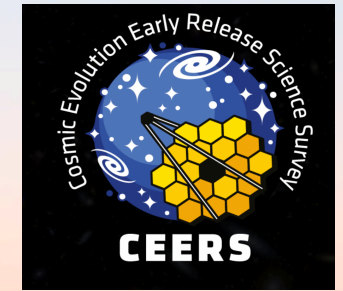


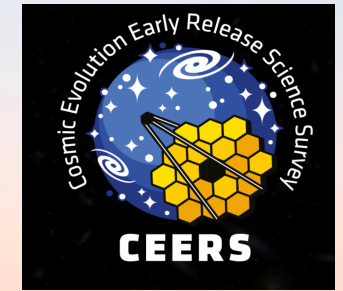
# The emergence of the Hubble Sequence as seen by COSMOS-Web

Marc HUERTAS-COMPANY

+ CEERS, COSMOS-Web, UniverseTBD, GalaxyZoo

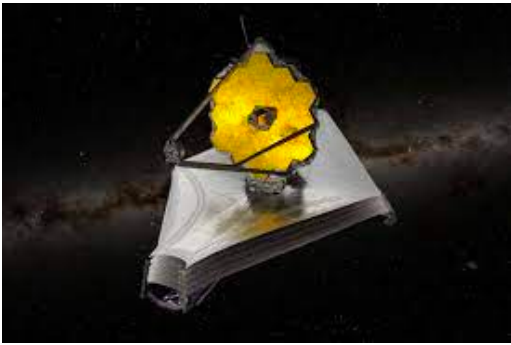


# **“At the Edge of the Universe (2006)”:** Morphology of $z \sim 1$ Galaxies from Deep K-band AO Imaging in the COSMOS Field

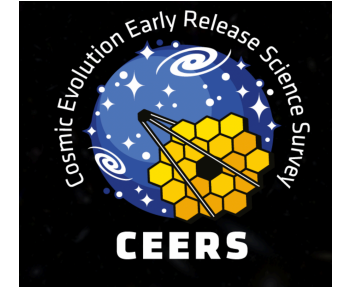
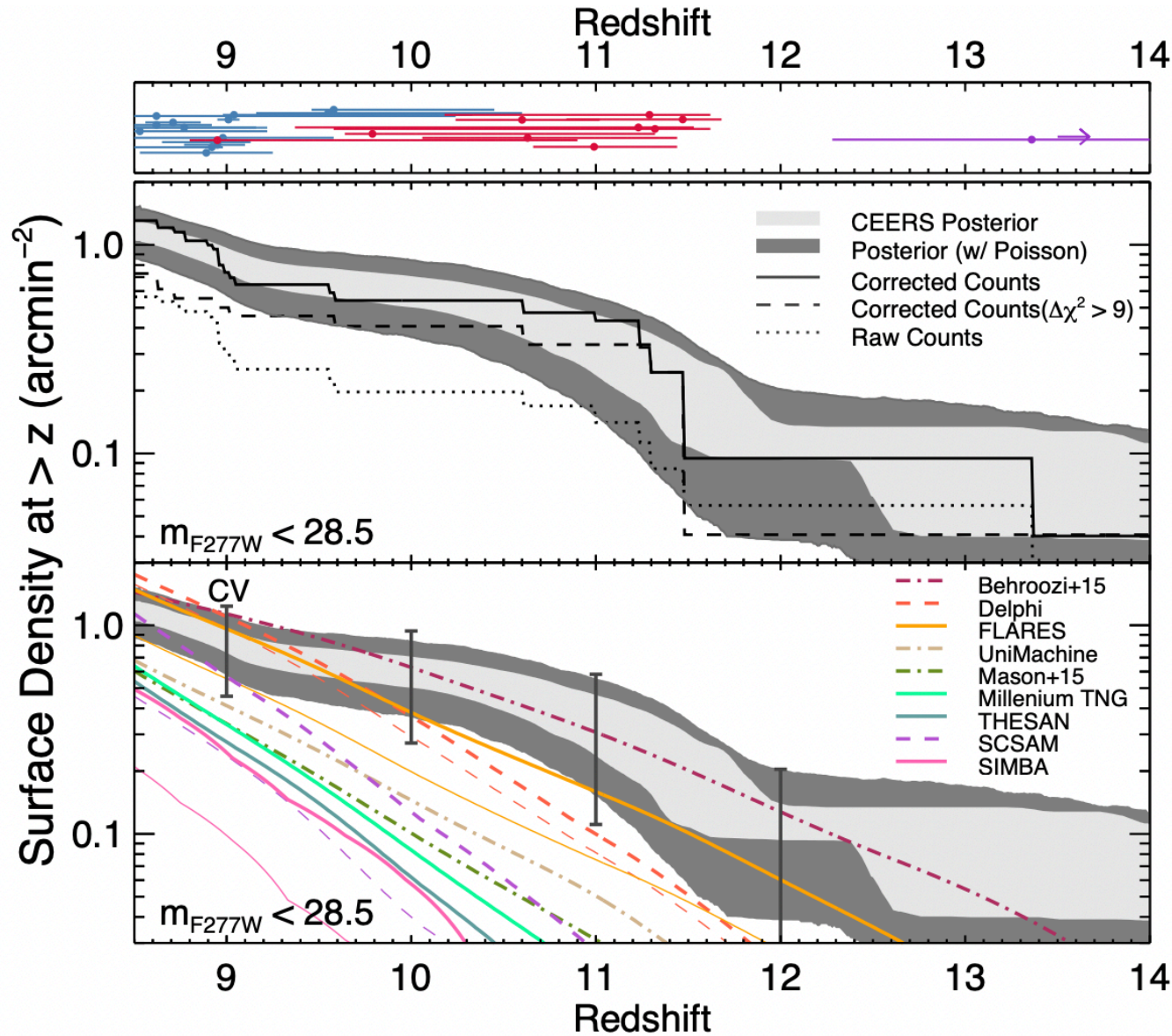


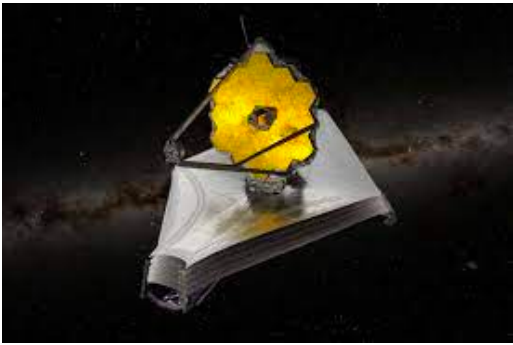
# **“At the Edge of the Universe (2006)”:** Morphology of $z \sim 1$ Galaxies from Deep K-band AO Imaging in the COSMOS Field

*We present the results of observations of  
distant galaxies ( $z \sim 0.8$ ) ....*

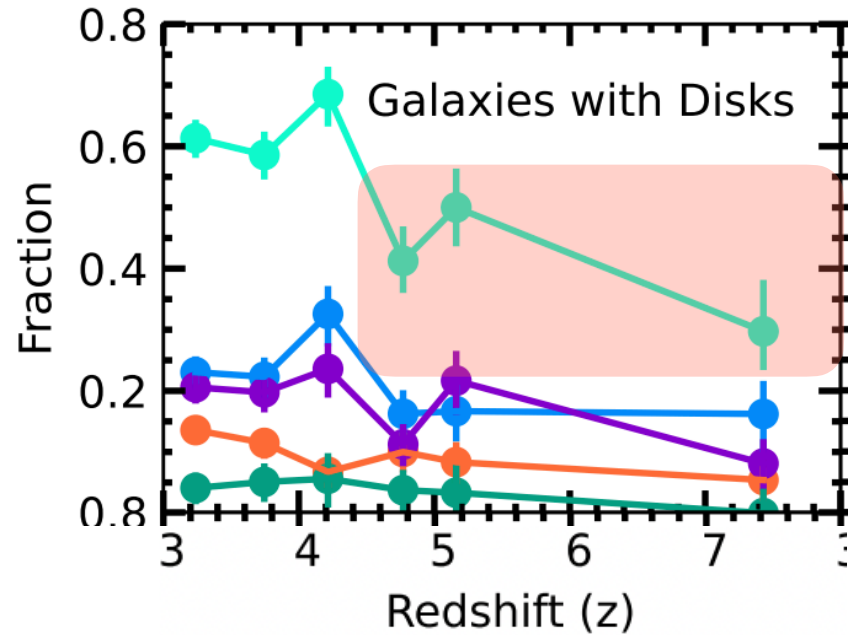
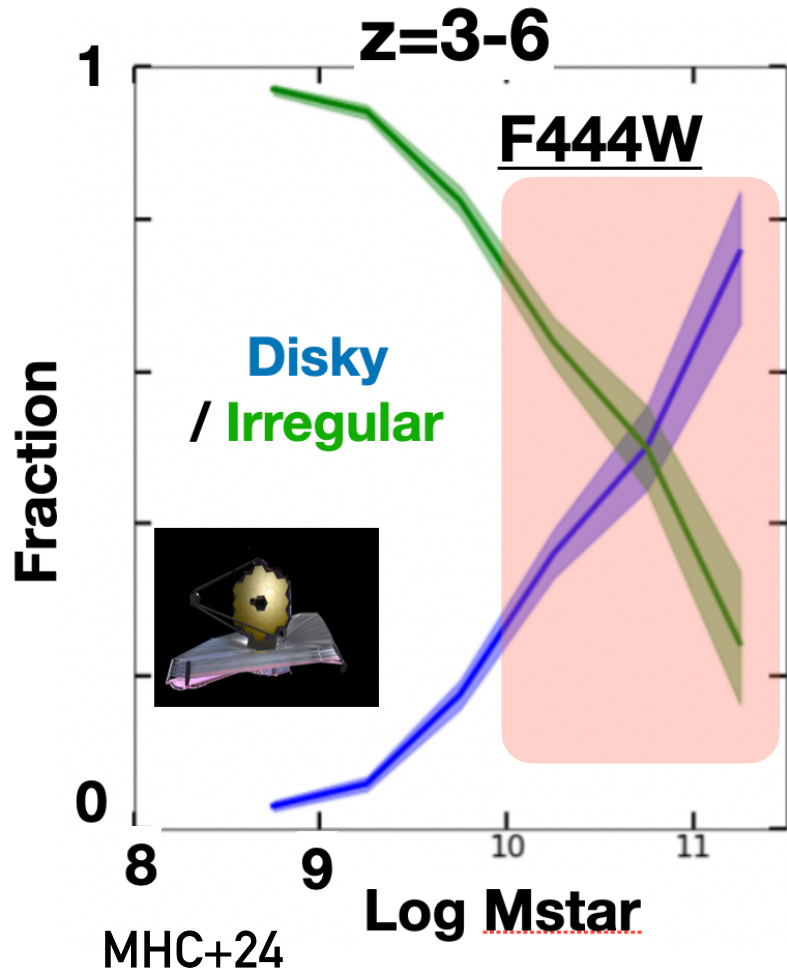


