

Panic! At the Disks: First Rest-frame  
Optical Observations of Galaxy  
Structure at  $z > 3$  with JWST in the  
SMACS 0723 Field

# Intro

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- SMACS 0723 is massive cluster of galaxies at  $z = 0.390$
- First image by JWST with objects that already have known redshifts
- Paper is a first look study of the evolution of galaxy morphology at higher redshift than we could achieve in the past with HST

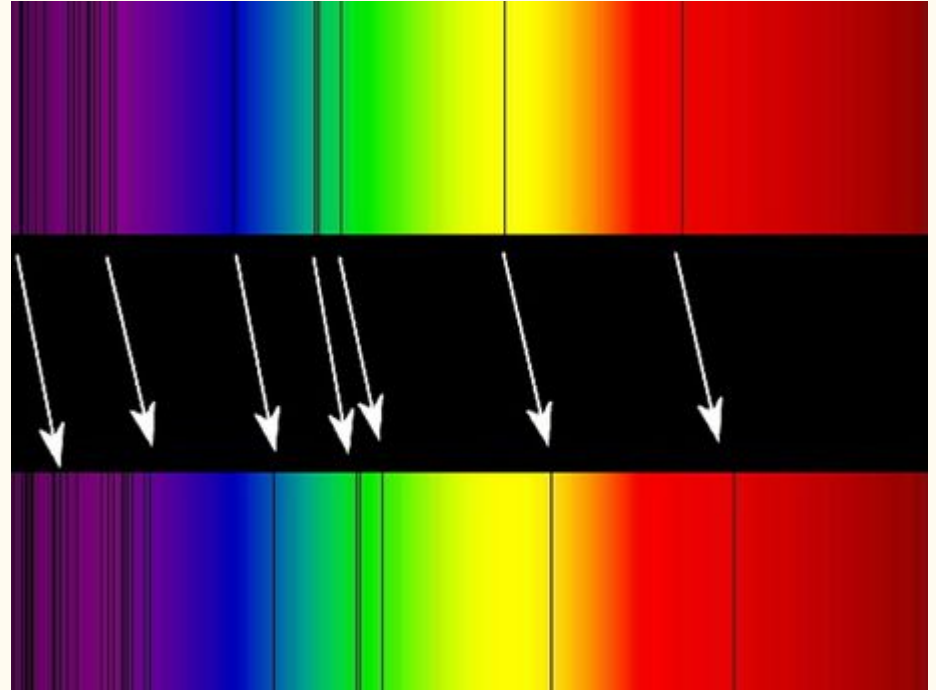


# What is redshift $z$ ?

Measures the distance to an object quite accurately if very far away

Noticed by the shift of typical spectral lines to the red end of the spectrum- in other words, light that has been stretched out

