A Comprehensive Study on Galaxies at z~9-17 Found in the Early JWST Data

Harikane et al. 2022c (arXiv:2208.01612, submitted to ApJS)

See also
Harikane et al. 2022a, ApJS, 259, 20, 37pp
Harikane et al. 2022b, ApJ 929, 1, 15pp

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Systematic Exploration in the Reionization Epoch using Nebular And Dust Emission (SERENADE, 2022.1.00055S)

- 47.2-hour program targeting 20 z~6 galaxies with [OIII]88um and [CII]158um (and dust) in cycle 9
- Statistical properties of FIR line and dust emission

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SERENADE: Systematic Exploration at Reionization Epoch using Nebula And Dust Emission **2022.1.00055.S**

ABSTRACT

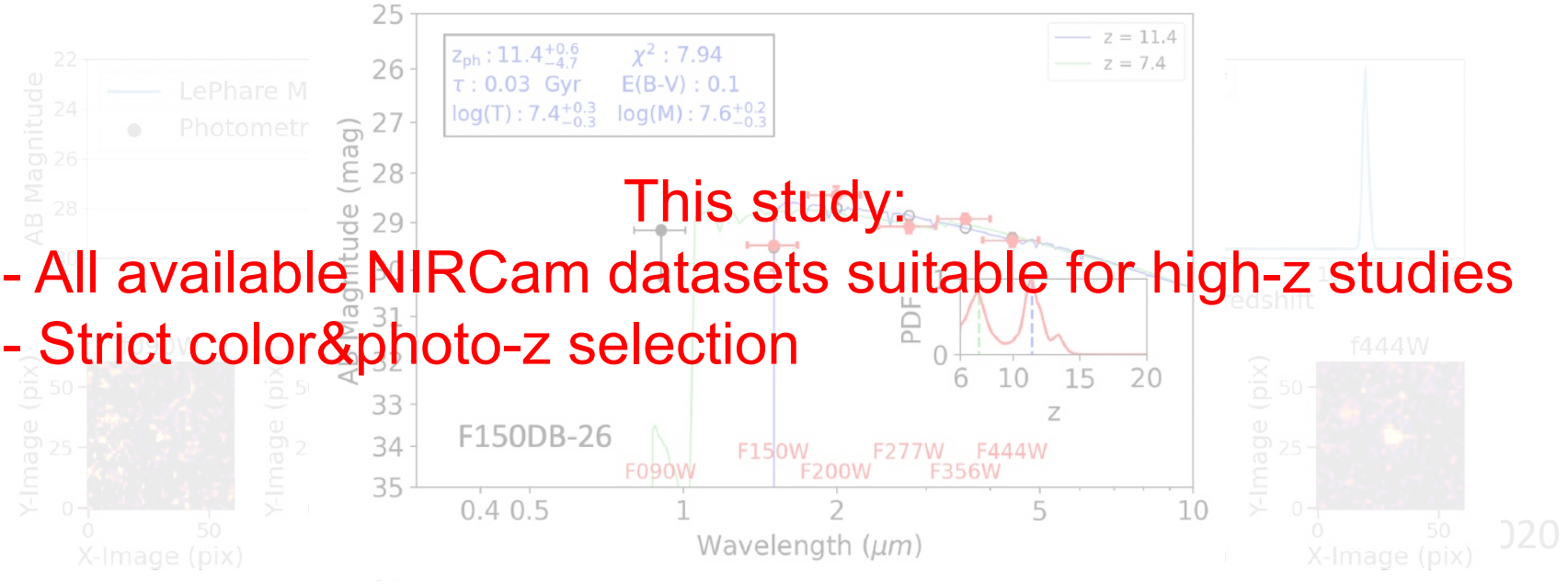
ALMA has played a distinct role in z>~6 galaxy studies through its unique probe of FIR diagnostic emission lines such as [OIII]88um and [CII]158um, as well as dust continuum. The line ratio of [OIII]/[CII] is particularly informative because it reflects physical conditions of the ISM due to their different ionization potentials. Previous studies report redshift evolution of the [OIII]/[CII] ratio from z~0 to z>6 and its tentative correlations with galaxy properties, but these results are based on only less than 10 galaxies.