# Is galaxy assembly faster than expected at cosmic dawn? Why and how?



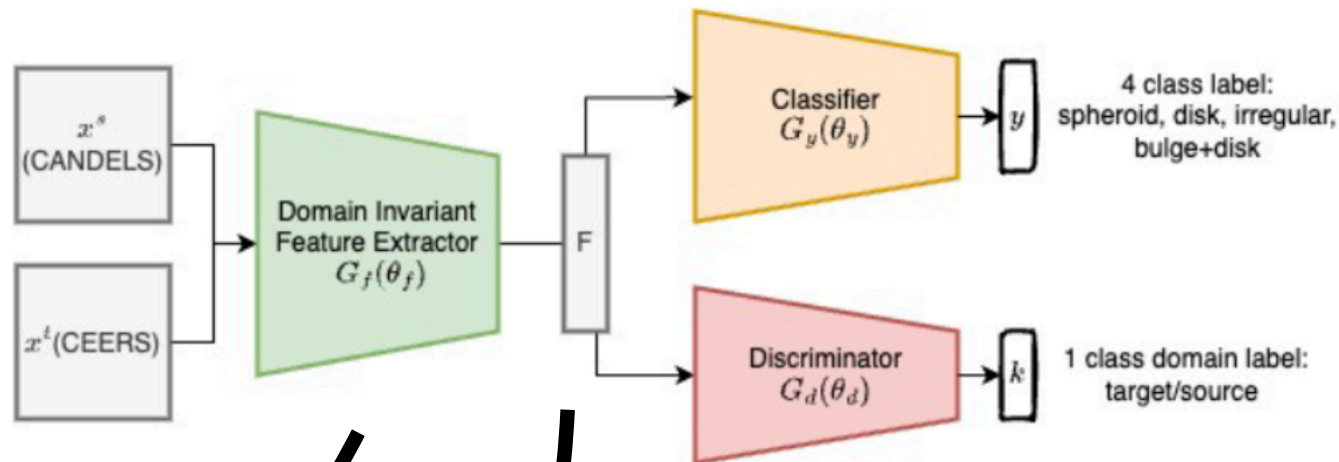


# Is galaxy assembly faster than expected at cosmic dawn? The morphology view

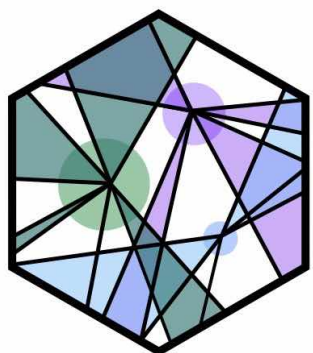


Kartaltepe+23





MHC+24



COSMOS  
**WEB**

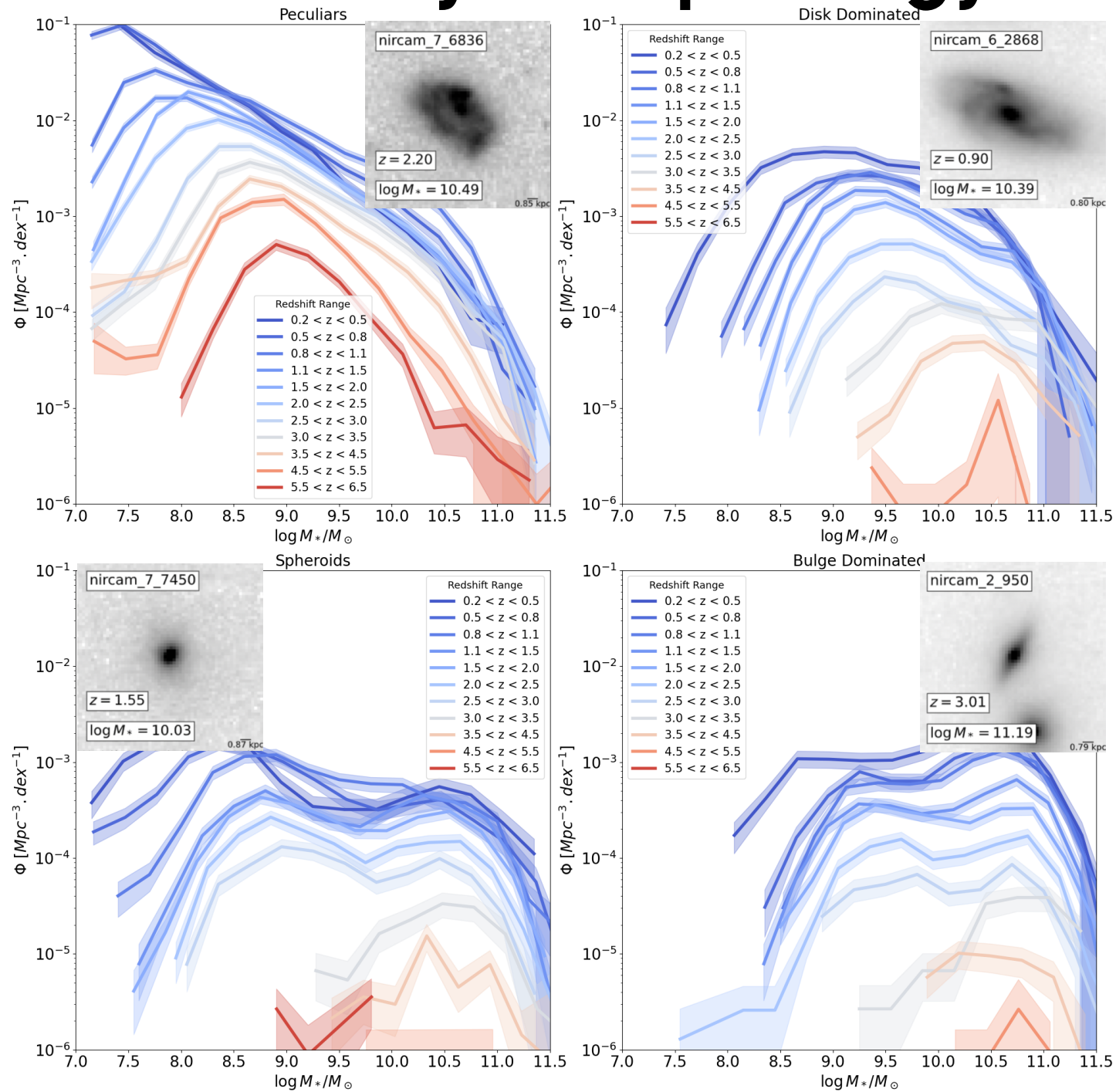
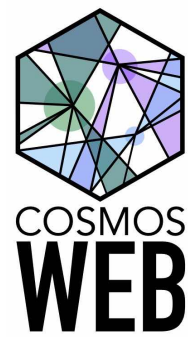


**NGDEEP**

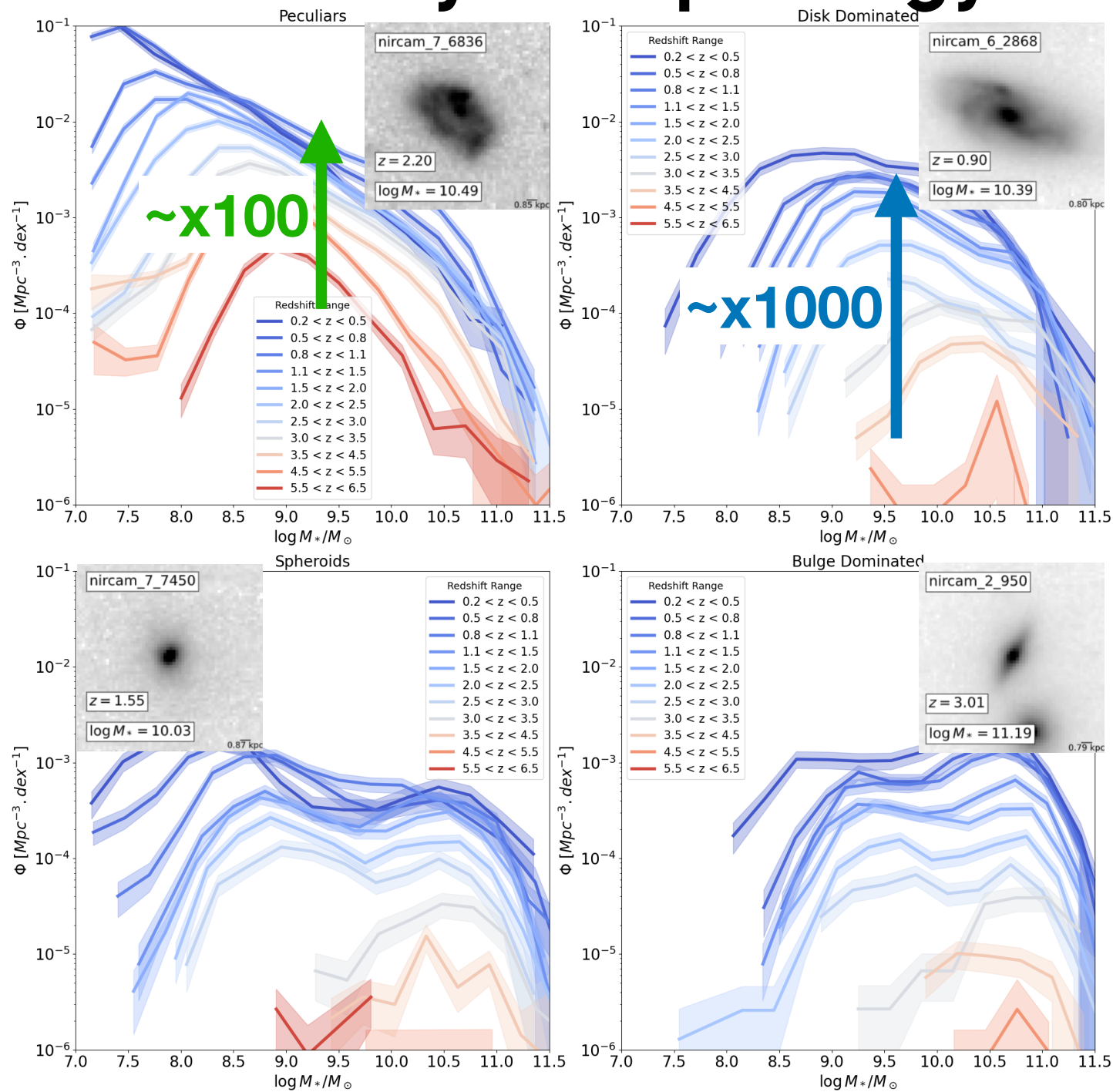
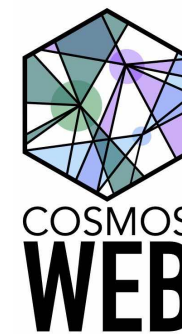


~ 500k galaxies,  $0 < z < 6$ ,  
Rest-frame optical  
(F150W  $\rightarrow$  F444W)

# SMFs by morphology

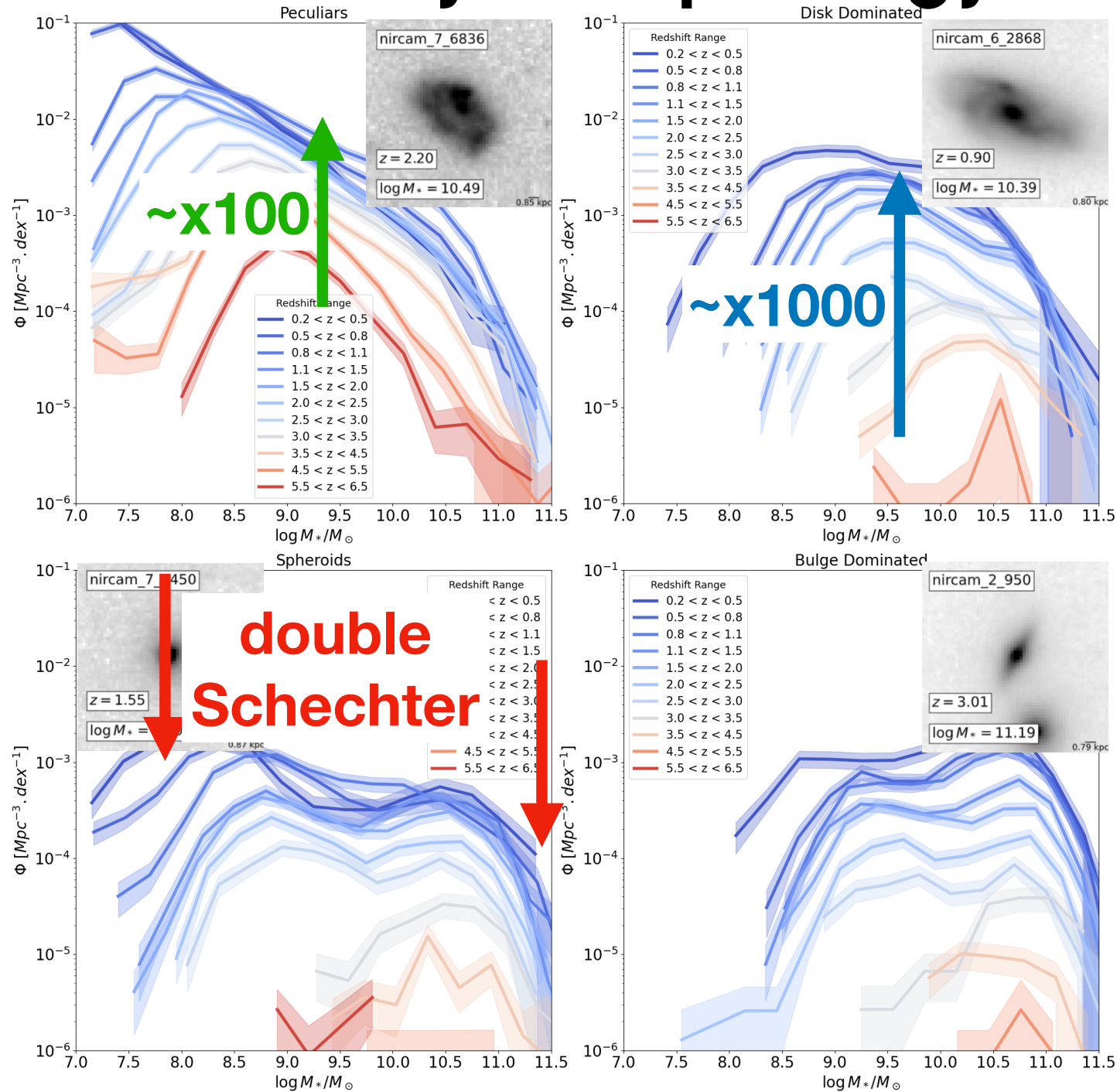
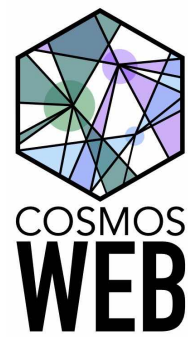