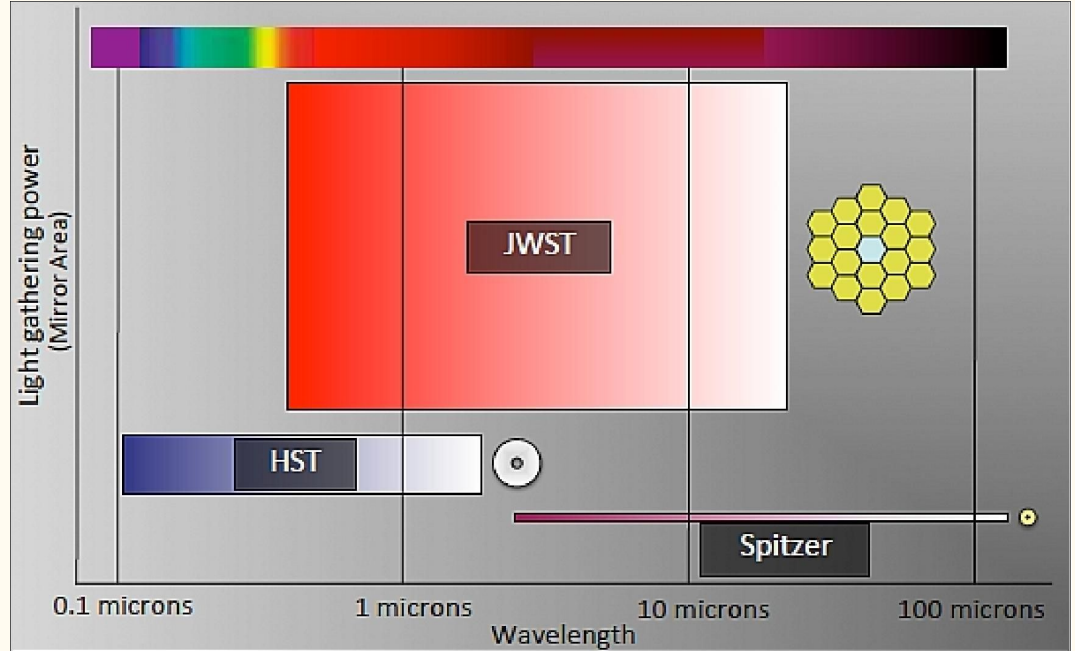
This is because of universal expansion



# Why was HST insufficient to observe high-z galaxies?

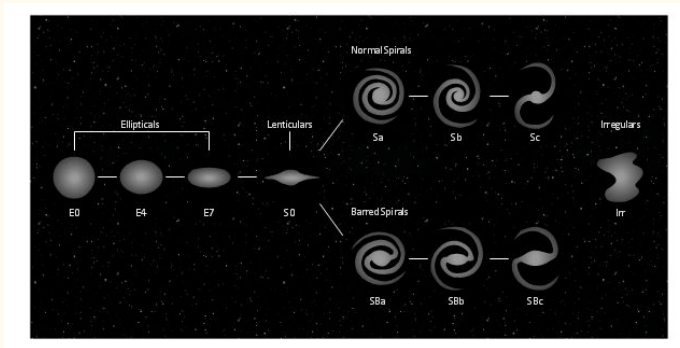
Its wavelength range couldn't see such high wavelength/redshifted light

Unless it started at a high frequency in the UV for example



# Conclusions about morphology from HST to JWST

- Since HST could only see short wavelength galaxies at such high  $z$ 's, this biased its view of them
- UV emitting galaxies at this time tended to be irregularly shaped
- This led to calculations indicating that the Hubble sequence had not been well defined at this time



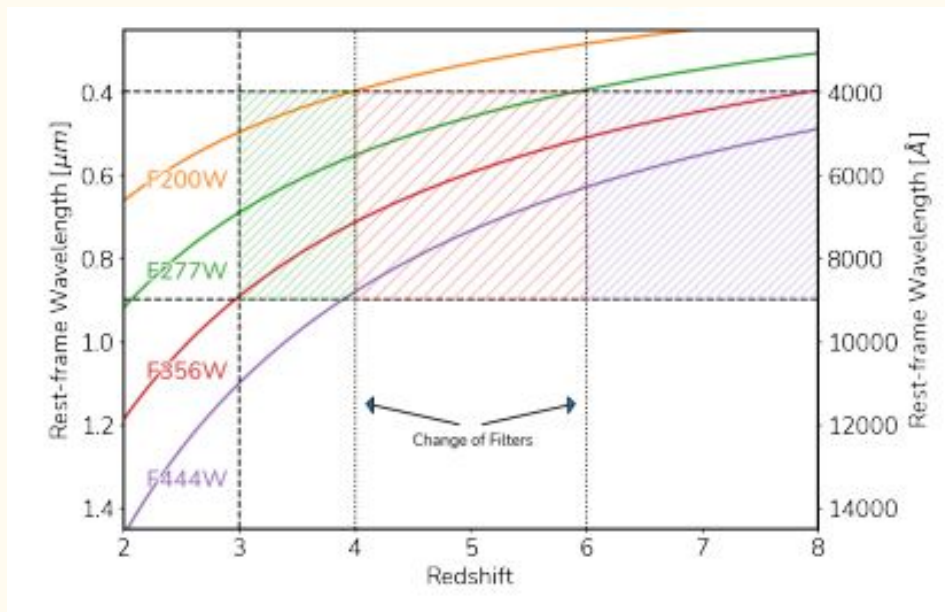
*the F160W band on HST only probes rest-frame optical light up to  $z \sim 2.8$ , whereas JWST permits us to obtain this information up to  $z = 8$  with F444W, and even beyond with MIRI*