Here we propose to conduct the first systematic program observing [OIII] and [CII] lines of 20 spectroscopically-confirmed galaxies at z~6, where Lya is visible and easily accessible from ground-based optical instruments, and both [OIII] and [CII] can be observed with ALMA. We will
1) measure [OIII]/[CII] ratios and its correlations with various galaxy properties (e.g., SFR, bolometric luminosity, Lya equivalent width) to study ISM physics and the escape of ionizing photons at the epoch of reionization, and
2) estimate dust temperatures using multi-band continuum observations to understand nature of some high redshift galaxies with very high dust temperatures.

- Another program (34.5h) studying [OIII]52um in z=6-7 galaxies w/ [OIII]88um and JWST obs (2022.1.00012.S, PI: Y. Harikane)

Recent JWST Studies

- Previous studies find many candidates at z>9 (e.g., Naidu+22, Castellano+22, Adams+22, Yan+22, Atek+22, Donnan+22, Finkelstein+22)
  - Contamination of low-z galaxies?
  - Not using all available fields/selection



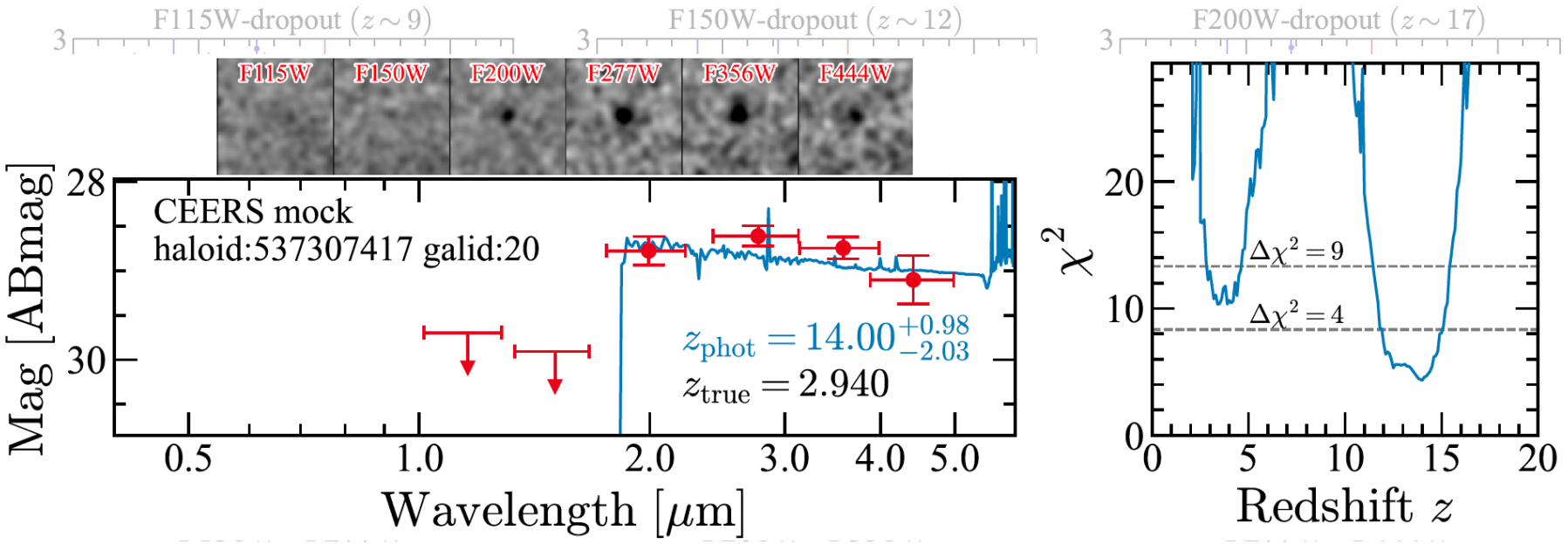
JWST Datasets

- All available NIRCam data suitable for high-z gals
  - A total of 90 arcmin^2

	Area	5σ Limiting Magnitude							
Field	(arcmin^2)	$F090W$	$F115W$	$F150W$	$F200W$	$F277W$	$F356W$	$F410M$	$F444W$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SMACS J0723	11.0	29.4	···	29.6	29.8	30.1	30.0	···	29.6
GLASS	6.8	29.5	29.6	29.4	29.5	29.7	29.8	···	29.6
CEERS1	8.4	···	29.1	29.1	29.4	29.6	29.6	28.9	29.0
CEERS2	8.5	···	29.3	29.1	29.7	29.5	29.6	28.9	29.3
CEERS3	8.1	···	29.5	29.3	29.4	29.6	29.6	28.9	29.1
CEERS6	8.1	···	29.5	29.3	29.4	29.5	29.6	28.9	29.0
Stephan's Quintet	39.5	27.7	···	27.9	28.0	28.7	28.7	···	28.3
PSF FWHM		0.″06	0.″07	0.″07	0.″08	0.″13	0.″14	0.″16	0.″16

Dropout Galaxy Selection

- Color selection
- Non-detection at bluer bands
- SED fitting (prospector) with $\Delta\chi^2>9$ (not $\Delta\chi^2>4$)