# SMFs by morphology

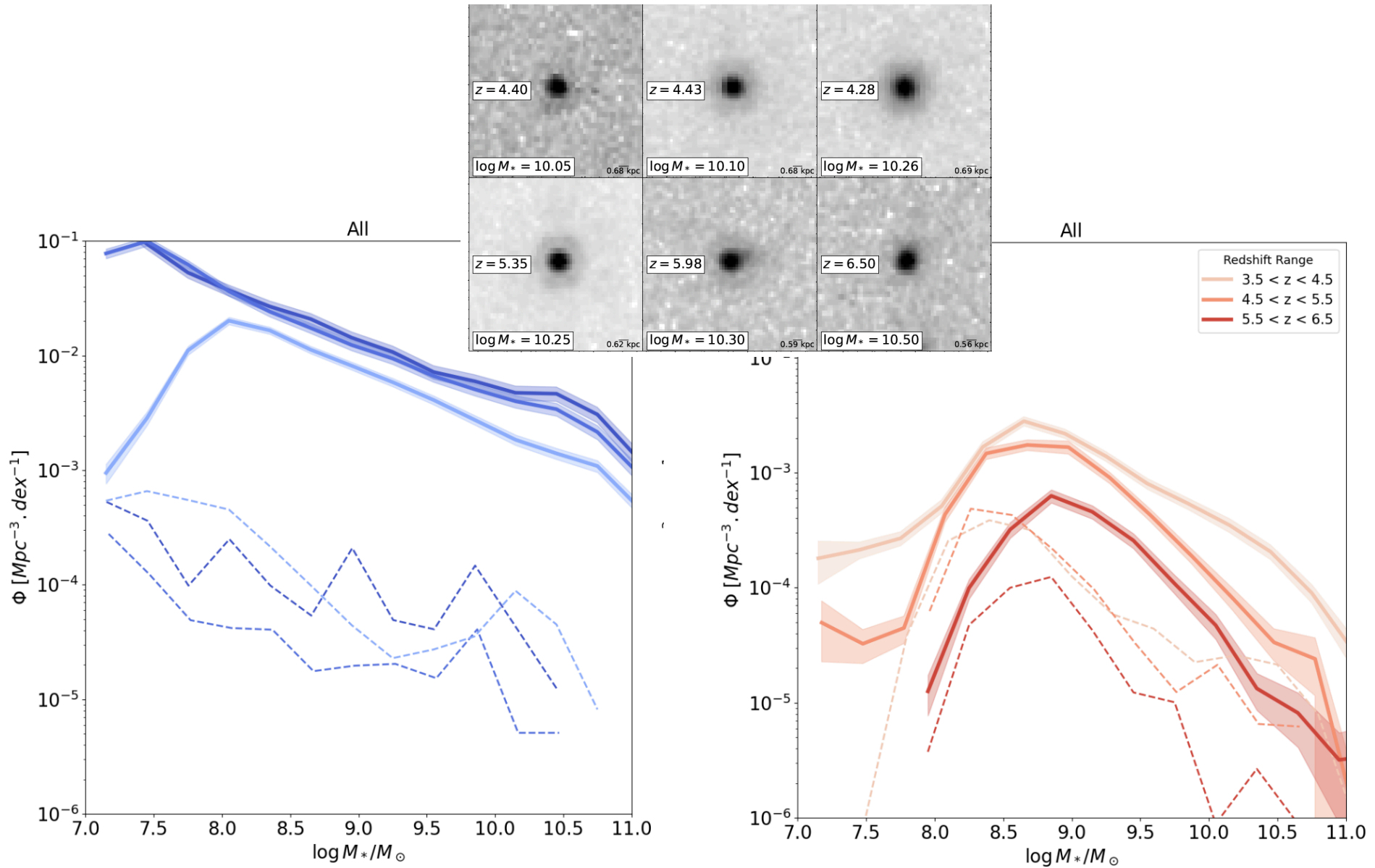




# SMFs by morphology



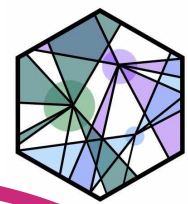
# Compact (Unresolved) Galaxies



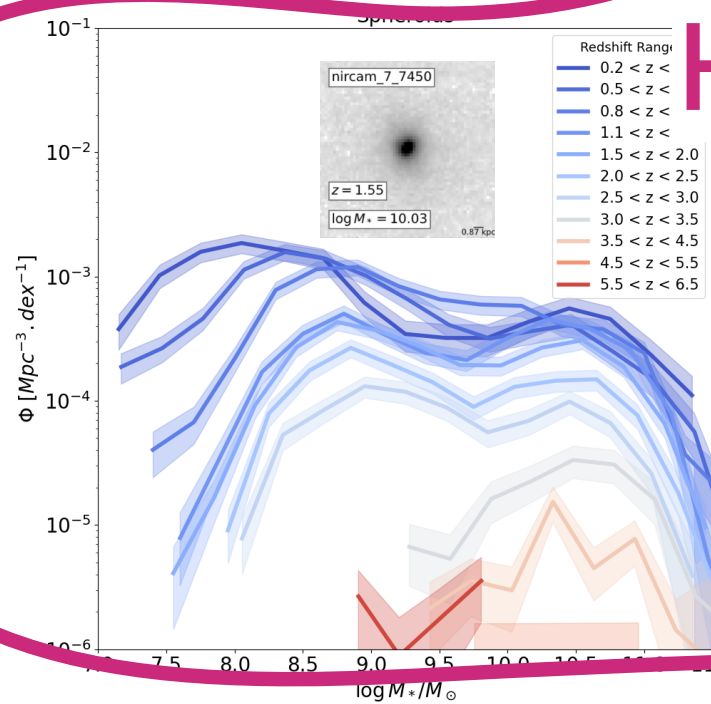
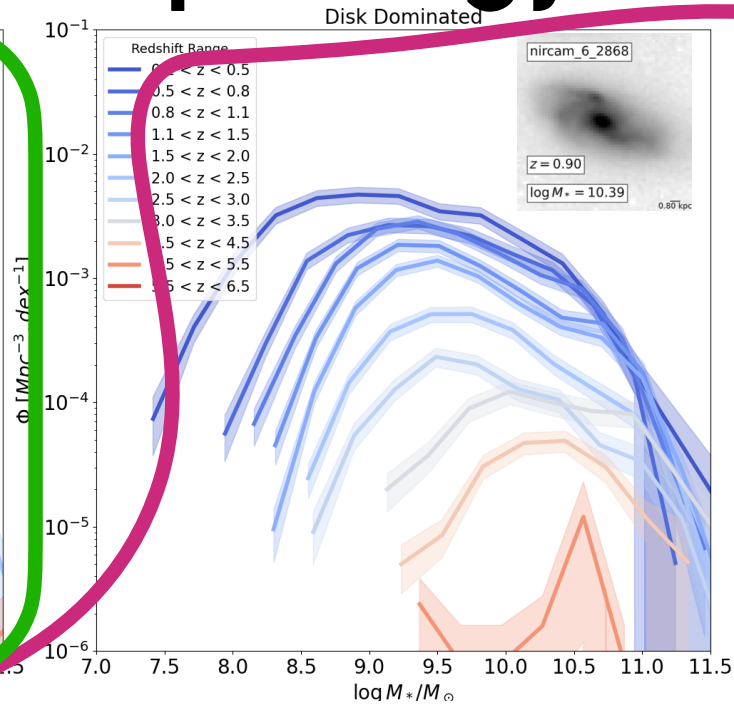
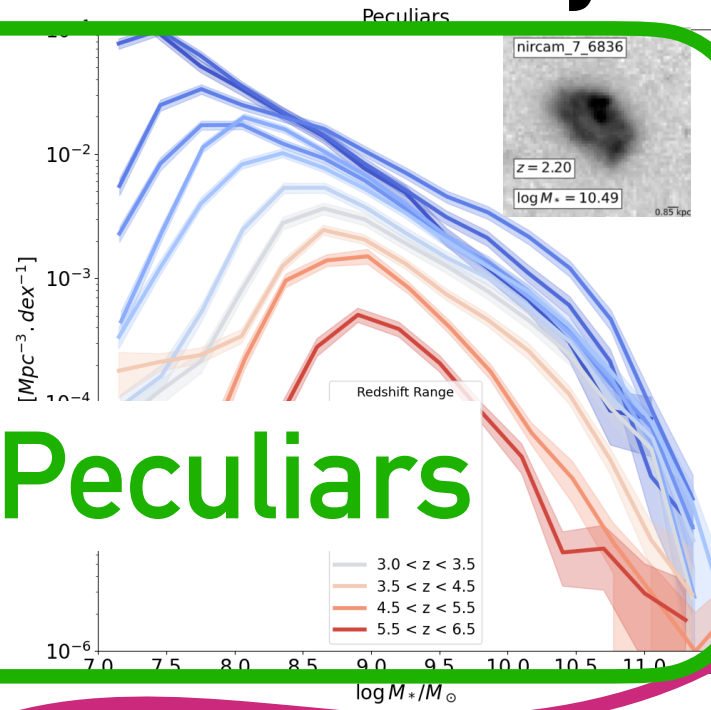
**A negligible fraction at z~2**

**~30% at z~5**

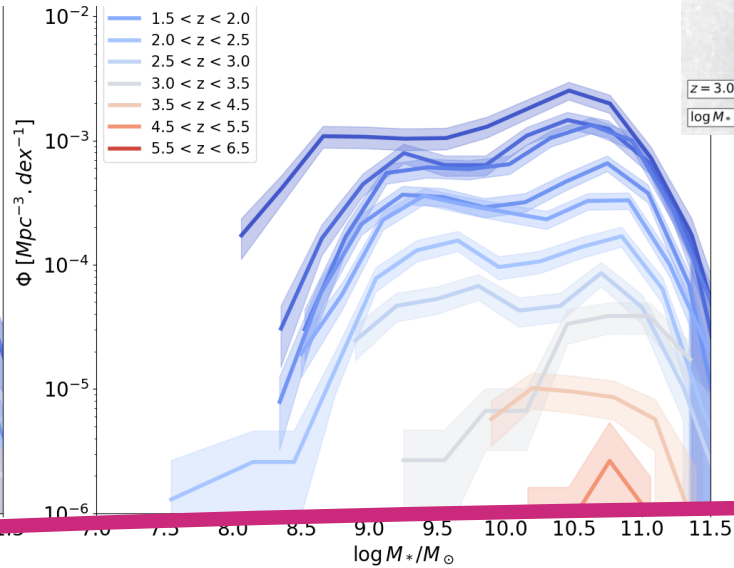
# SMFs by morphology



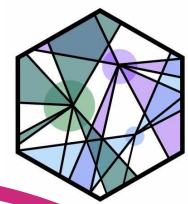
COSMOS  
WEB



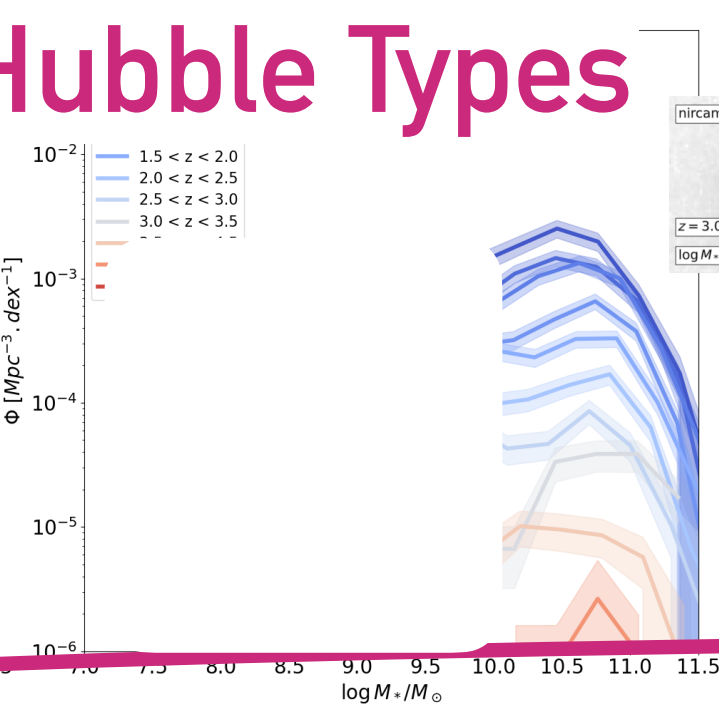
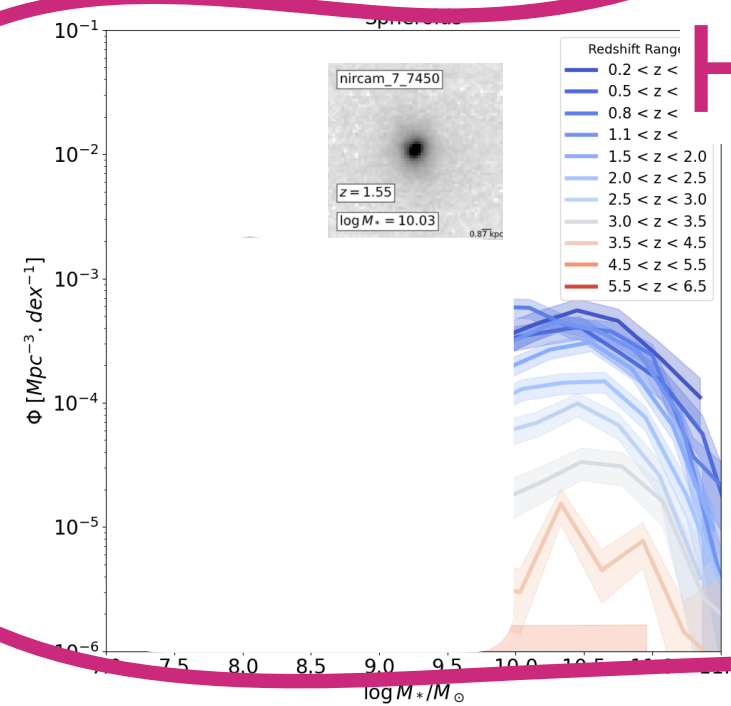
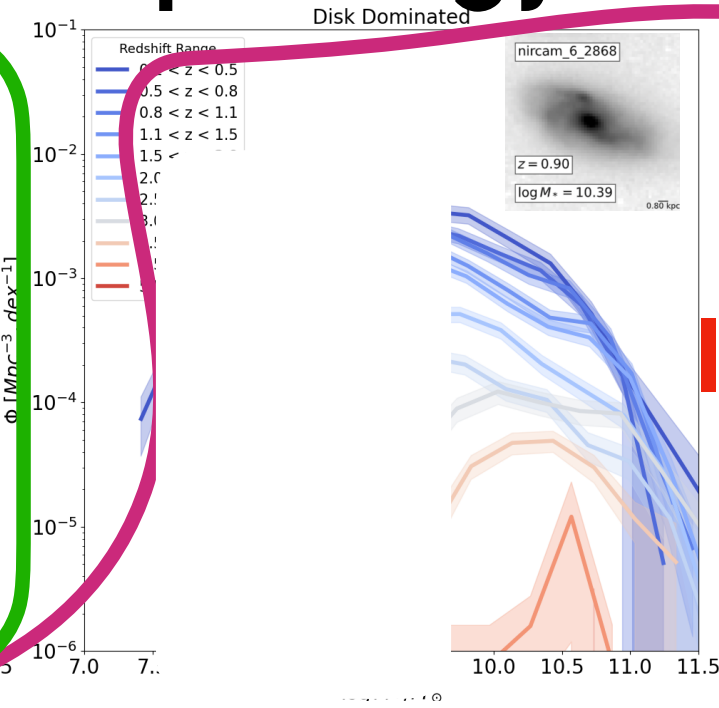
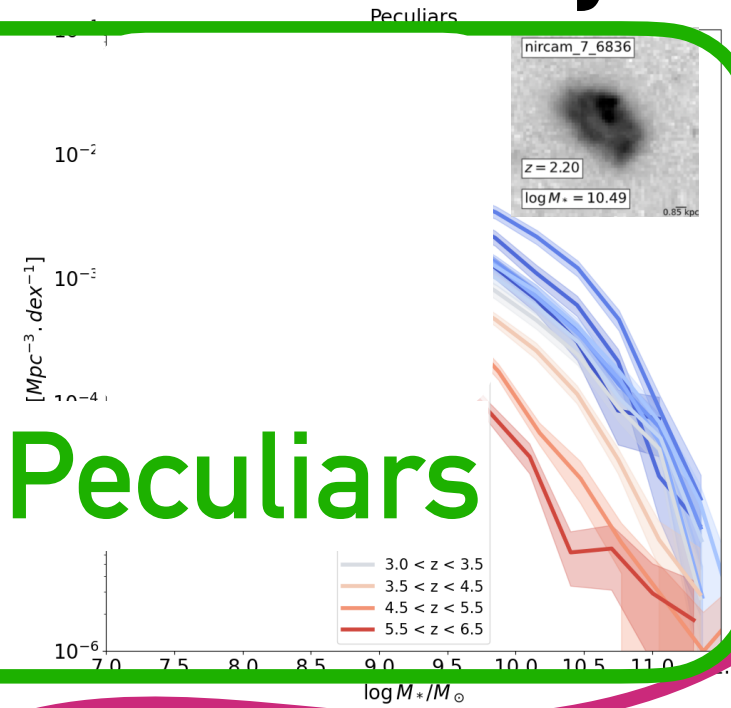
## Hubble Types