Data



# Data and Processing

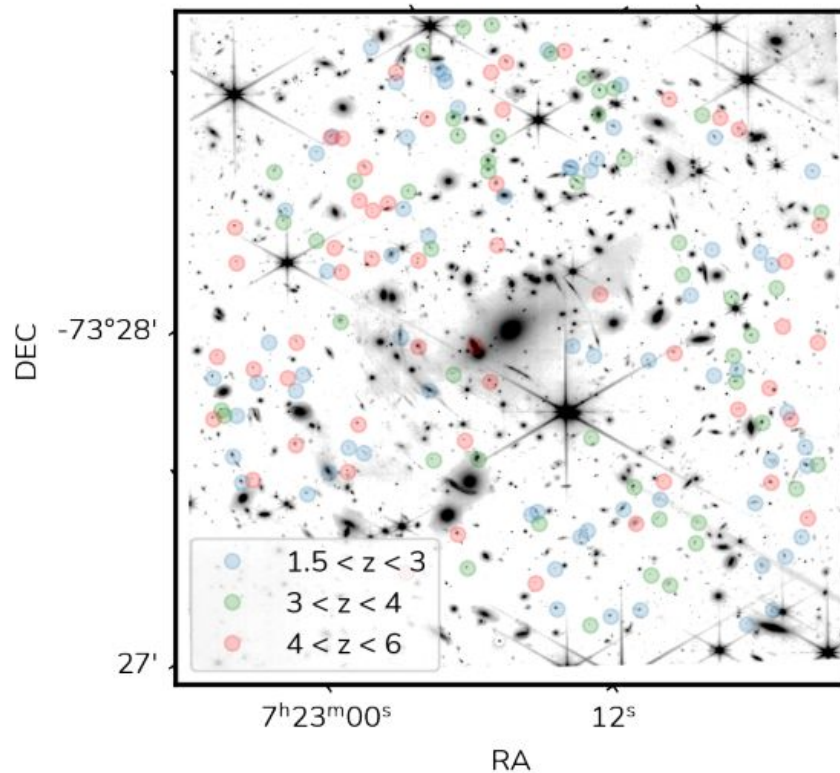
- Early Release Observations of SMACS 0723
- F090W, F150W, and F200W short-wavelength (SW) bands, and F356W, F277W, and F444W long-wavelength (LW) bands
- Integration time is 12.5 hr
- Slightly modified JWST pipeline
- photometric redshifts derived through the Bayesian photo-z code (BPz) by RELICS program





# Data and Processing

- 355 galaxies with RELICS photometric redshifts from the JWST
- $Z = 1.5 \leq z \leq 8$ .
- Out of 355, 280 were considered classifiable



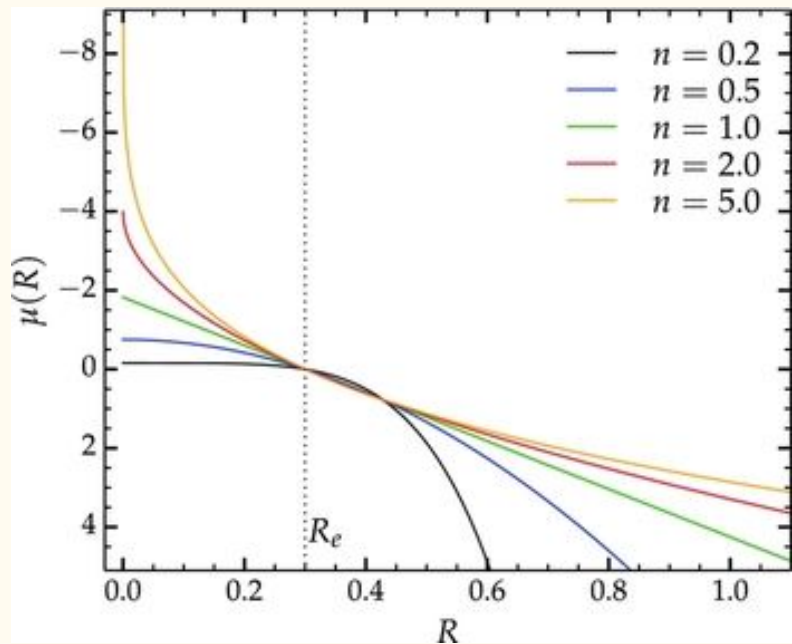
# Data: Morphologies

## Morphometry

- Estimates and removes background and other sources
- Single component Sersic model fitting
- Center, position angle, axial ratio
- Symmetry, spirality, concentration