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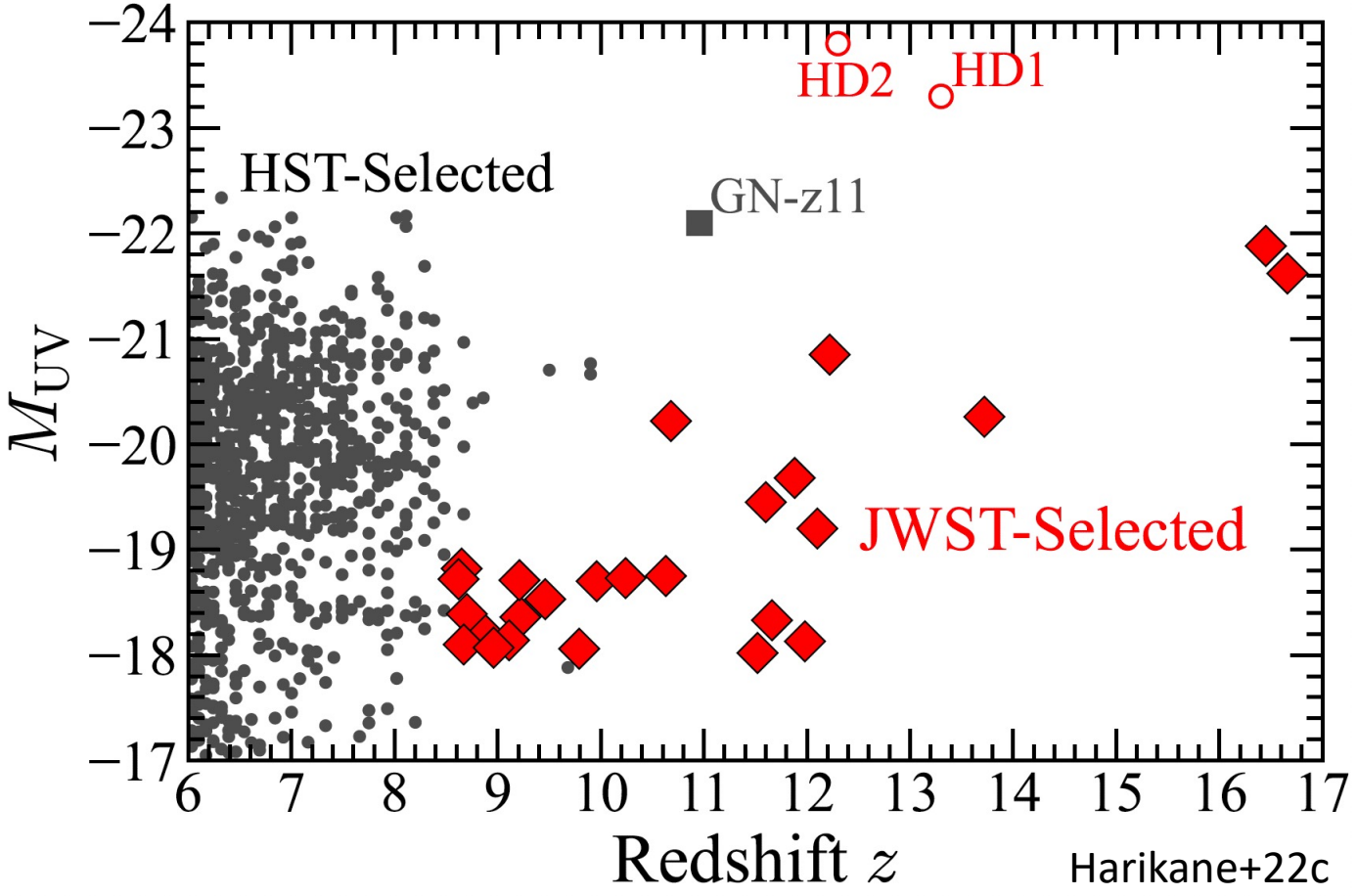