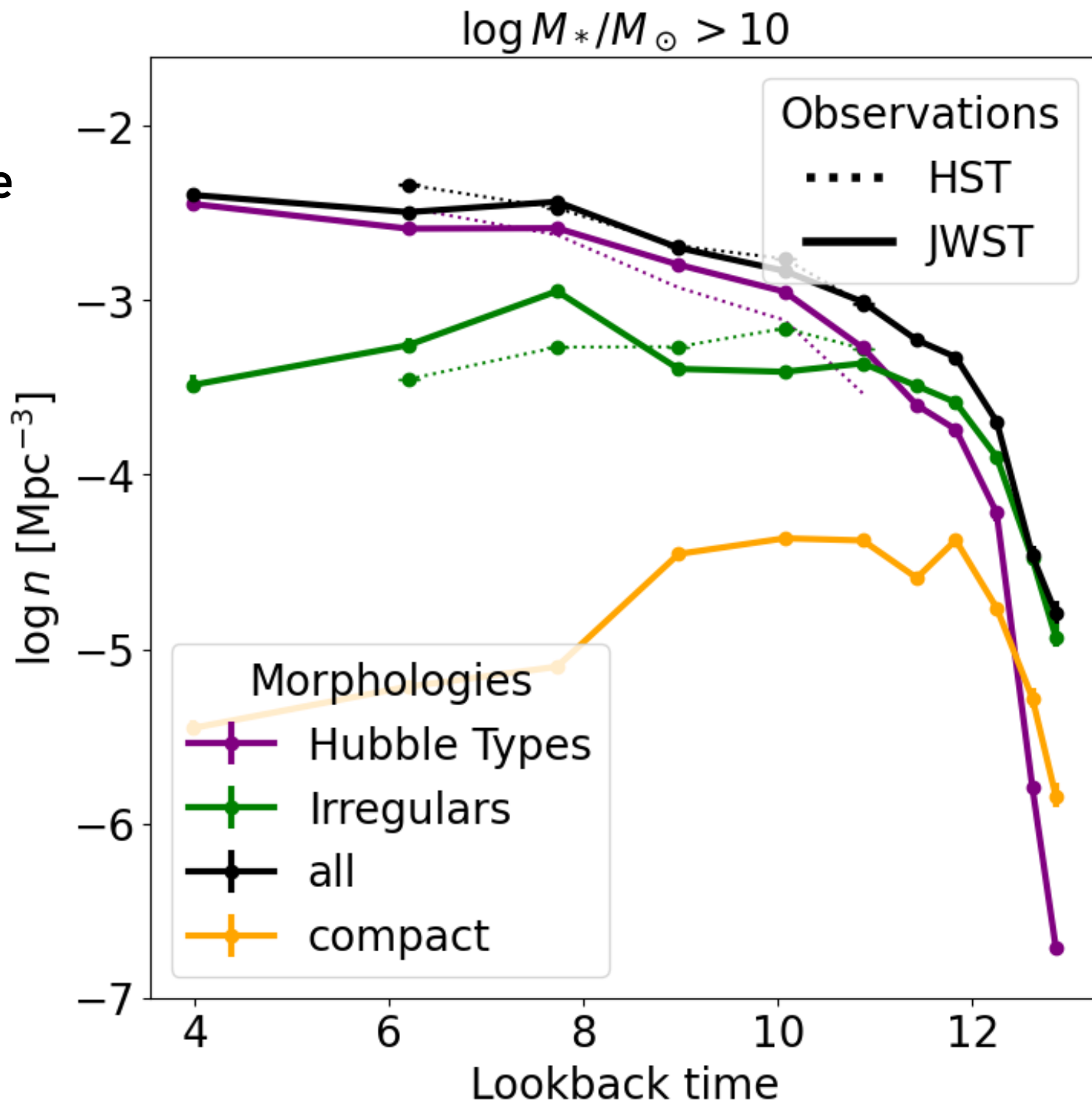
# SMFs by morphology



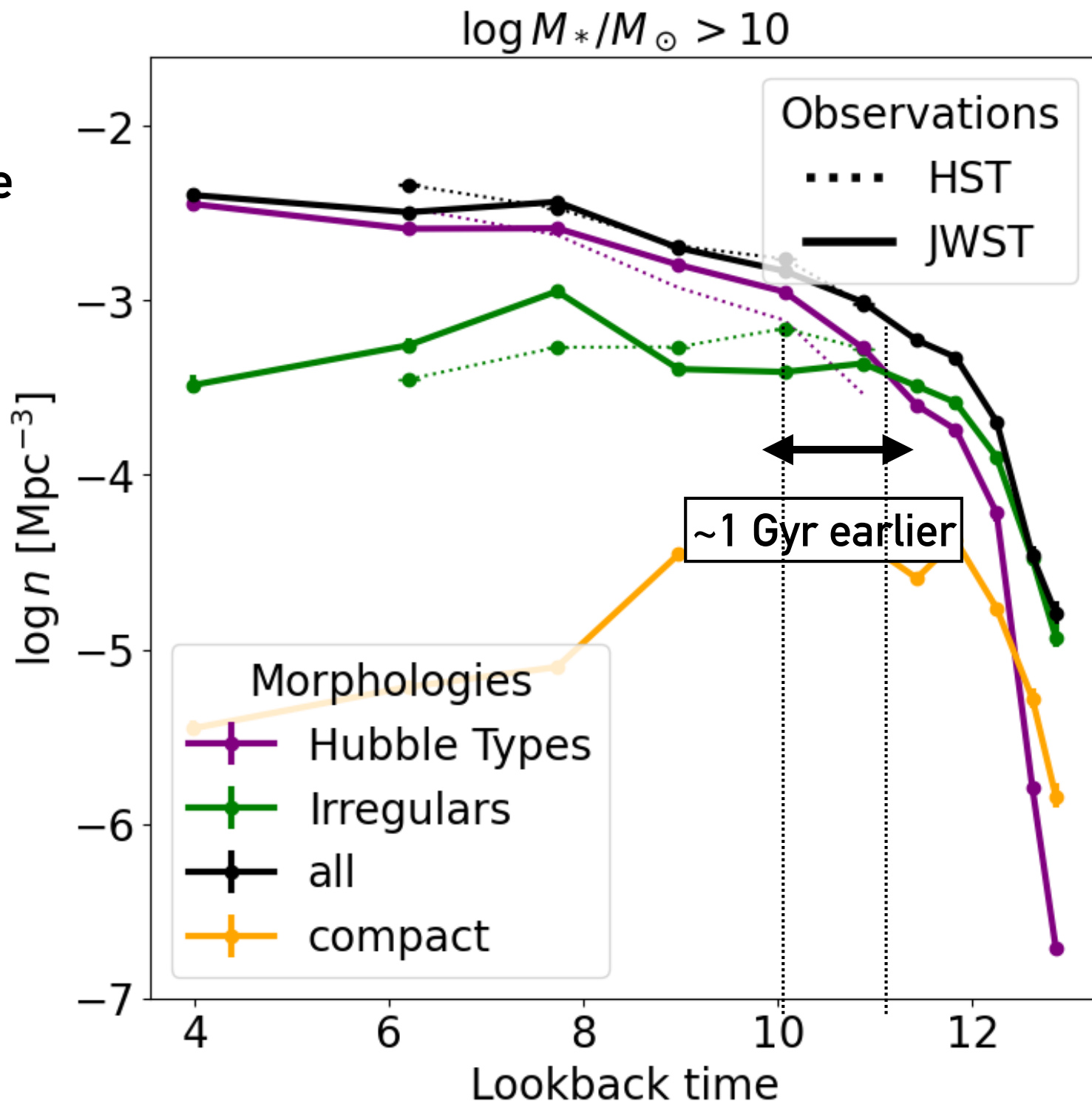
COSMOS  
WEB



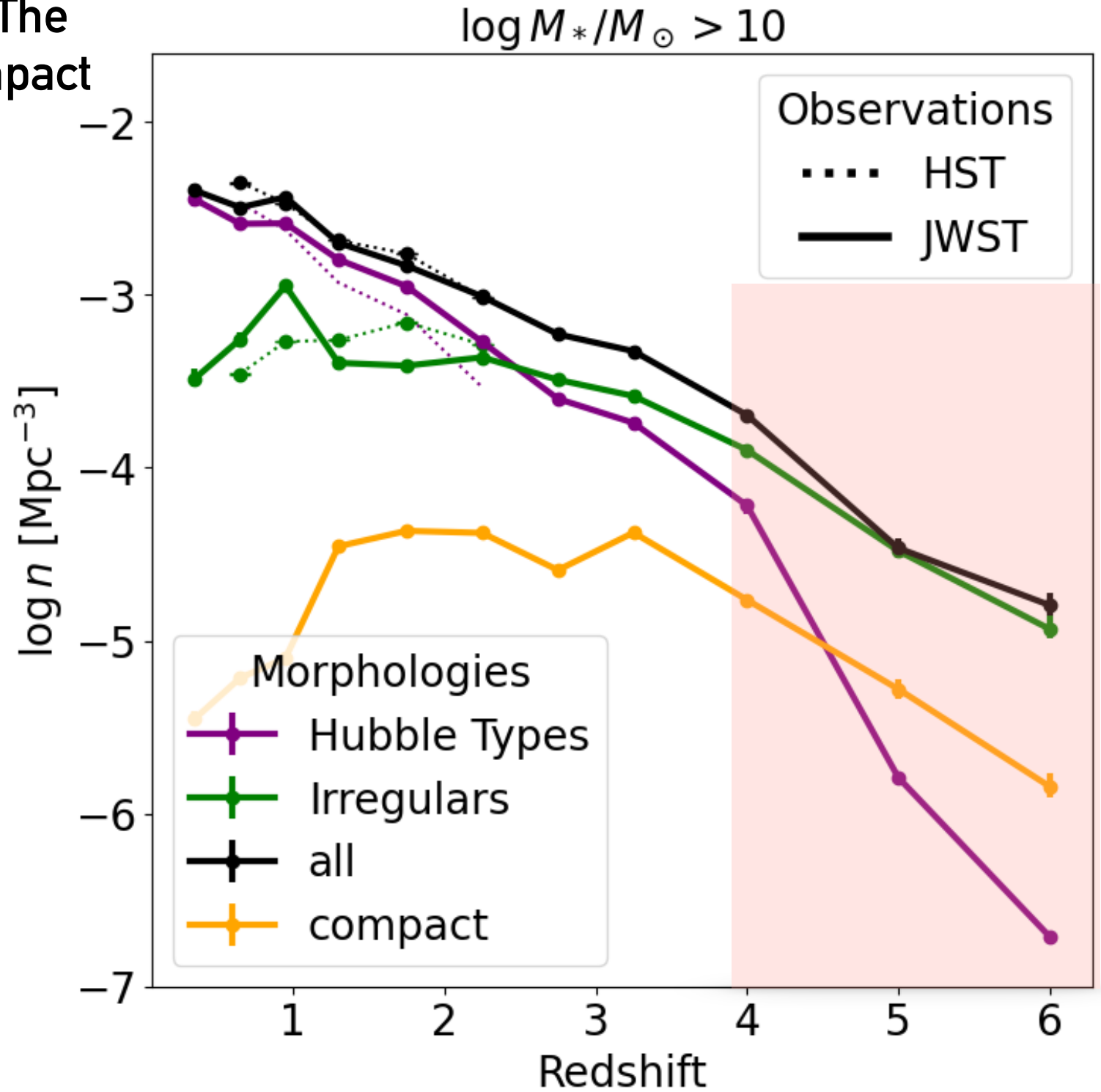
The emergence  
of the  
Hubble sequence  
as seen  
by  
JWST



