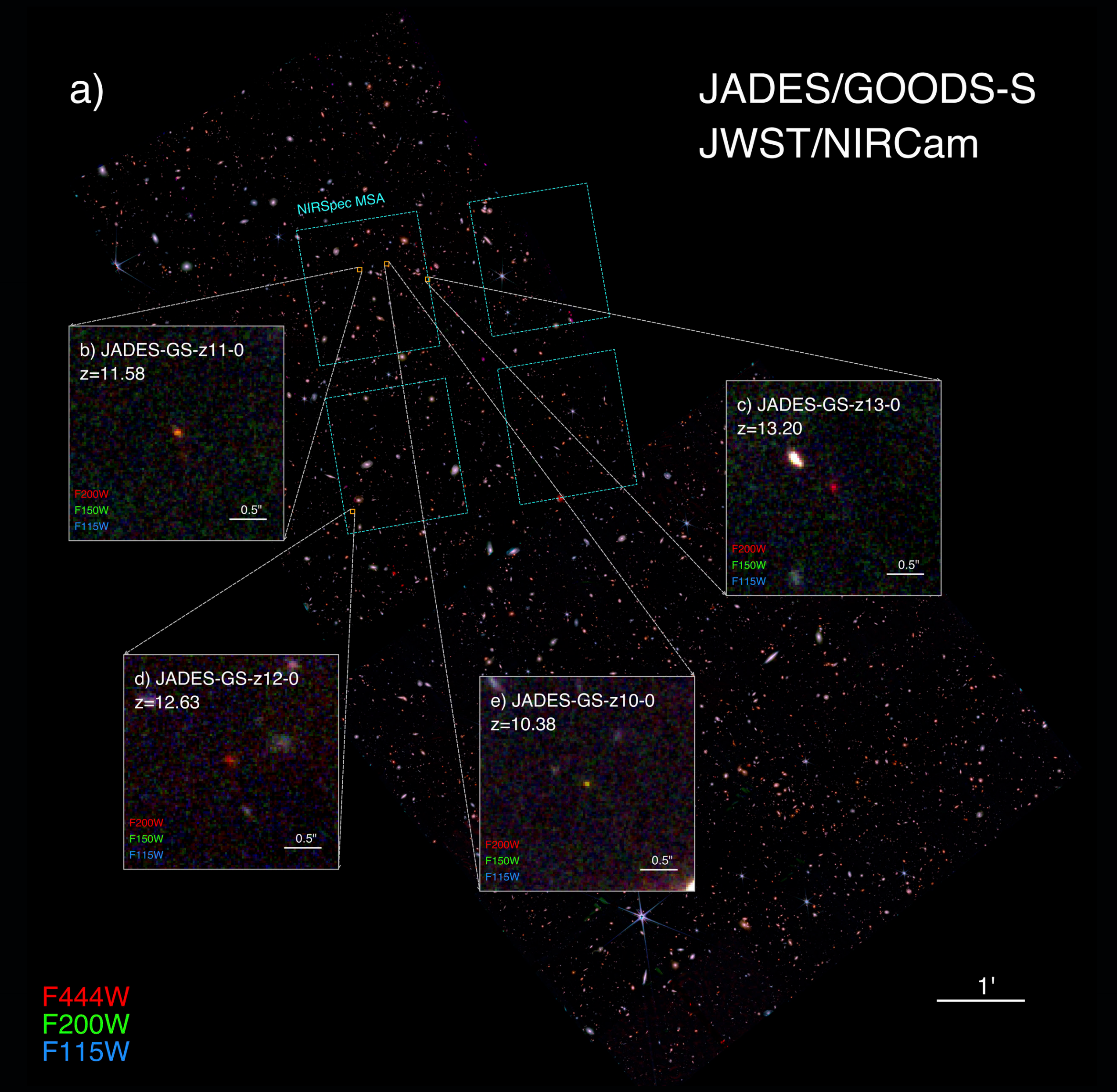




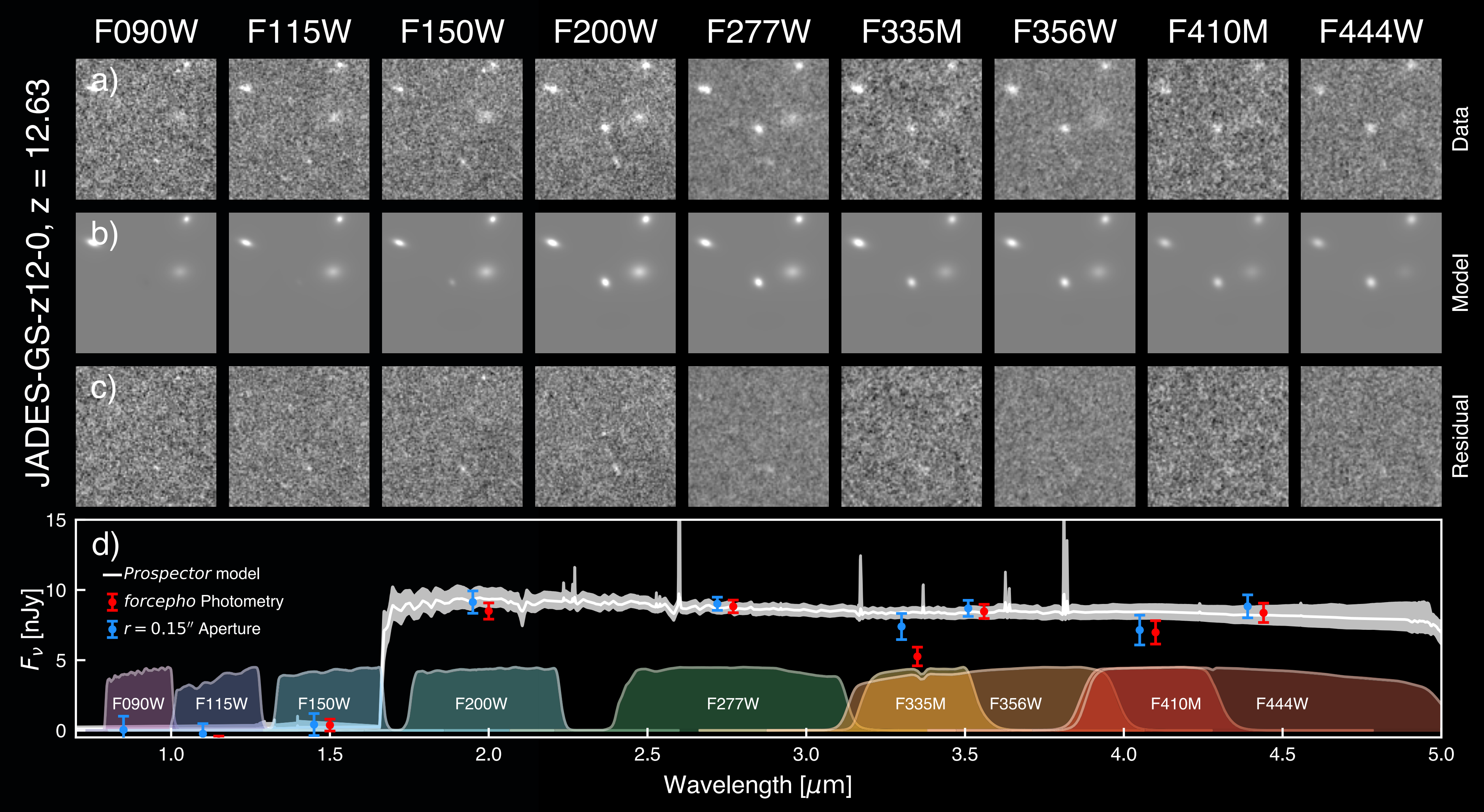
Casey, Kartaltepe+ BER et al., arXiv:2211.07865

