A&A, 685, A48 (2024) https://doi.org/10.1051/0004-6361/202346800 © The Authors 2024

Galaxy morphology from $z \sim 6$ through the lens of JWST^{*}

M. Huertas-Company^{1,2,3,4,30}, K. G. Iyer^{5,**}, E. Angeloudi^{1,4}, M. B. Bagley⁷, S. L. Finkelstein⁷, J. Kartaltepe¹⁸, E. J. McGrath²⁹, R. Sarmiento^{1,4}, J. Vega-Ferrero^{1,4,9,10}, P. Arrabal Haro⁶, P. Behroozi^{8,9}, F. Buitrago^{10,11}, Y. Cheng¹², L. Costantin¹³, A. Dekel^{14,15}, M. Dickinson⁶, D. Elbaz¹⁶, N. A. Grogin¹⁹, N. P. Hathi¹⁹, B. W. Holwerda¹⁷, A. M. Koekemoer¹⁹, R. A. Lucas¹⁹, C. Papovich^{20,21}, P. G. Pérez-González¹³, N. Pirzkal²², L.-M. Seillé²³, A. de la Vega²⁴, S. Wuyts²⁵, G. Yang^{26,27}, and L. Y. A. Yung²⁸

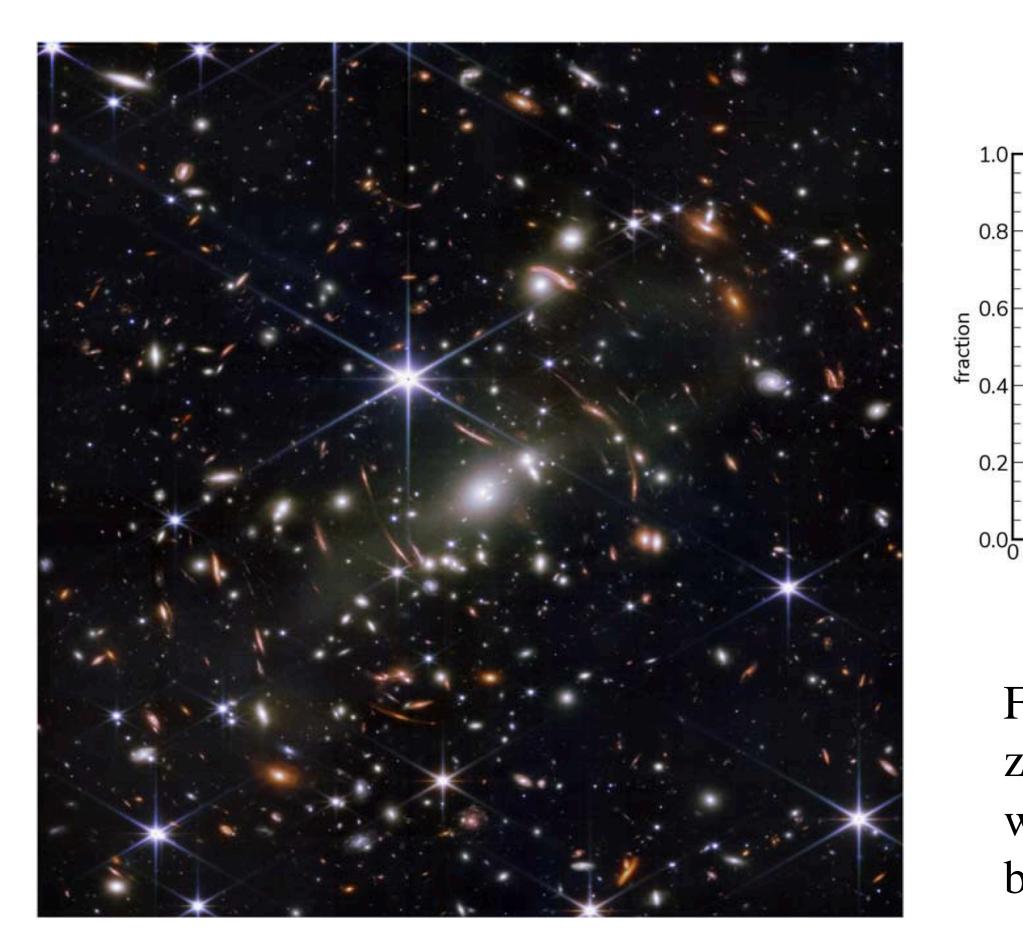
(Affiliations can be found after the references)