The emergence  
of the  
Hubble sequence  
as seen  
by  
JWST

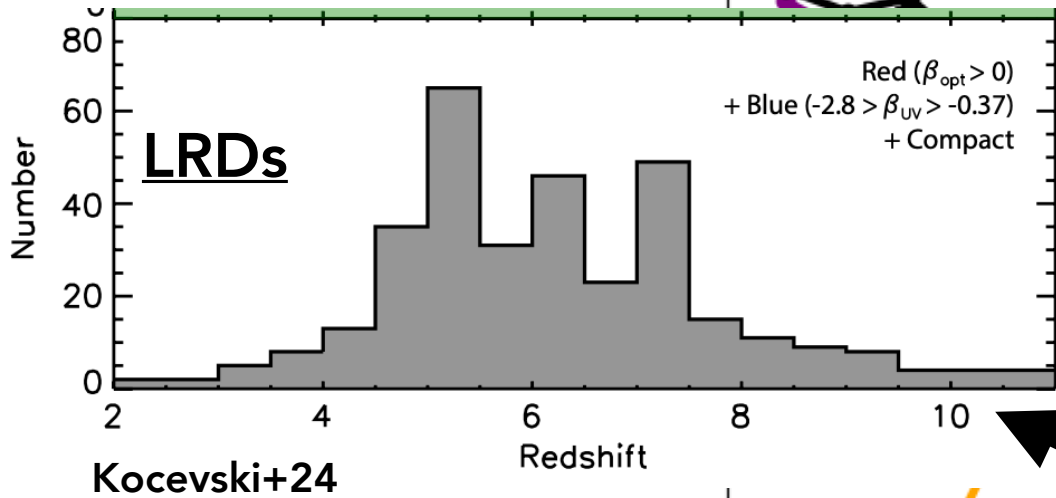


# Cosmic Dawn: The clumpy and compact phase



# Cosmic Dawn: The clumpy and compact phase

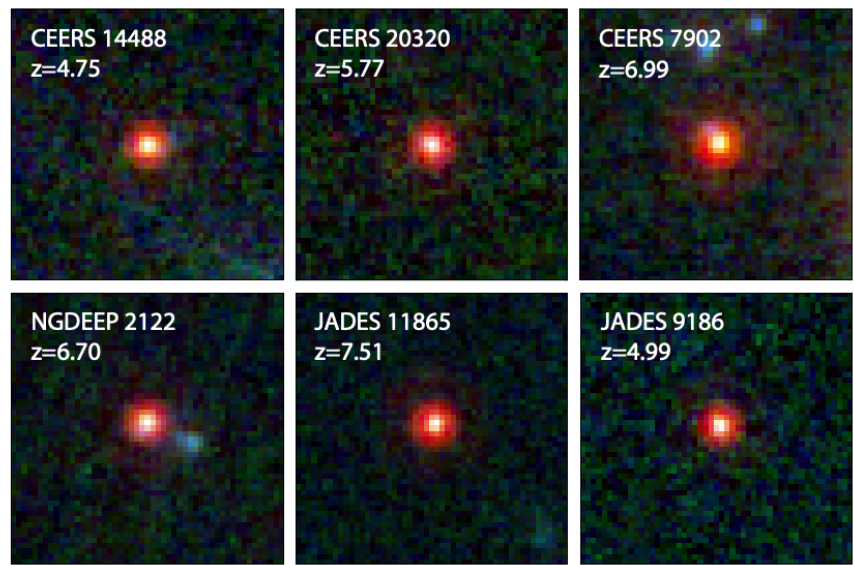
$\log M_*/M_\odot > 10$



ogn

Observations

- ..... HST
- JWST

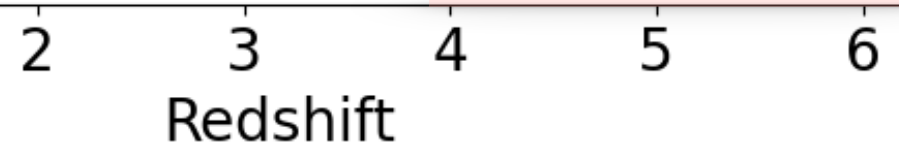


Morphologies

Hubble Types

Irregulars

all compact



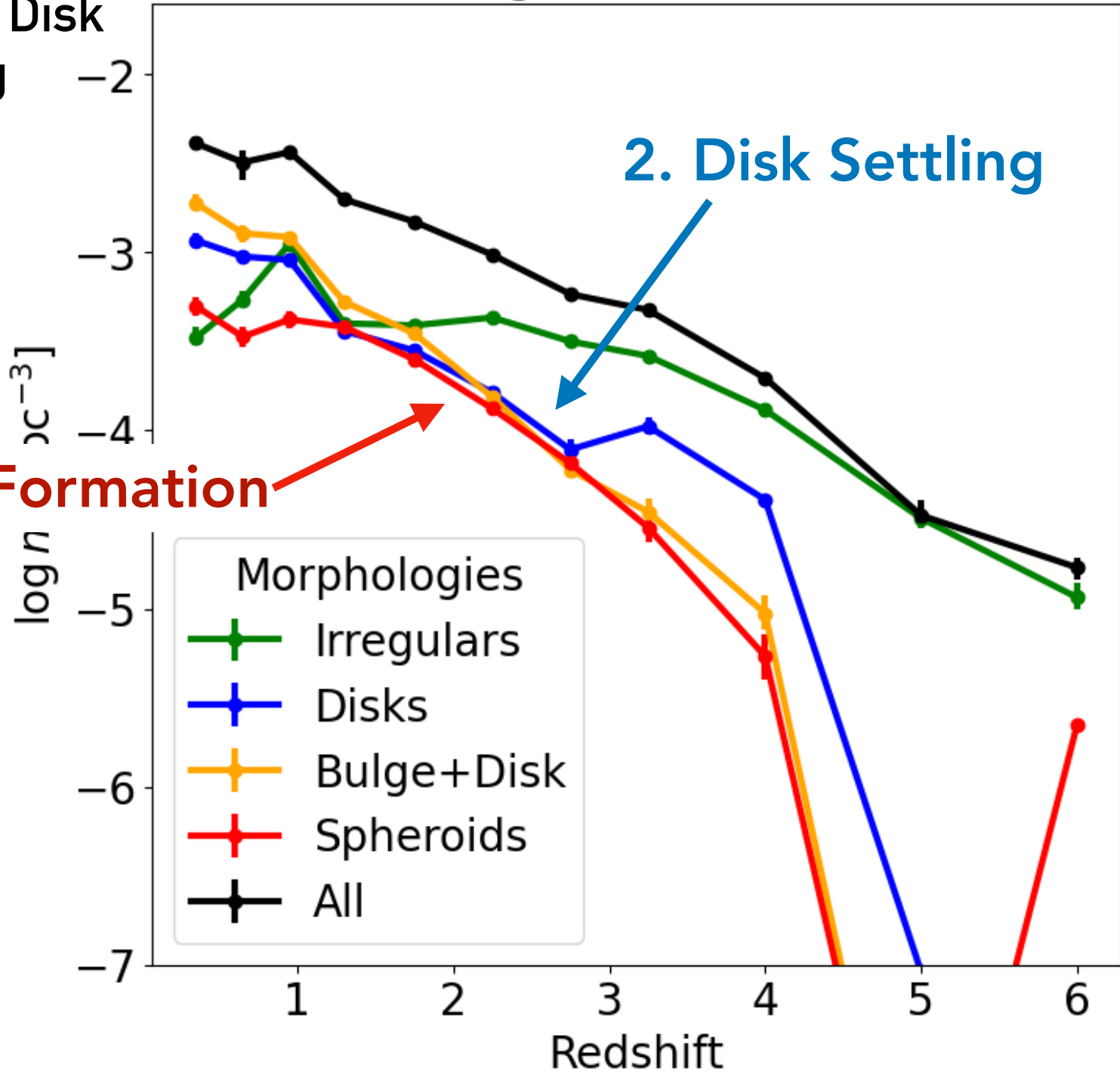


**Cosmic Dawn: Bulge  
Growth and Disk  
Settling**

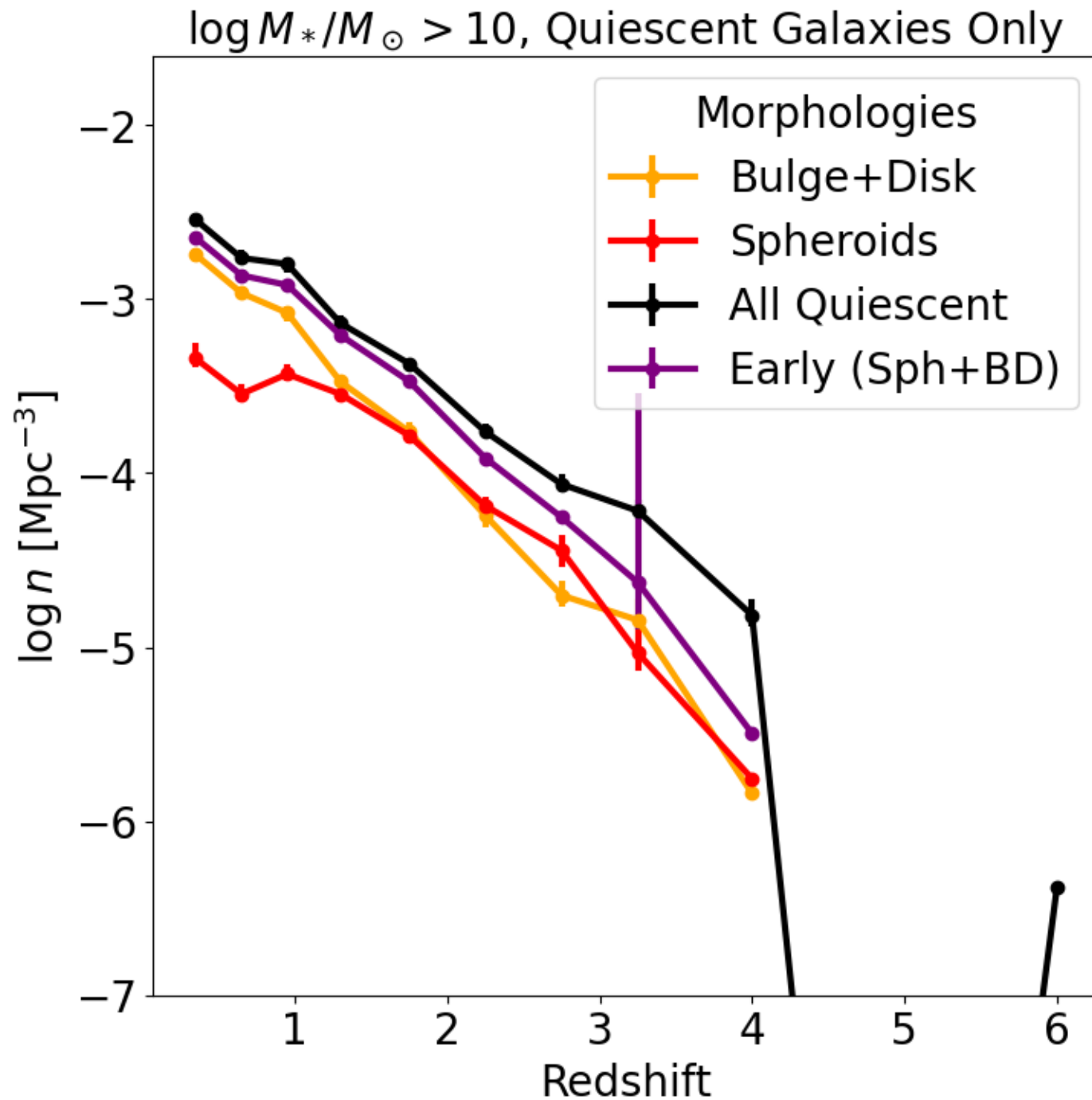
$\log M_*/M_\odot > 10$

**1. Bulge Formation**

**2. Disk Settling**



# Bulge formation tracks quenching



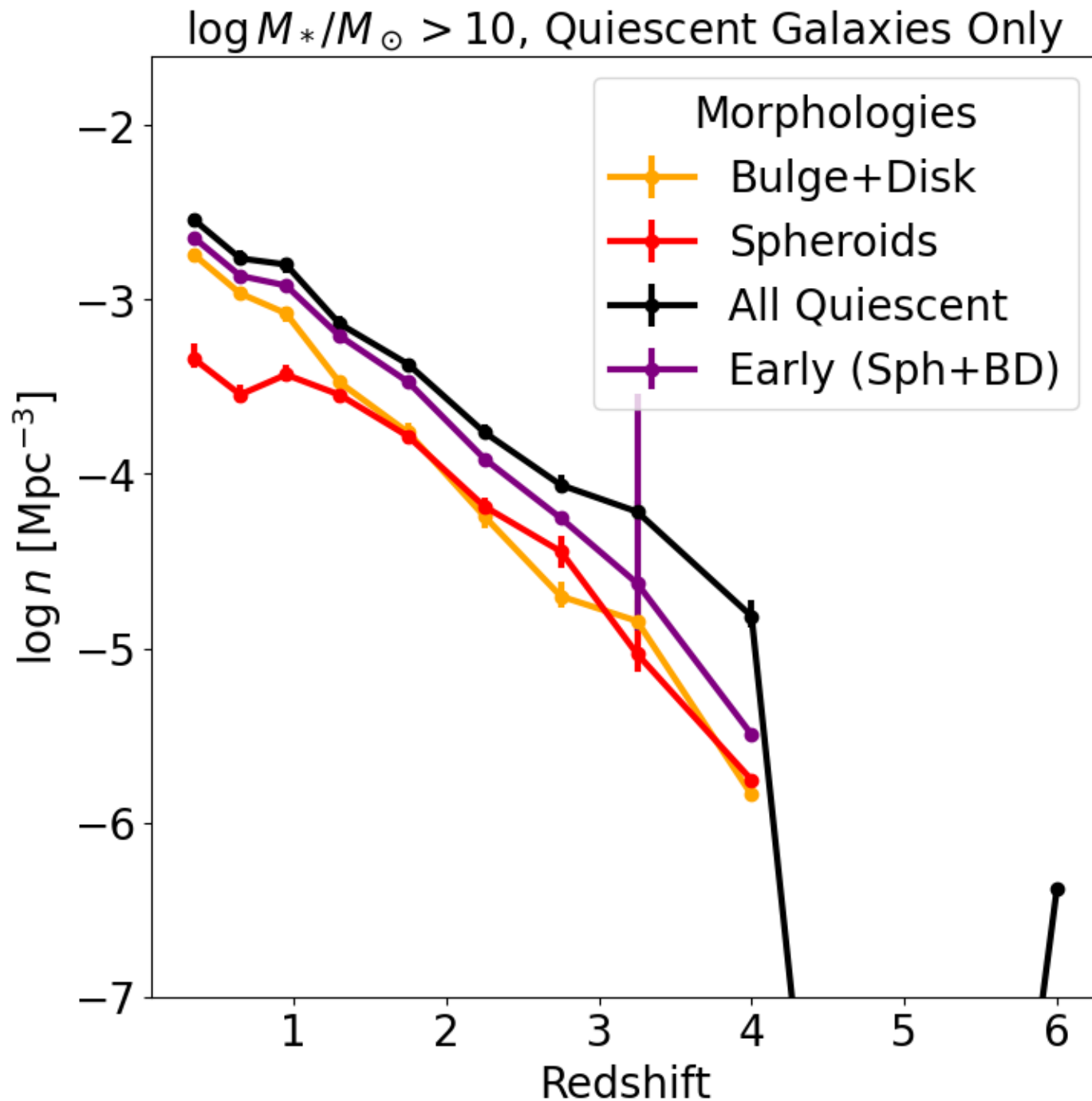
(See also talk by M. Shuntov)