SUMMARY: EARLIEST GALAXIES

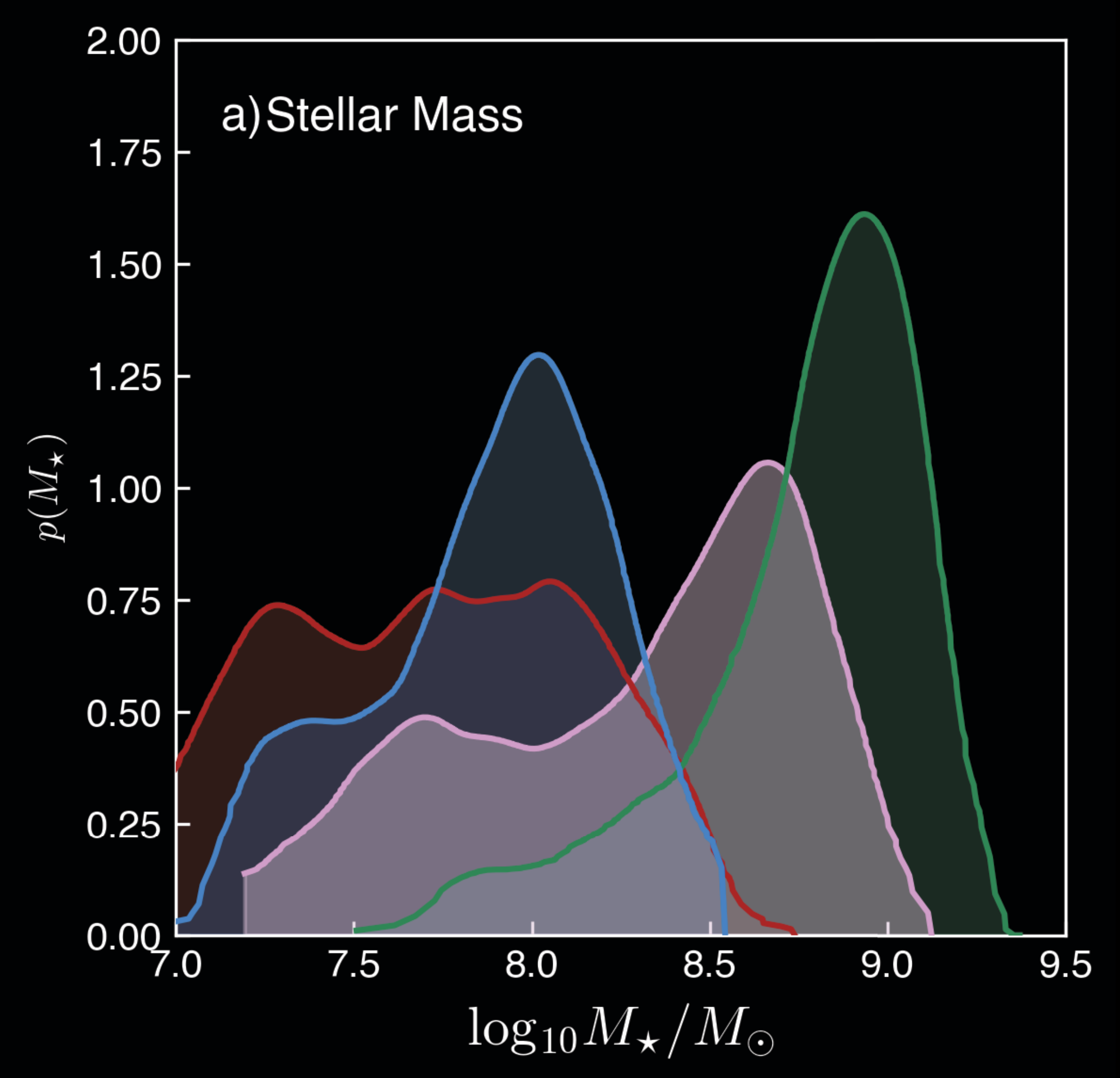
arXiv:2212.04480



We have discovered galaxies at z>12 with JWST and spectroscopically confirmed their distances.



Using forward modeling of the light profile, we can simultaneously infer photometry and constrain the structures at these fantastically distant galaxies.



The galaxies' properties are not extreme, with between 100 million and a billion solar masses of stars formed over <~100 million year times.

Thanks!

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