## Visual Classification

- Done by 3 experienced authors
- Enabled by JWST resolution in rest-frame optical

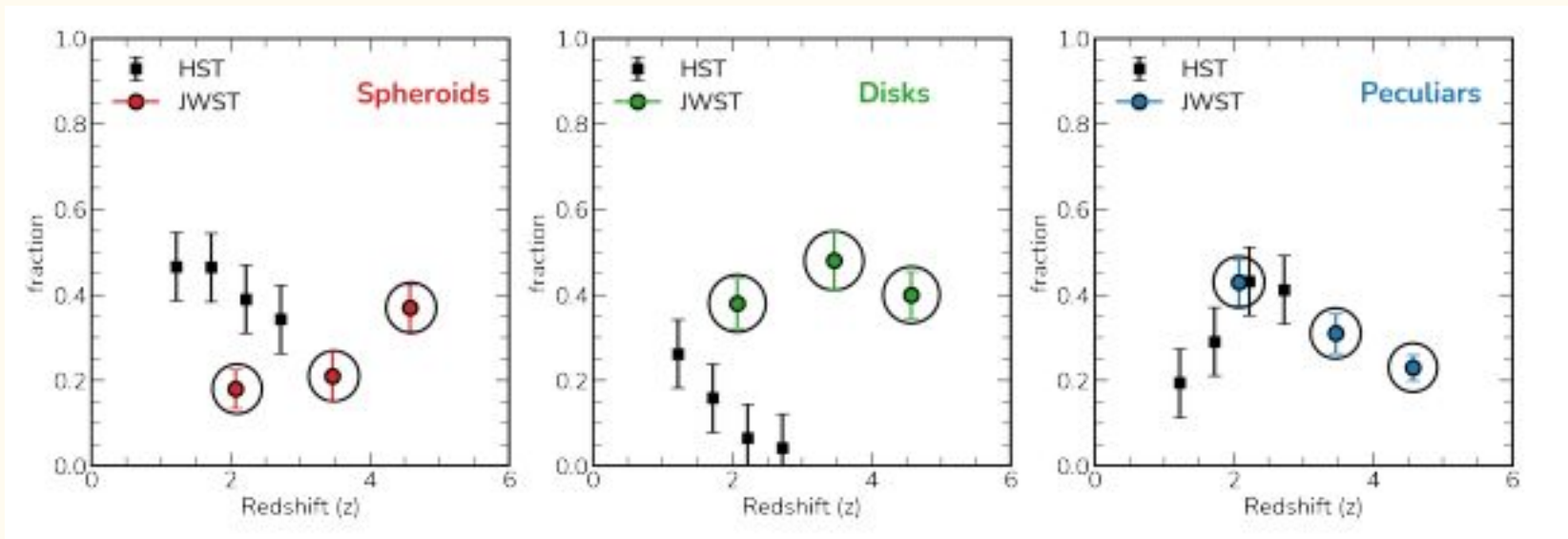


# Results



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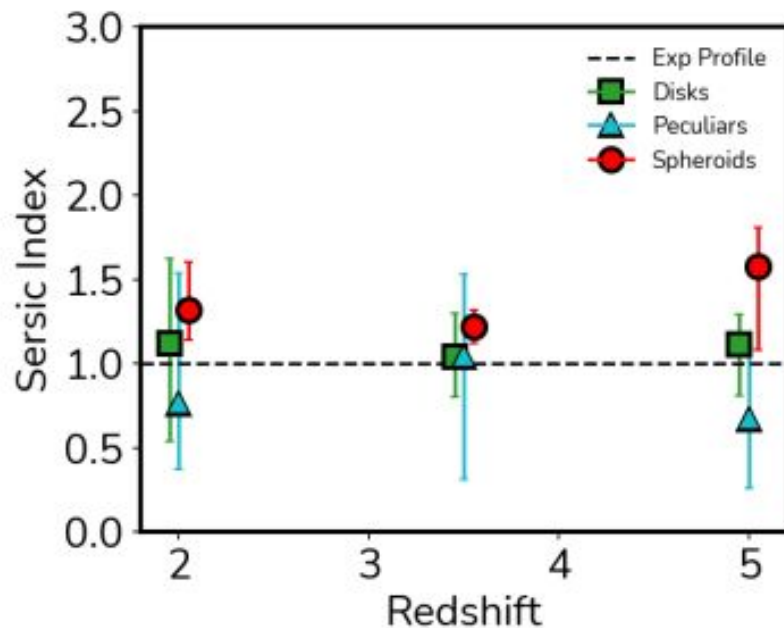
*“Overall, we find that the disk galaxy population makes up about half of the galaxies that are identified within the field of SMACS 0723 at  $z > 2.5$ .”*