# Bulge formation tracks quenching

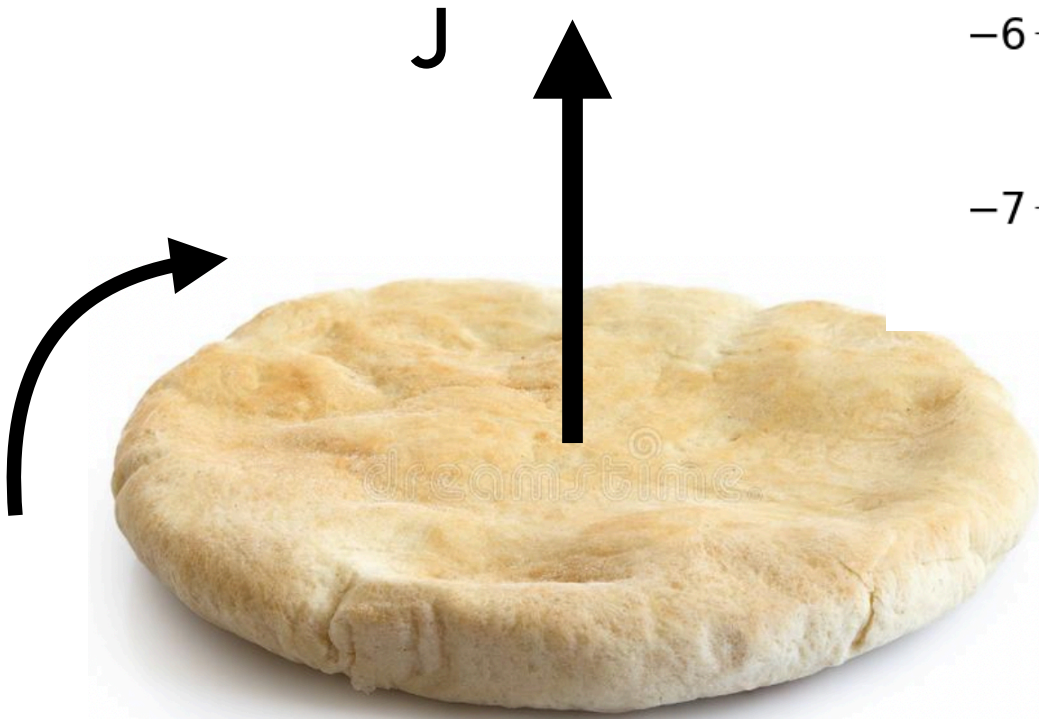
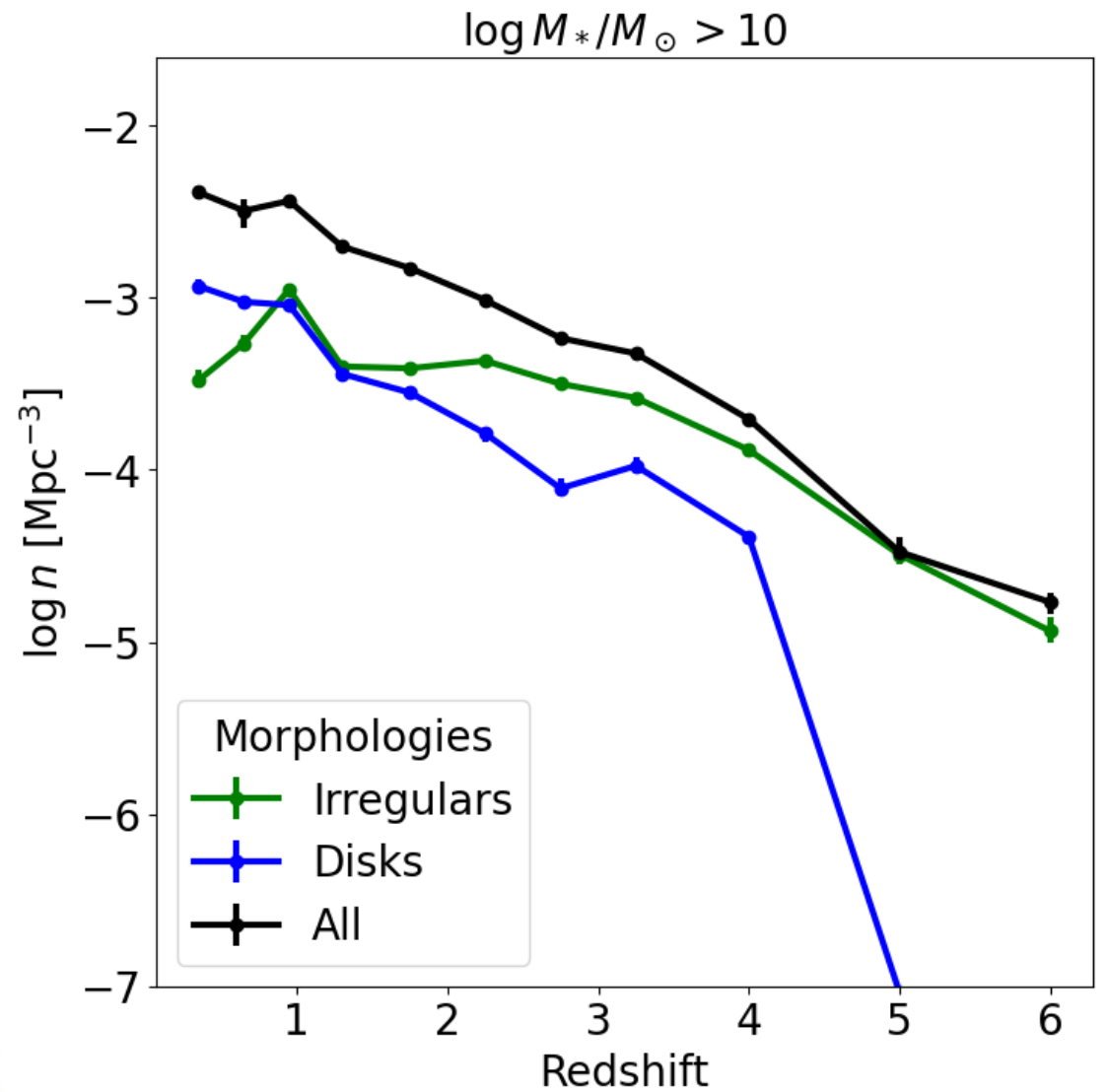
1. Little room for progenitor bias

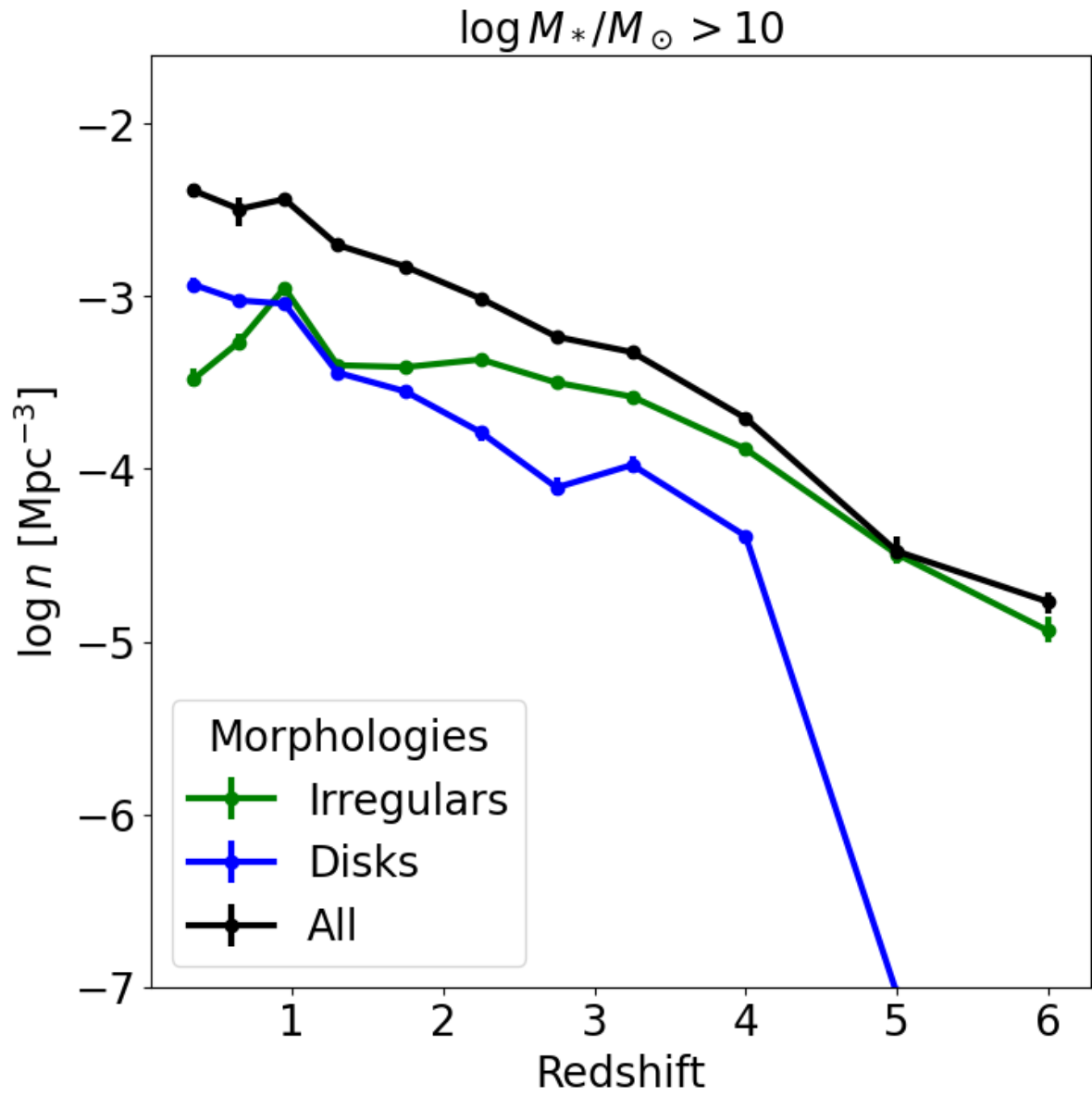
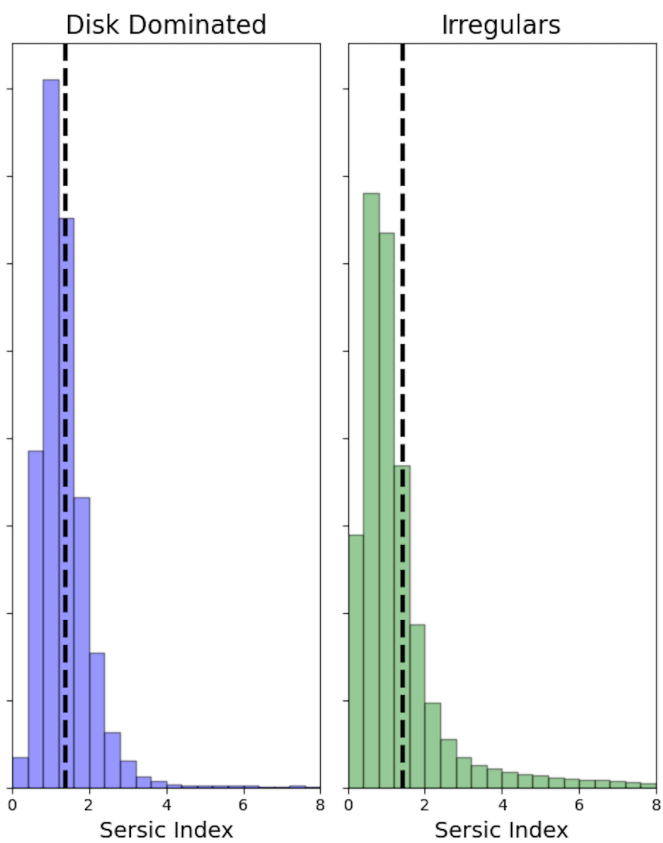
2. The difference between “true quenching” and “napping” might be in the morphological transformation

(See also talk by M. Shuntov)

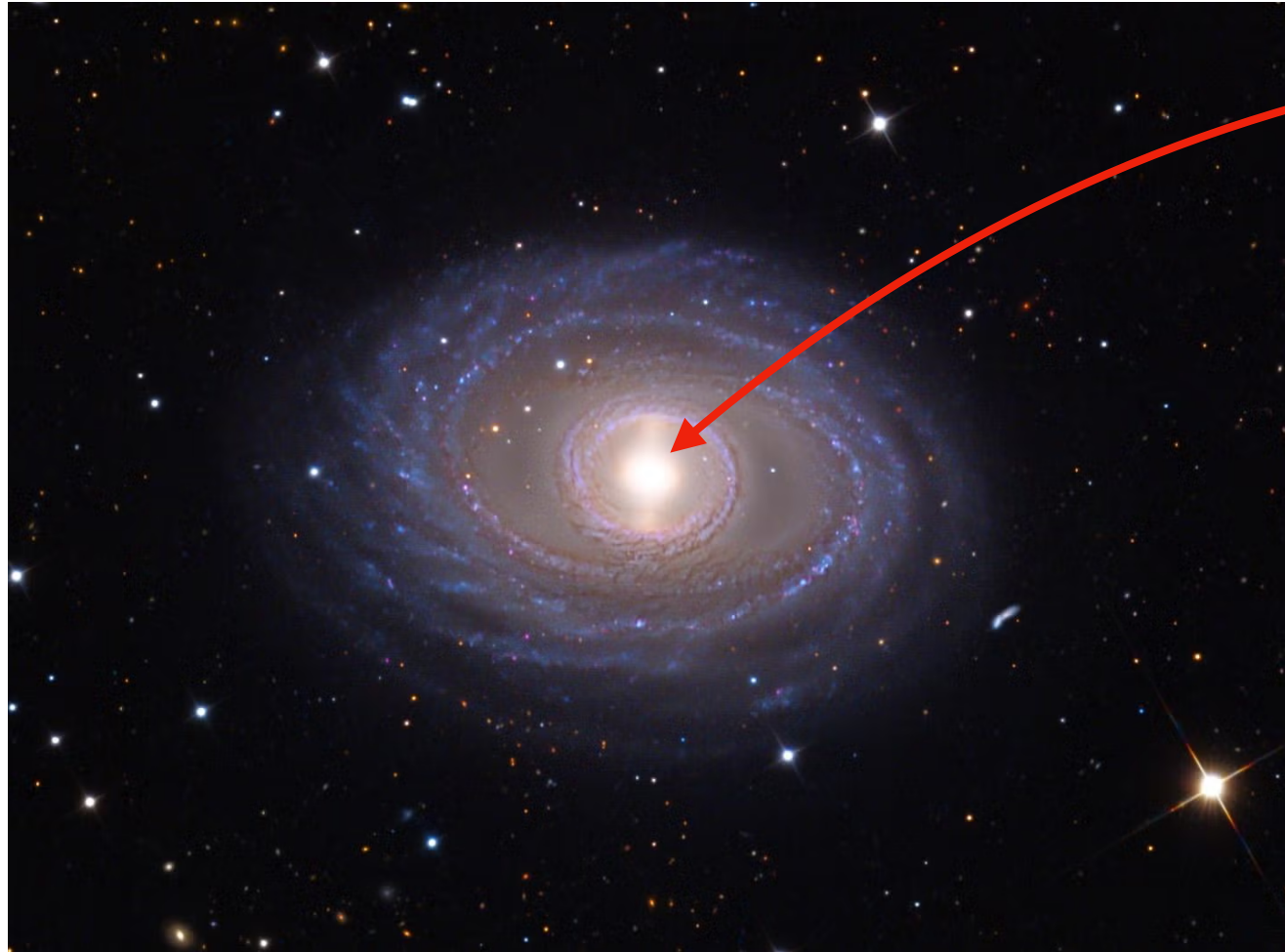


Disk Settling: are these galaxies true cold disks?