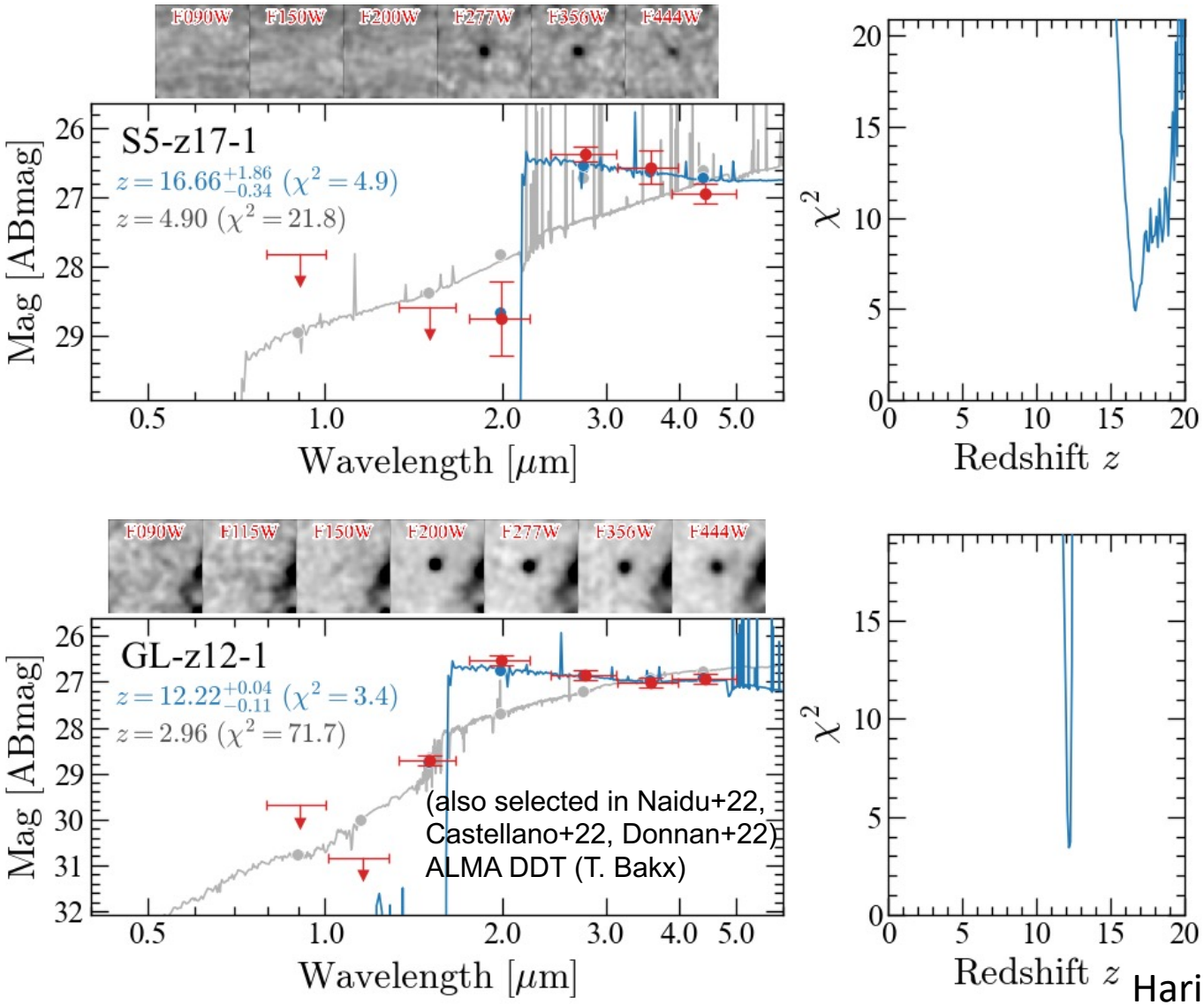
JWST Galaxy Sample at z~9-17