Received 2 May 2023 / Accepted 8 October 2023



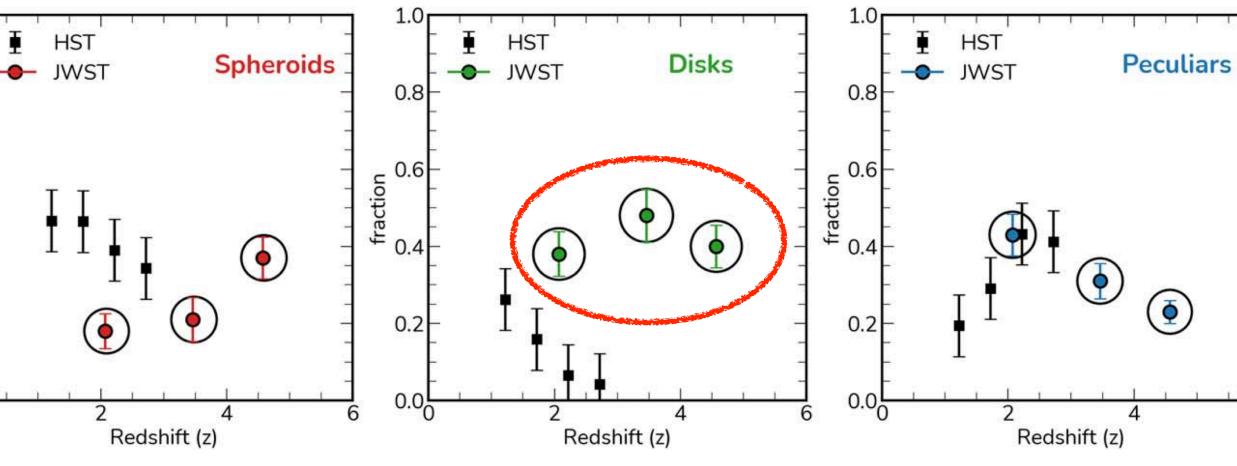
Reported by Dezi Liu

2024-10-09 @ SWIFAR for Journal Club



Ferreira et al (2022) found that disk galaxies are quite common at $z \sim 3-6$, where they make up ~50% of the galaxy population, which is over 10 times as high as what was previously thought to be the case with HST observations.