# Hunting the emergence of dynamically cold disks through bars



Stellar Bars



# Pathfinder

LLM enabled literature search

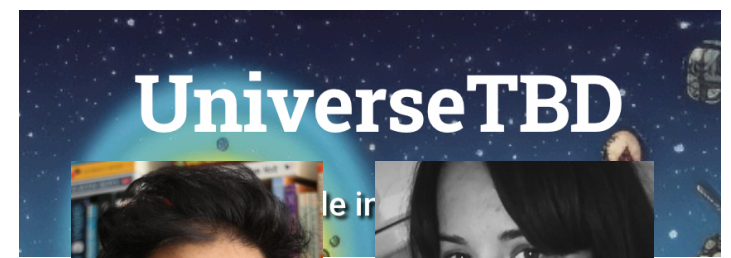


[huggingface.co](https://huggingface.co)

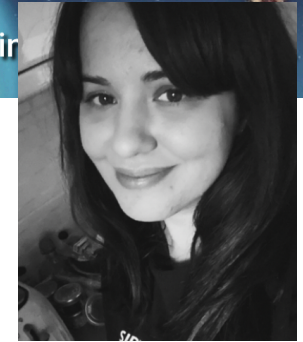
Ask me anything:

how are stellar bars formed

lyer+24



**K. Iyer**



**I. Ciuca**



# Pathfinder

LLM enabled literature search

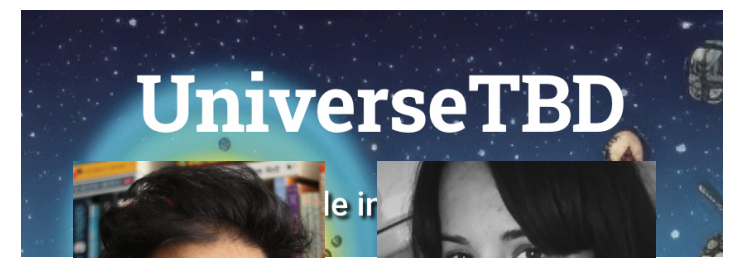


huggingface.co

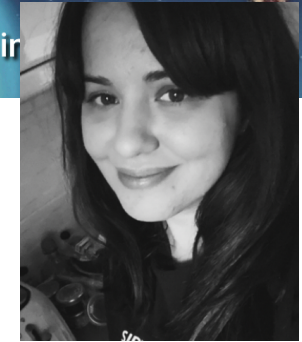
Ask me anything:

how are stellar bars formed

Iyer+24



**K. Iyer**



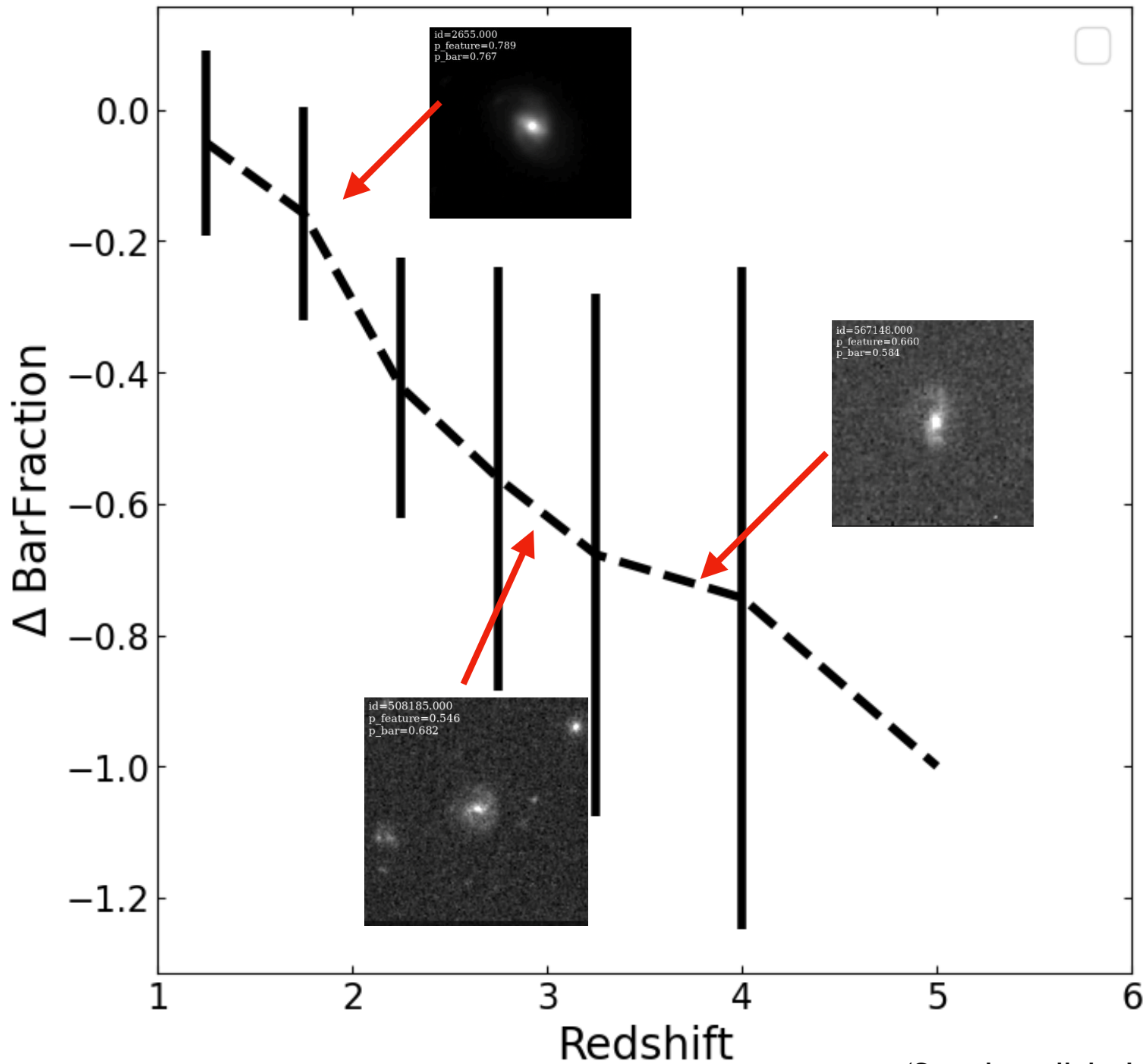
**I. Ciuca**

To understand how stellar bars are formed in galaxies, we can break down the process into several key steps:

1. **Galactic Structure:** Stellar bars are non-axisymmetric structures that typically form in the disks of spiral galaxies. They are characterized by a linear arrangement of stars that extends across the center of the galaxy.
2. **Conditions for Formation:** The formation of stellar bars is often linked to the dynamics of the stellar disk. A crucial factor is the stability of the disk. If the disk is sufficiently cold (i.e., has low velocity dispersion), it can become dynamically unstable, leading to the formation of a bar. This is referred to as "bar instability."
3. **Role of Dark Matter Halos:** The presence of a mildly triaxial cold dark matter (CDM) halo can influence the formation of bars. The gravitational potential created by the dark matter can help stabilize the disk and facilitate the conditions necessary for bar formation.
4. **Evolution of Bars:** Once formed, stellar bars can evolve over time. They tend to increase in both linear and vertical extents, which can affect the overall dynamics of the galaxy. The properties of the bars can show recurrent behavior, meaning they may undergo cycles of growth and decay.
5. **Mass Dependency:** The likelihood of bar formation can depend on the mass of the galaxy. Lower mass galaxies may not form bars as readily because they can be dynamically hotter, meaning their stars have higher velocity dispersions, which can inhibit the conditions necessary for bar instability.

In summary, stellar bars form through a combination of dynamic instability in a cold stellar disk, influenced by the gravitational effects of dark matter halos, and are subject to evolutionary changes over time. The mass of the galaxy plays a significant role in whether or not bars can form.