- A total of 25 galaxy candidates at z~9-17



Bright Galaxy Candidates



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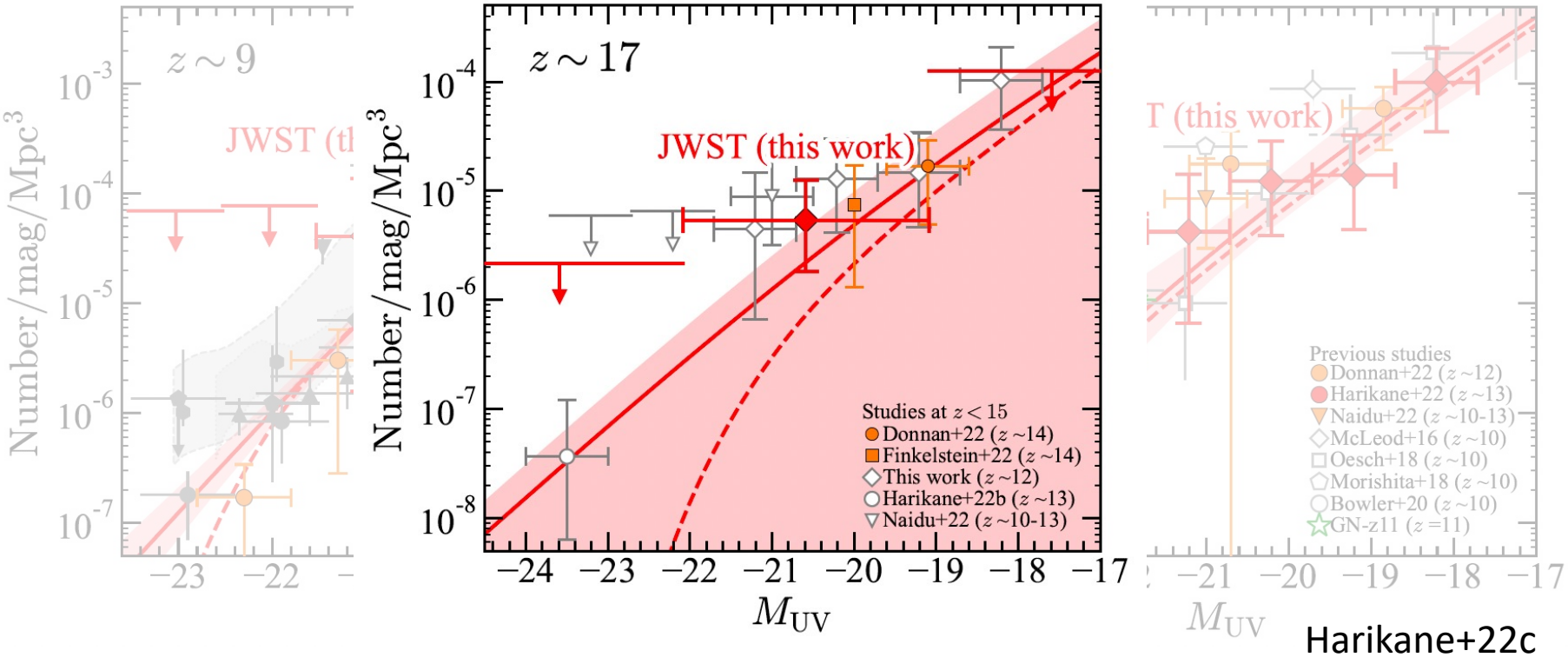
UV Luminosity Function