JWST color image of SMACS 0723

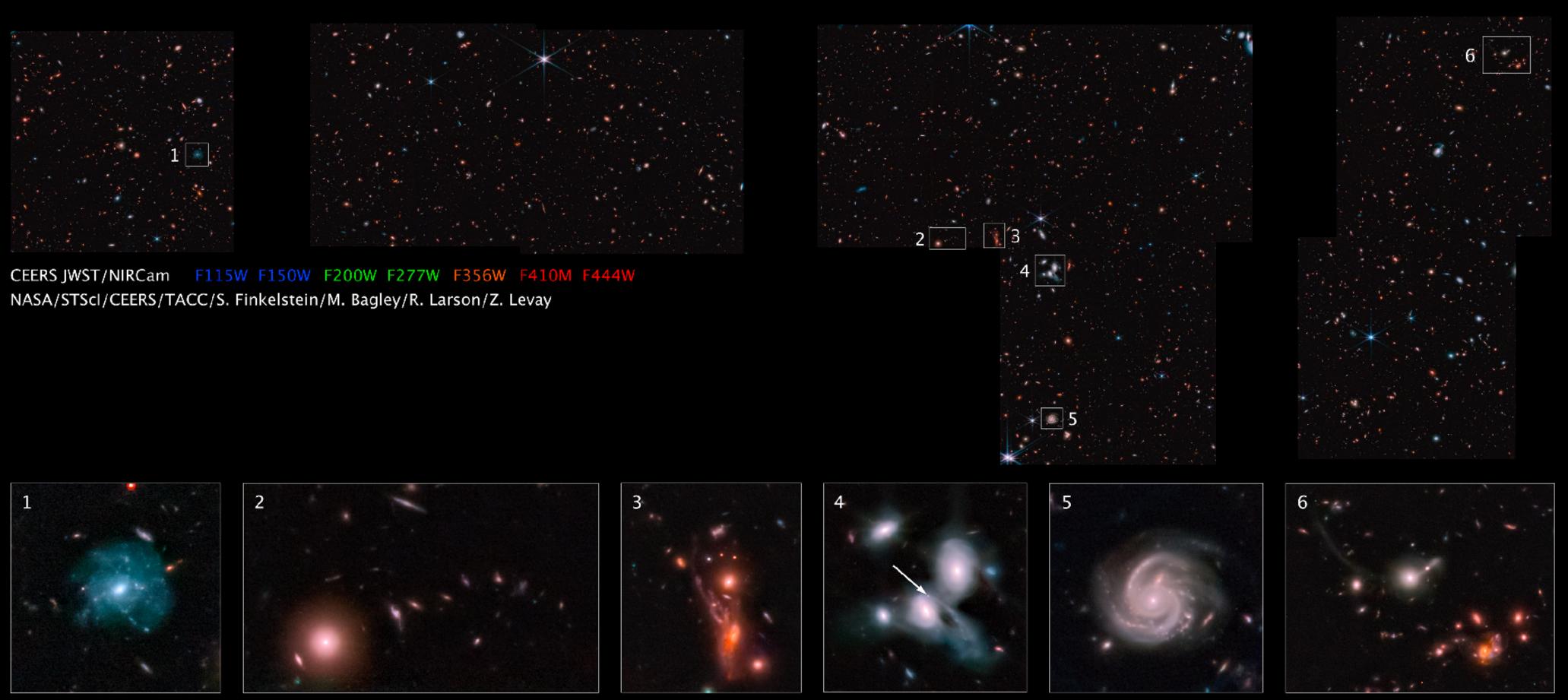






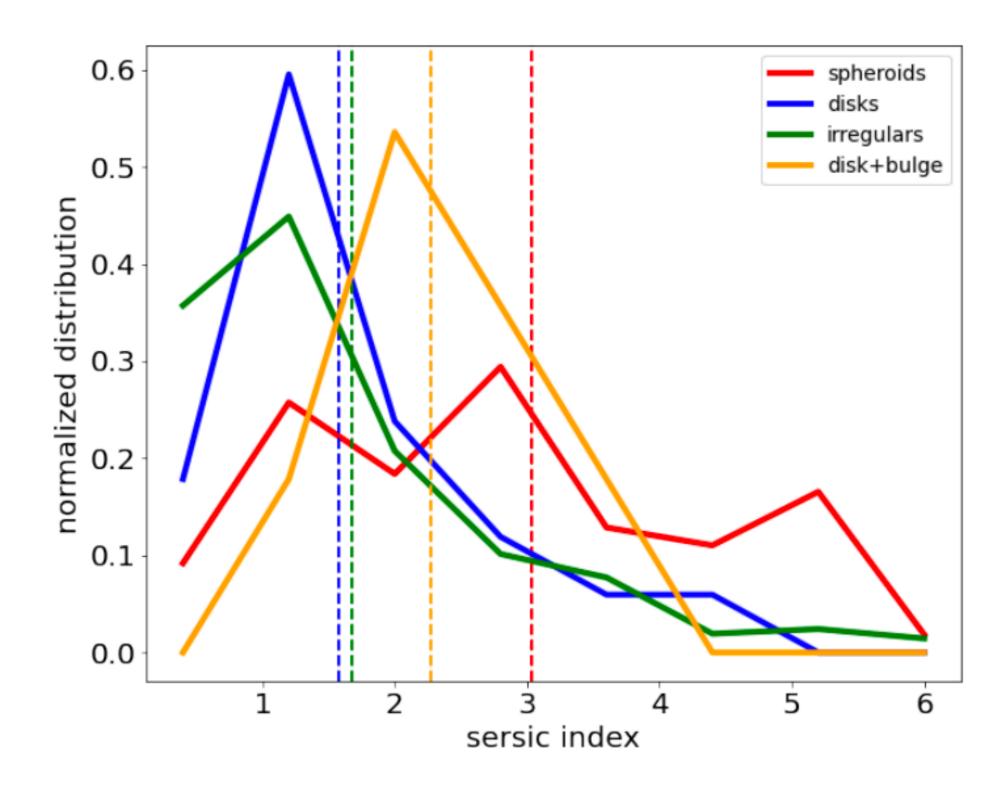
In this work, the authors selected <u>23,674</u> galaxies from JWST/CEERS survey:

- Four filters: F150W, F200W, F356W, and F444W
- Photo-zs, physical parameters (e.g. stellar mass), and Sersic parameters

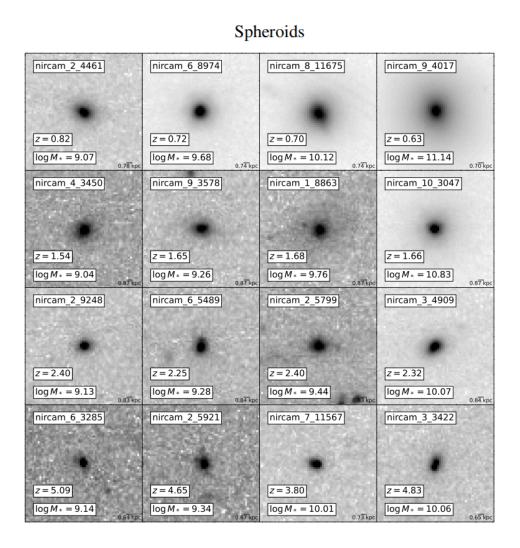


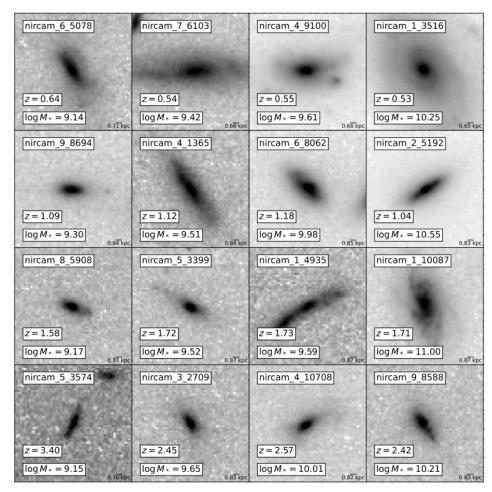


- Four classes: (1) spheroids/pure bulge; (2) disks; (3) bulge+disk; (4) irregulars/disturbed/peculiar
- Further combinations:
- A. Early-type galaxies: class (1) + class (3)
- B. Late-type galaxies: class (2) + class (4)



Galaxy classifications by neural network with training sample from HST/CANDELS F160W images:





Disks

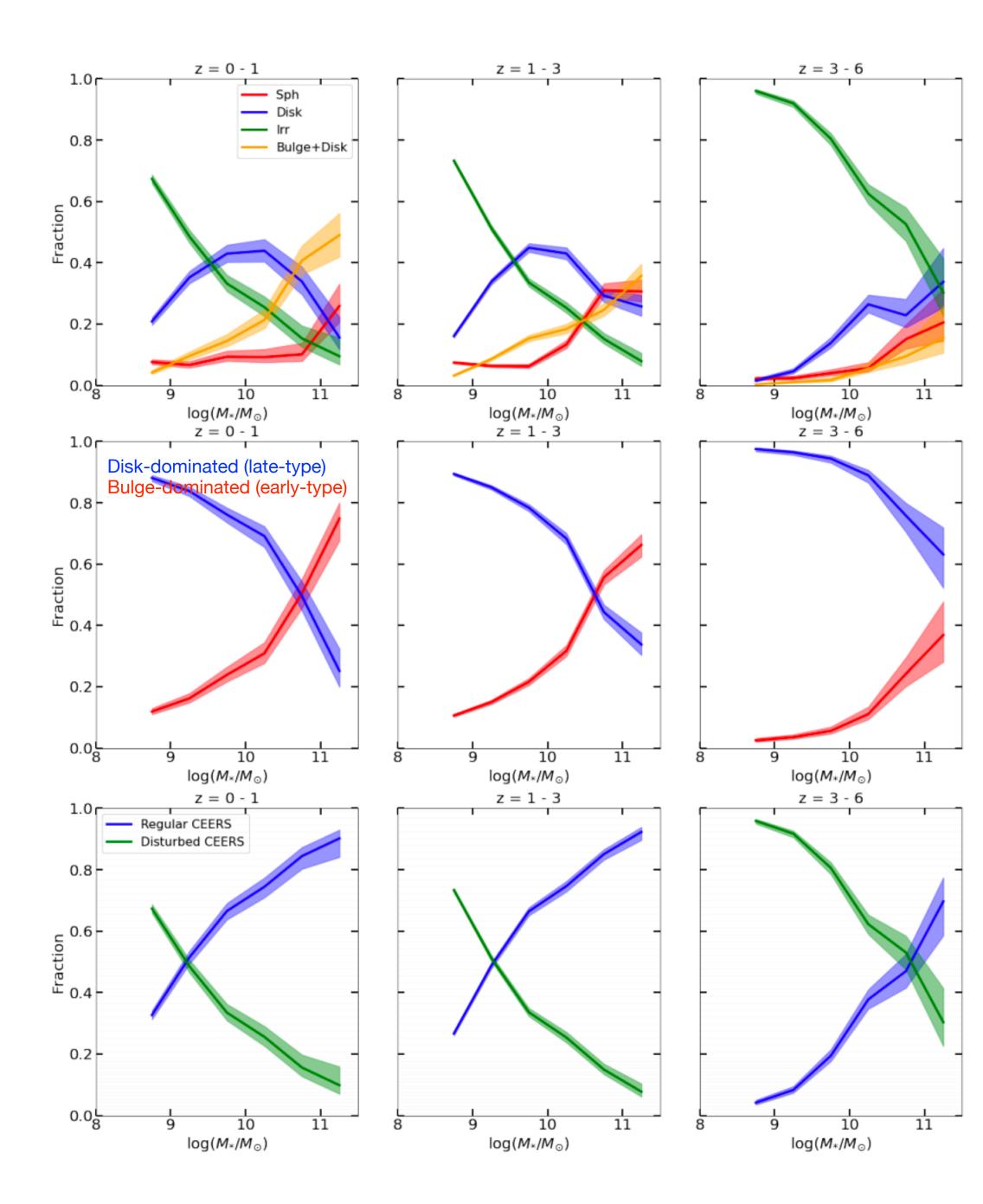
Irregulars

nircam_8_10600	nircam_2_4219	nircam_9_5378	nircam_2_3254
and the second second	Sec. 1	C. Long Cola	1000
	1200000000	CARLES OF C	CONTRACTOR OF
z = 0.64	<i>z</i> = 0.79	z = 0.87	<i>z</i> = 0.76
$\boxed{\log M_* = 9.09}_{0.71 \text{kpc}}$	log M * = 9.31	$\log M_* = 9.39$	$\log M_* = 9.88$
nircam_9_9383	nircam_3_7785	nircam_2_8899	nircam_6_4989
1	CR. Dalamark	-	
z = 1.66	z = 1.61	z = 1.68	z = 1.75
$\log M_* = 9.06$	$\log M_* = 9.18$	$\log M_* = 9.81$	$\log M_* = 10.04$
nircam_5_1827	nircam_1_926	nircam_1_11550	nircam_4_4987
		and the second second	
	P de		
z = 2.39	z = 2.50	z = 2.26	z = 2.30
$\log M_* = 9.03$ 0.83 kpc	$\log M_* = 9.25$ 0.83 kpc	$\log M_* = 9.95$ 0.84 kpc	$\boxed{\log M_* = 10.31}_{0.84 \text{ kpc}}$
nircam_6_11958	nircam_8_7791	nircam_10_7233	nircam_10_8225
			14,10% State
			5 - C
z = 5.20	z = 4.14	z = 4.56	z = 5.34
$\log M_* = 9.02$	log M * = 9.52	$\log M_* = 9.90$	$\log M_* = 10.08$