Galaxy Zoo



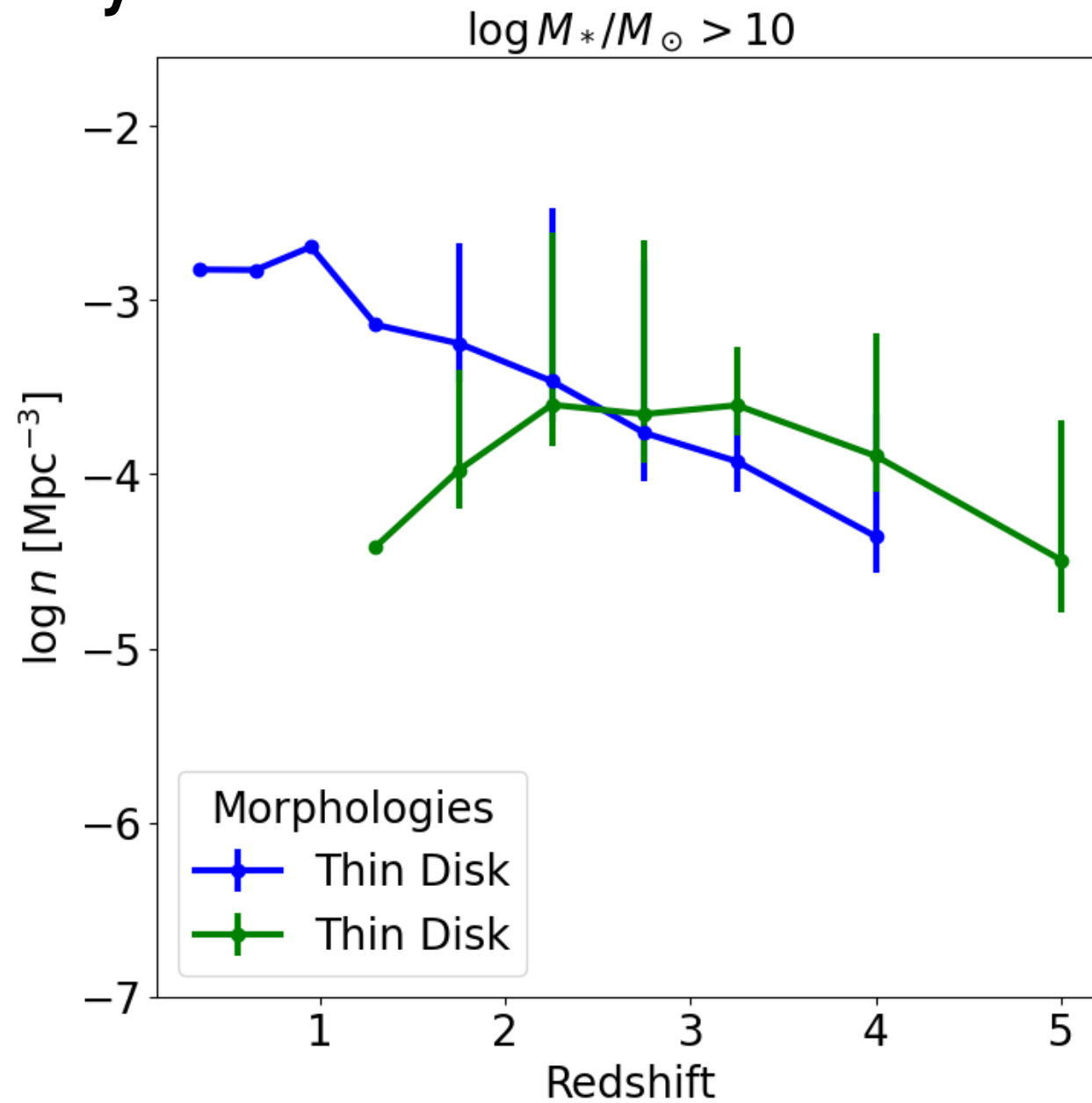
huggingface.co

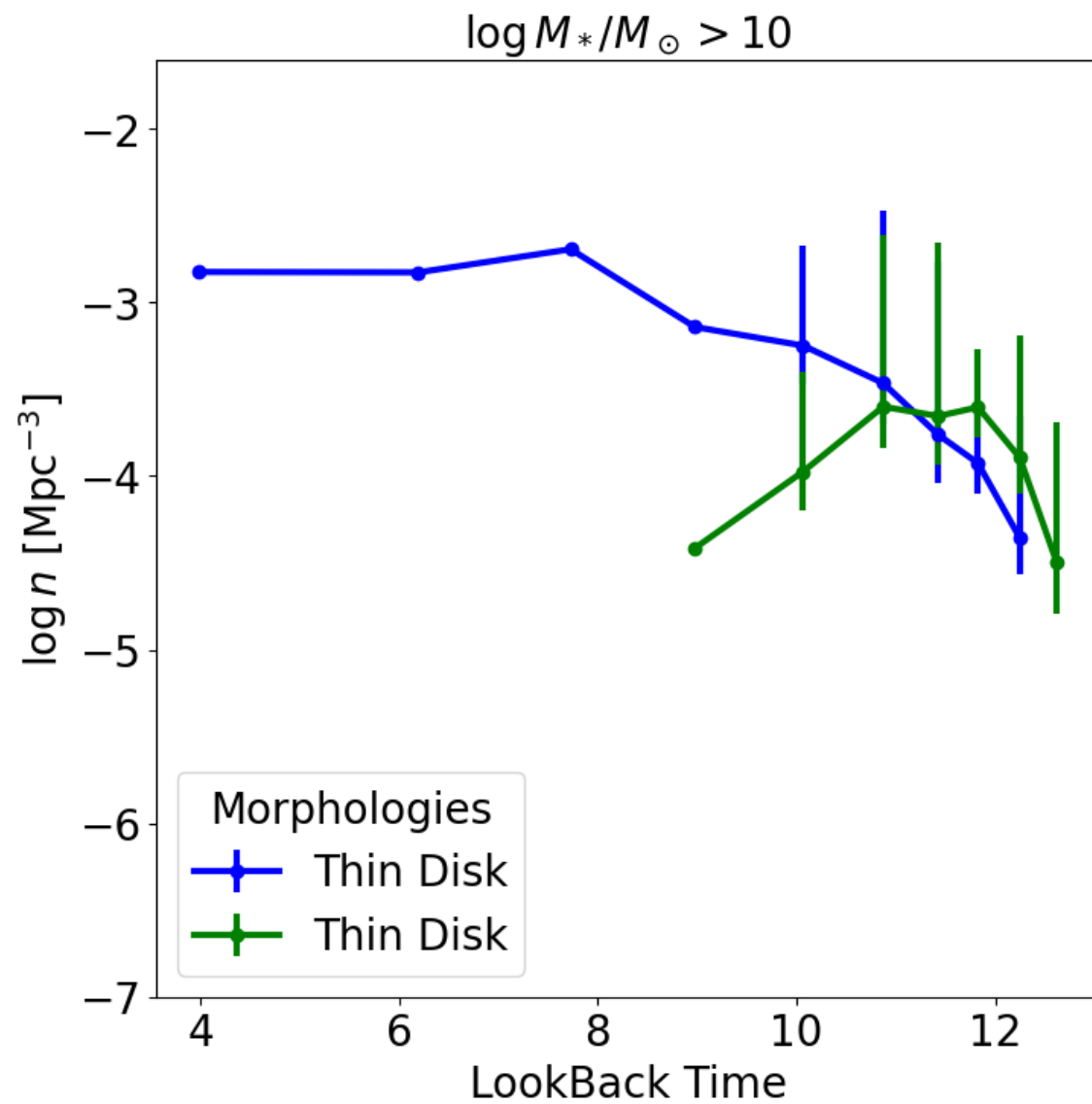
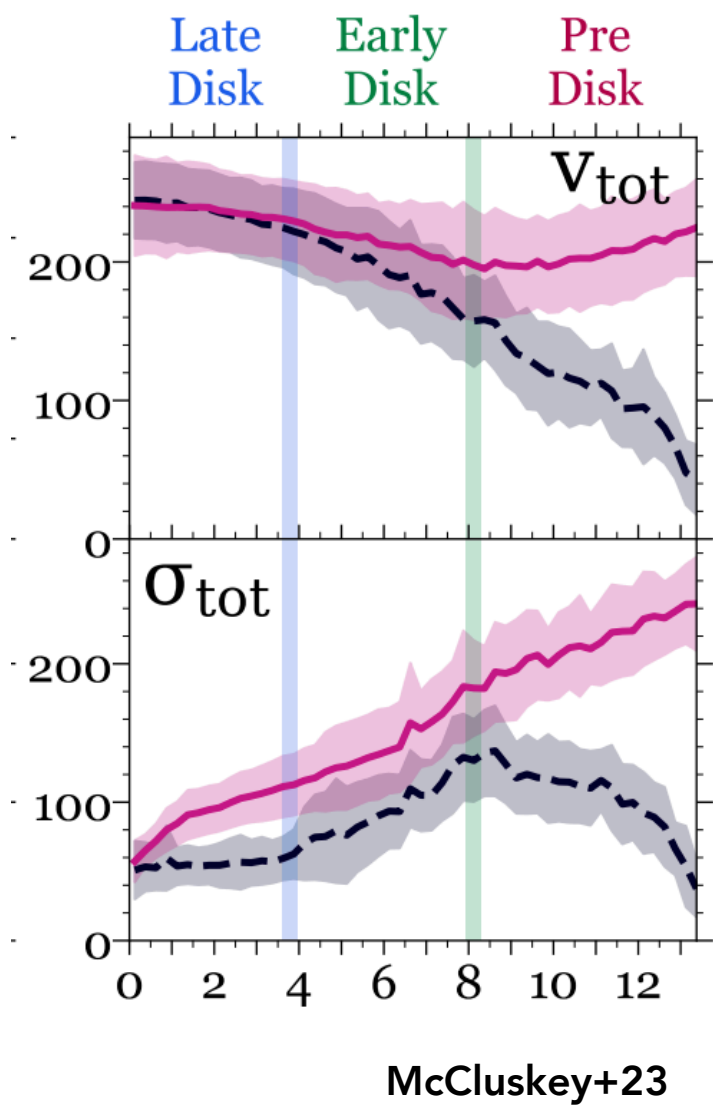


Zoobot

(See also talk by L. Costantin)

# Preliminary

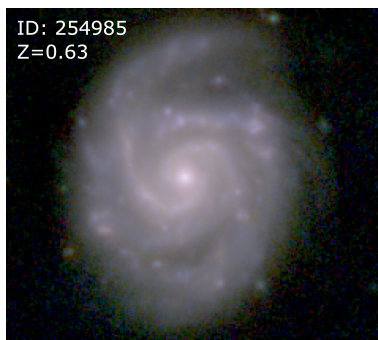
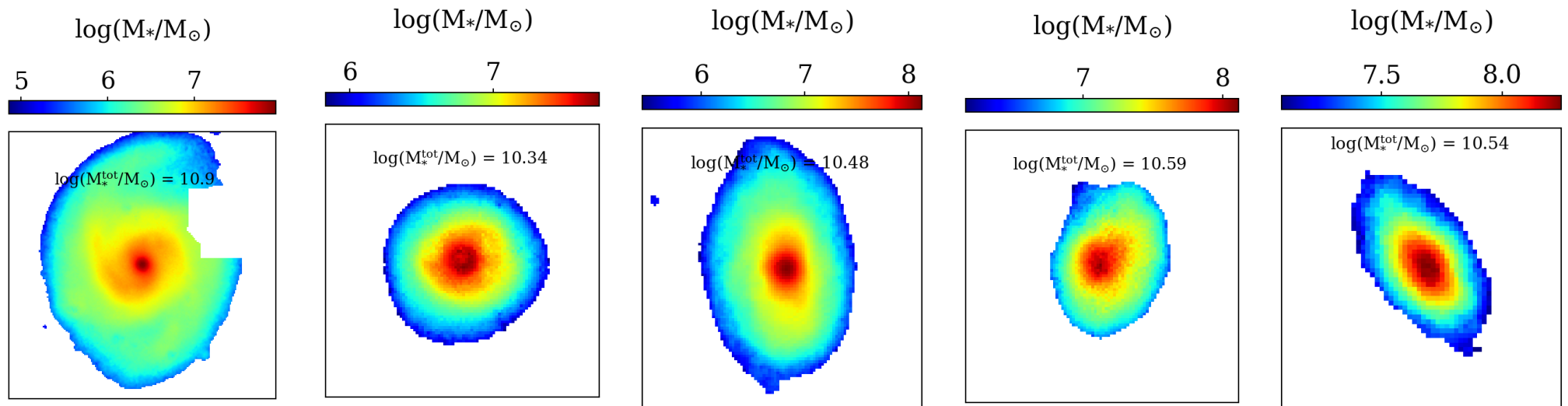




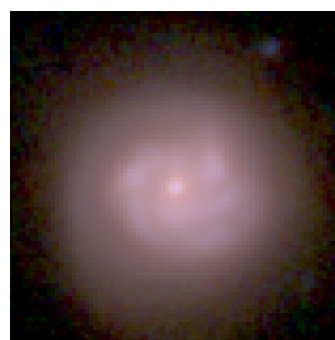
# ML based Simulation Based Inference of resolved stellar populations



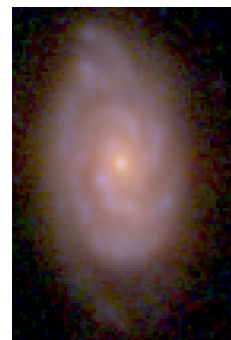
P. Iglesias-Navarro



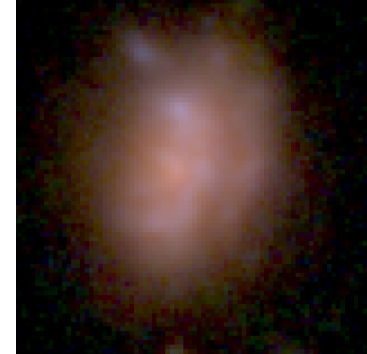
$z=0.63$



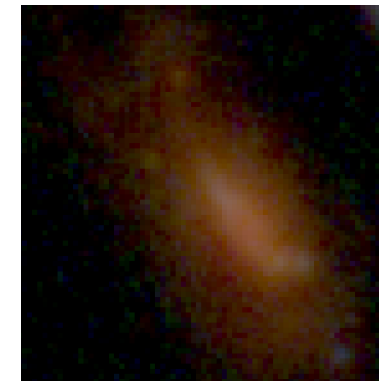
$z=1.09$



$z=1.29$



$z=2.30$

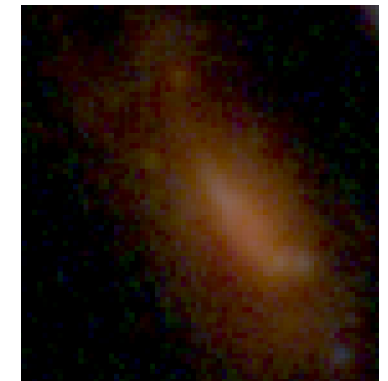
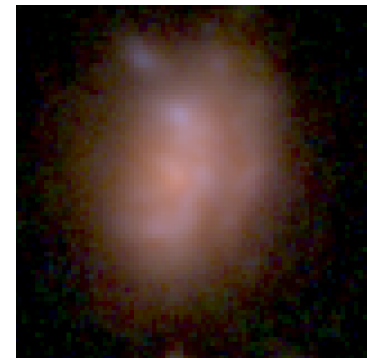
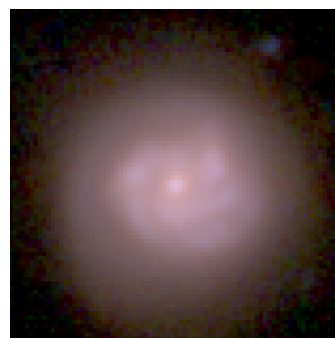
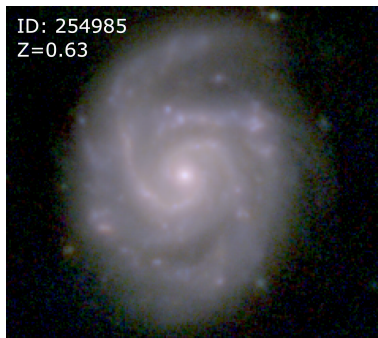
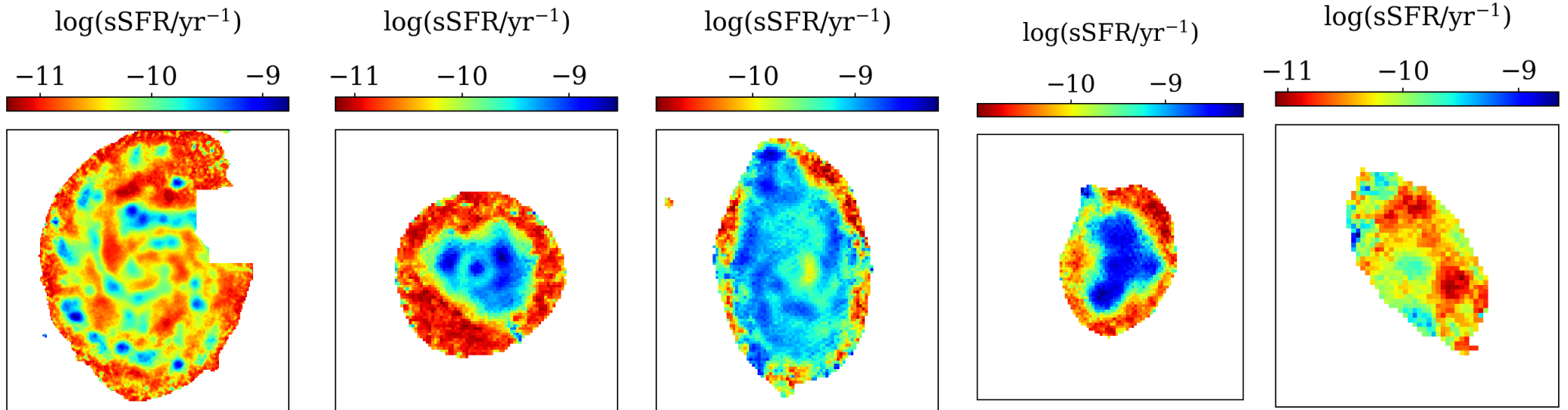


$z=3.59$

# ML based Simulation Based Inference of resolved stellar populations



P. Iglesias-Navarro



**z=0.63**

**z=1.09**

**z=1.29**

**z=2.30**

**z=3.59**

# Summary and Conclusions

- From a pure morphological point of view: JWST finds that **Hubble Types dominate among massive galaxies since  $\sim 11$  ( $z \sim 3$ ) billion years ago**
- **At  $z > 4$ : compact galaxies represent  $\sim 30\%$  of the galaxy population**
- **Bulge growth and quenching linked since  $z \sim 4$**  - Morphology as a tracer of permanent quenching?
- The internal structure (bars) suggests that **cold stellar disks might be common since  $z \sim 2$** . Impact of **selection biases** needs to be calibrated.
- Future - Moving to **more physical space: resolved stellar populations, stellar kinematics?**