- Consistent w/ recent HST&JWST results at z~9,12
- New measurements at z~17



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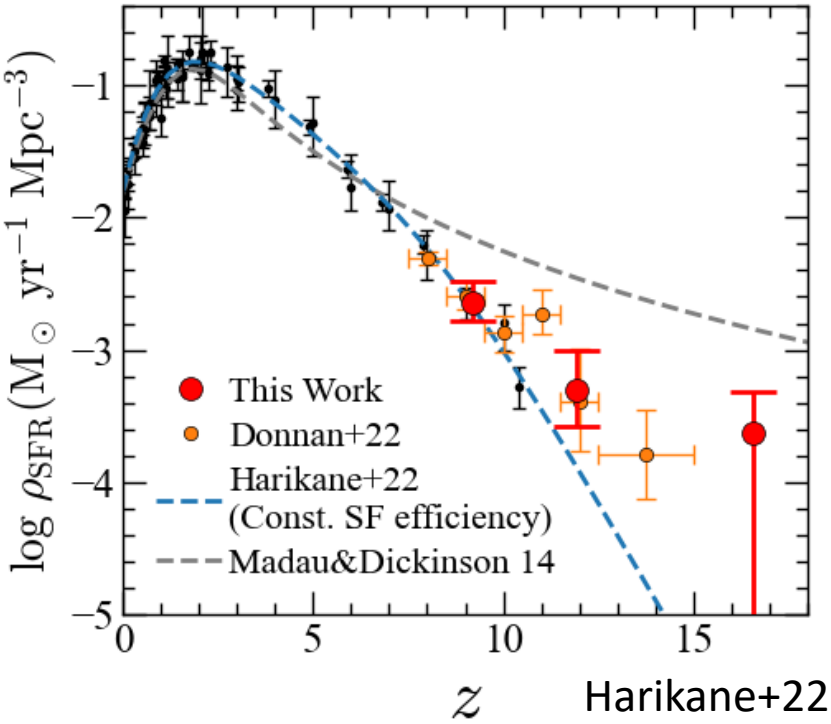
Cosmic SFR Density

- UV -> SFR: $SFR(M_\odot\ \mathrm{yr}^{-1}) = \mathcal{K}_{\mathrm{UV}} L_{\mathrm{UV}}(\mathrm{erg\ s}^{-1}\ \mathrm{Hz}^{-1})$,
  $\mathcal{K}_{\mathrm{UV}} = 1.15 \times 10^{-28}\ M_\odot\,\mathrm{yr}^{-1}/(\mathrm{erg\ s}^{-1}\mathrm{Hz}^{-1})$
- Higher than constant SF efficiency model ($SFR/(dM_h/dt)$=const)