# Results

*Previous work has shown that almost all massive galaxies at  $z > 2$  have Sersic indices which are  $n \sim 1$ , which differs for galaxies at lower redshifts where  $n \sim 4$  for similar mass galaxies...many of our galaxies contain indices with  $n \sim 1$ , with most disks around this value, as expected...on average these spheroids have a larger  $n$  value.*



# Discussion



**“We have not reached the limit of where the first ellipticals and spheroids have formed. We will need to probe even higher redshifts to find when and if there are no spheroids or disk galaxies. Thus, at least some aspect of the Hubble sequence was in place at  $z \sim 6$ .”**



**“This implies that disk galaxies have existed in large numbers for quite a significant amount of time. This may mean that the morphologies of some disk galaxies, such as the Milky Way, have remained in their current form for over 10 billion years.”**

# Key Takeaways

- Galaxy structure was formed much earlier than we had previously thought or even been able to see
- At  $z$  3-6, spirals may make up 50% of the population of galaxies
- They are more regular and less asymmetric and clumpy than previously thought



# Images/paper

<https://www.redshift-live.com/en/magazine/articles/Astronomy/18416-Redshift-1.html>

<https://arxiv.org/abs/2207.09428>

[https://www.eoportal.org/web/eoportal/satellite-missions/pag-filter/-/asset\\_publisher/8jbNpfmcMhvK/content/jwst-content?redirect=https%3A%2F%2Fdirectory.eoportal.org%2Fweb%2Feoportal%2Fsatellite-missions%2Fpag-filter%3Fp\\_p\\_id%3D101\\_INSTANCE\\_8jbNpfmcMhvK%26p\\_p\\_lifecycle%3D0%26p\\_p\\_state%3Dnormal%26p\\_p\\_mode%3Dview%26p\\_p\\_col\\_id%3Dcolumn-1%26p\\_p\\_col\\_pos%3D1%26p\\_p\\_col\\_count%3D2%26101\\_INSTANCE\\_8jbNpfmcMhvK\\_cur%3D29%26101\\_INSTANCE\\_8jbNpfmcMhvK\\_keywords%3D%26101\\_INSTANCE\\_8jbNpfmcMhvK\\_advancedSearch%3Dfalse%26101\\_INSTANCE\\_8jbNpfmcMhvK\\_delta%3D15%26101\\_INSTANCE\\_8jbNpfmcMhvK\\_andOperator%3Dtrue](https://www.eoportal.org/web/eoportal/satellite-missions/pag-filter/-/asset_publisher/8jbNpfmcMhvK/content/jwst-content?redirect=https%3A%2F%2Fdirectory.eoportal.org%2Fweb%2Feoportal%2Fsatellite-missions%2Fpag-filter%3Fp_p_id%3D101_INSTANCE_8jbNpfmcMhvK%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-1%26p_p_col_pos%3D1%26p_p_col_count%3D2%26101_INSTANCE_8jbNpfmcMhvK_cur%3D29%26101_INSTANCE_8jbNpfmcMhvK_keywords%3D%26101_INSTANCE_8jbNpfmcMhvK_advancedSearch%3Dfalse%26101_INSTANCE_8jbNpfmcMhvK_delta%3D15%26101_INSTANCE_8jbNpfmcMhvK_andOperator%3Dtrue)

<https://www.conceptdraw.com/examples/fork>