Bulge+disk

nircam_5_12788	nircam_2_9576	nircam_6_6126	nircam_7_6097
	100		10000
			COLUMN TO A
z = 0.29 $\log M_* = 9.56$	z = 0.31 $\log M_* = 10.14$	z = 0.22 log $M_* = 10.34$	$z = 0.64$ $\log M_* = 10.90$
0.45 kpc	0.47 kpc	0.36 kpc	0.71 kpc
nircam_7_13728	nircam_5_5098	nircam_5_10545	nircam_9_4104
		1000000	
z = 1.20 log $M_* = 9.26$	$z = 1.10$ $\log M_* = 9.74$	z = 1.12	z = 1.23
0.85 kpc	0.84 kpc	$\log M_* = 10.48$	log M * = 11.03
nircam_1_2687	nircam_8_12889	nircam_1_3578	nircam_1_4331
10-10-10 A. 21	11. A.		1000
	- Carlos - Carlos - Carlos	Contraction of the	
z = 1.60 $\log M_* = 9.31$	z = 1.59 $\log M_* = 9.85$	z = 1.66 $\log M_* = 10.80$	z = 1.69 $\log M_* = 11.13$
0.87 kpc	0.87 kpc	0.87 kpc	0.87 kpc
nircam_2_7906	nircam_5_5871	nircam_7_8350	nircam_9_11123
	and the second		
z = 3.39	z = 3.00	z = 2.55	z = 3.51
$\log M_* = 9.02$	$\log M_* = 9.86$	$\log M_* = 10.13$	$\log M_* = 10.71$

Example of galaxies observed with F200W filter



Evolution of the fractions of different morphological types in <u>rest-frame $\sim 0.8-1\mu m$ </u> as a function of stellar mass and redshift. Filters F200W, F356W and F444W are used to infer galaxy morphology in the redshift bins 0 < z < 1, 1 < z < 3, and 3 < z < 6, respectively.

- The fraction of bulge-dominated galaxies (early-type) shows a strong correlation with stellar mass. The behavior is surprisingly similar at all redshifts probed, suggesting similar physical processes for bulge formation at all epochs.
- Early-type galaxies start dominating the massive end of the galaxy population since $z \sim 3$. While late-type galaxies dominate at all redshifts at lower mass bins.
- The abundance of irregular galaxies is a strong function of stellar mass at all redshifts, with low-mass galaxies being predominantly peculiar.