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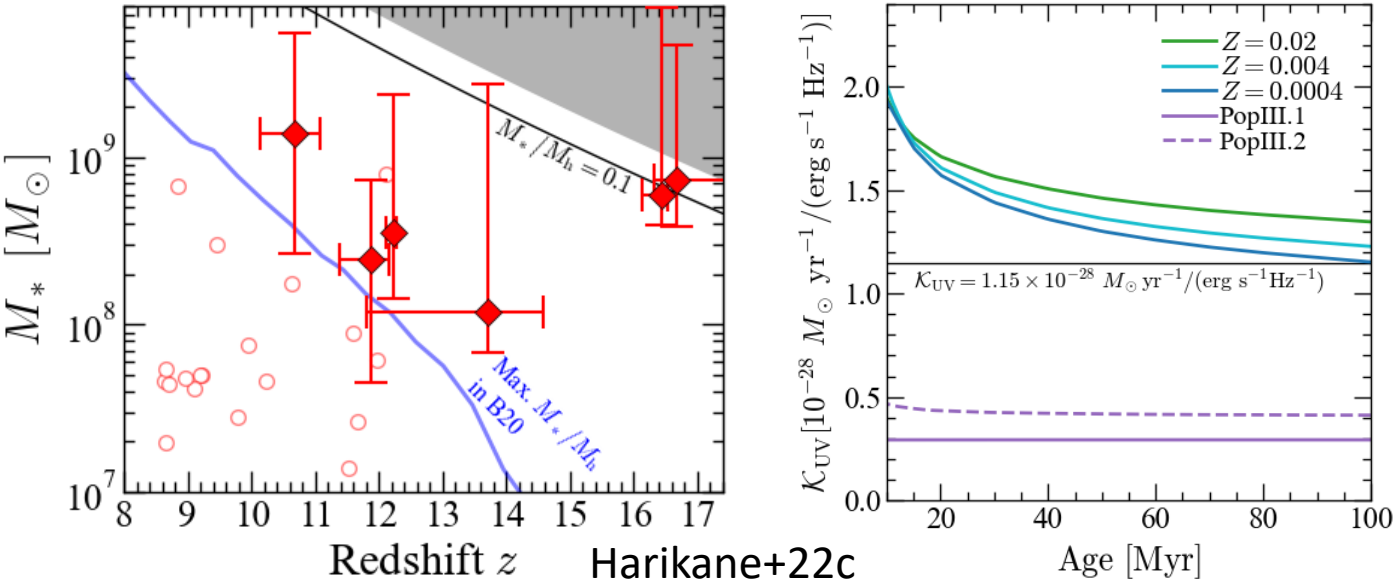
Too Many Bright Galaxies?

- $M_*>10^8\ M_{sun}$ (w/ high sSFR~$10^{-8}\ yr^{-1}$)
  - M_*/M_h~0.1 at z~16-17 -> 60% SF efficiency??

1. No suppression of SF by UV background at pre-EoR (e.g., Susa&Umemura 04)
2. AGN (some galaxies are extended -> unlikely?)
3. Pop-III stellar population with a top-heavy IMF



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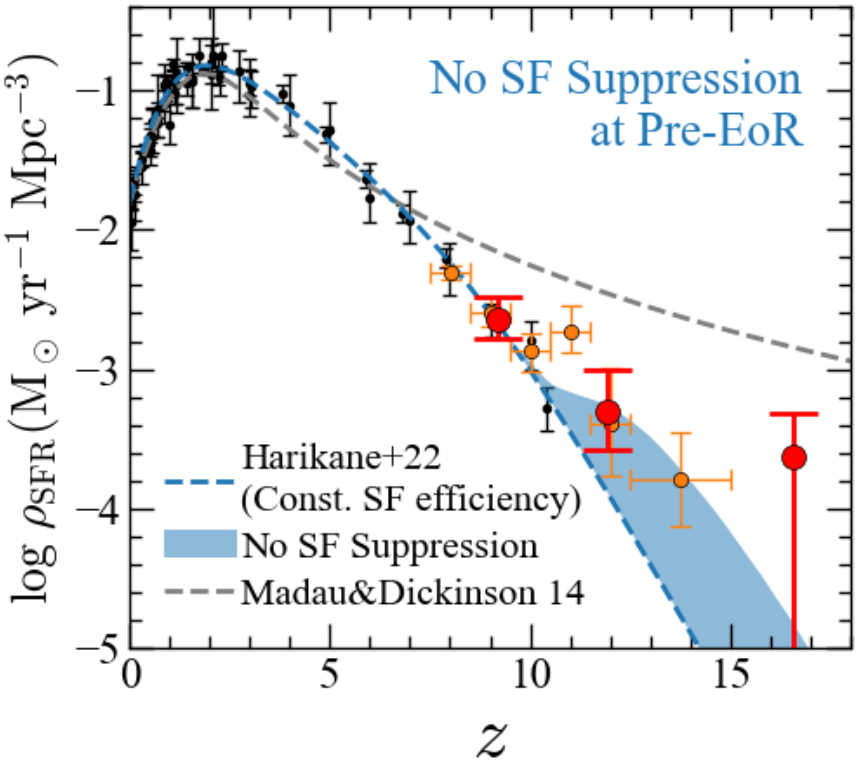
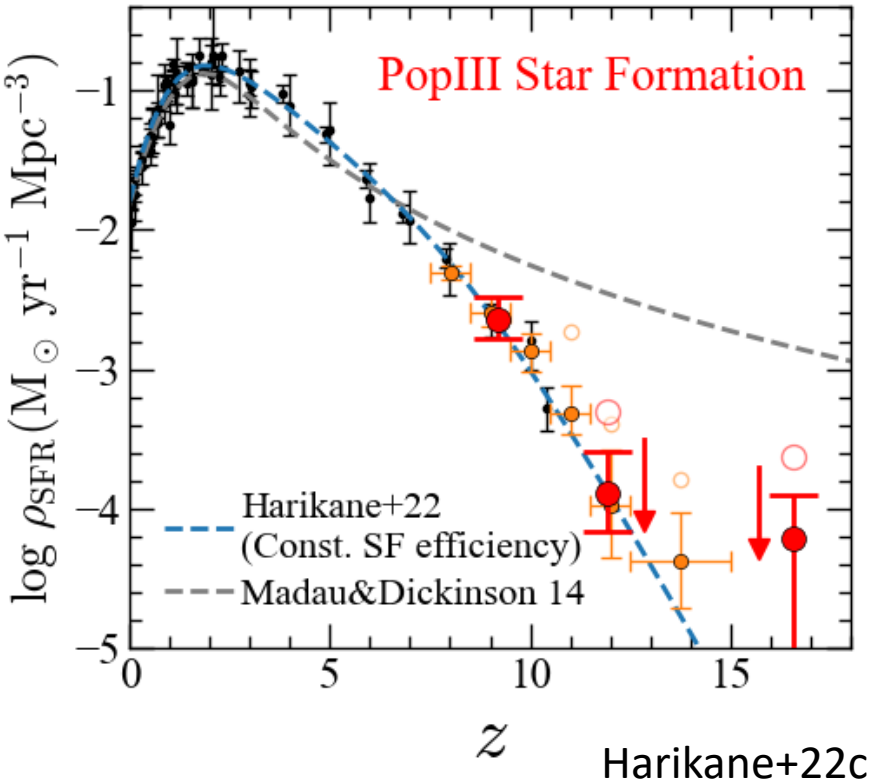
Higher SFR Densities

- Observed SFR densities matched to the model
  - 1) no SF suppression by UV background at pre-EoR
  - 3) Pop-III stellar population with a top-heavy IMF





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Summary

- Our comprehensive analysis w/ all available NIRCam data -> 25 galaxy candidates at z~9-17
  - UV luminosity functions at z~9-17
  - SFR densities higher than a constant SF efficiency model
  - Bright galaxies implying high SF efficiency (M_*/M_h~0.1)
  - No SF suppression at z>11 or Pop-III w/ top-heavy IMF?