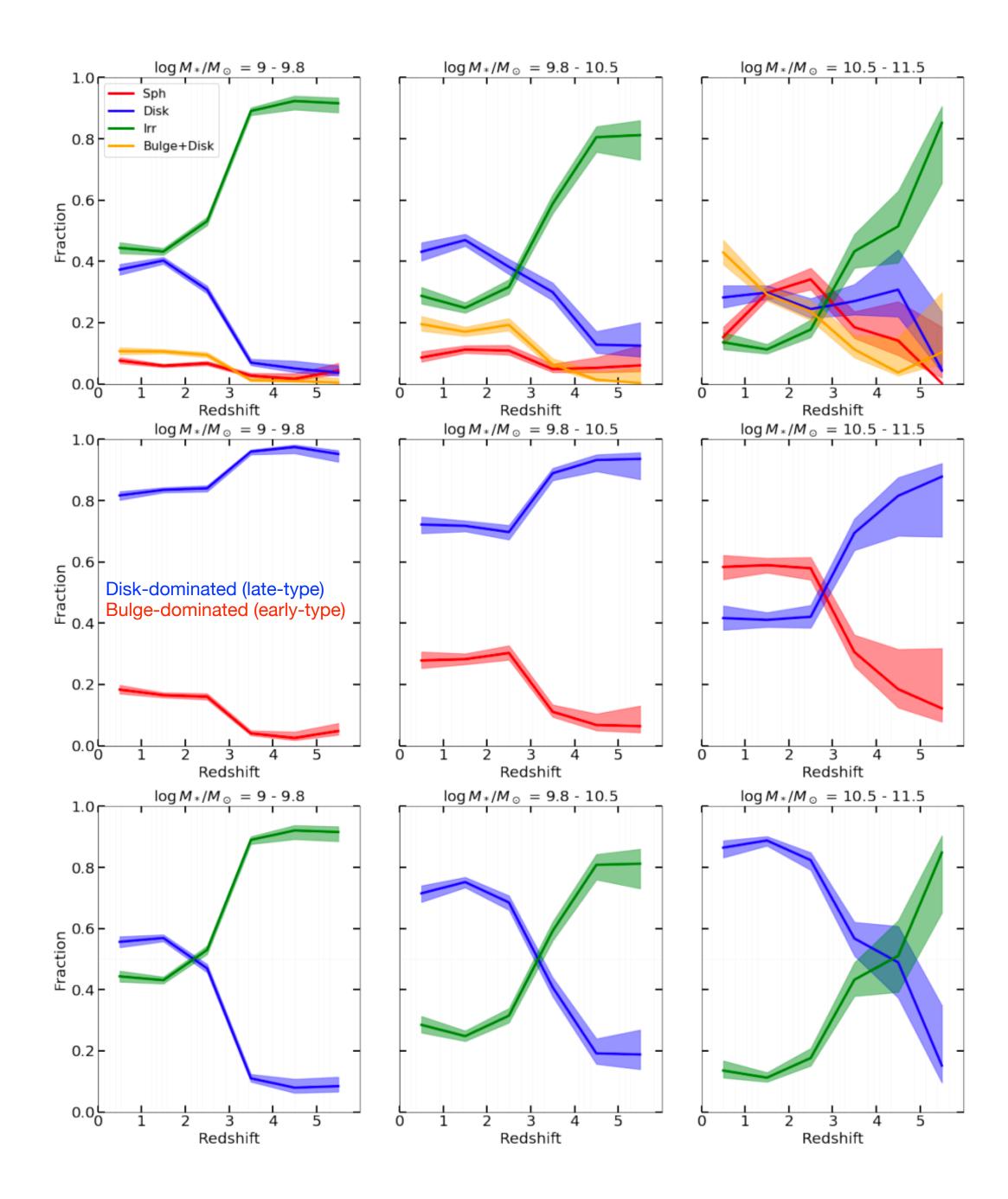












Evolution of the fractions of different morphological types in rest-frame ~ $0.8-1\mu$ m as a function of stellar mass and redshift.

- Disk (late-type) galaxies dominate the high-mass end even at $z\sim5$
- The abundance of irregular galaxies increases with resdshift even when probing the rest-frame NIR. This suggests that, at early epochs, the distribution of stellar mass is also perturbed and that it is not only a consequence of the presence of bright star-forming regions emitting in the UV.



This study indicates a complex morphological diversity already in place ~ 1 Gyr after the Big Bang.

- the stellar mass distribution is more disturbed at high redshift.
- morphologies even at $z\sim5$, indicating that disk formation may be in place at very early epochs.

• The fraction of bulge-dominated galaxies increases at the high-mass end, even at $z\sim5$, indicating that the processes of bulge formation in massive galaxies are already in place at these early cosmic epochs.

• The fraction of peculiar galaxies also increases with redshift, even in the NIR rest-frame, suggesting that

• The high-mass end of the galaxy distribution (log $M_{\star}/M_{\odot} > 10.5$) is dominated by undisturbed disk-like



Thank You