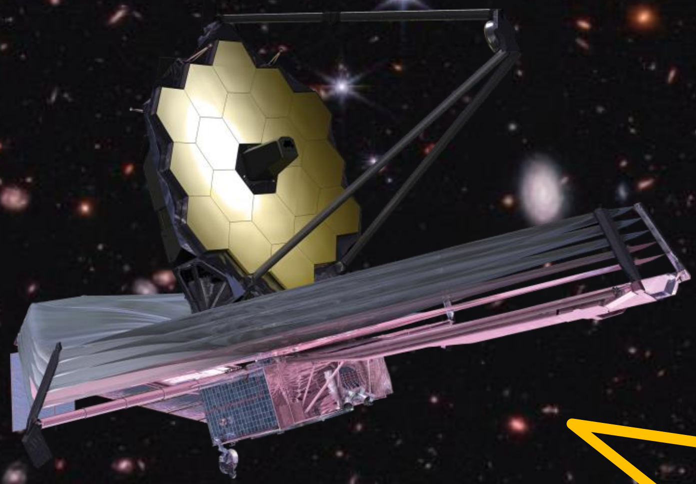
Survey Science Group Workshop 2025

(Session Ⅰ. Space Missions)

Recent Studies on High-redshift Galaxies with JWST

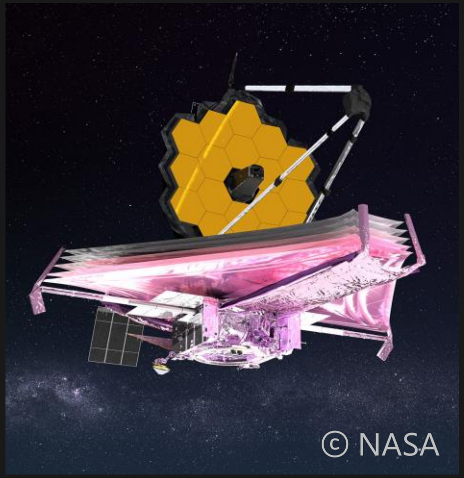


CEERS Deep Field
(NASA, ESA, CSA, and S. Finkelstein)

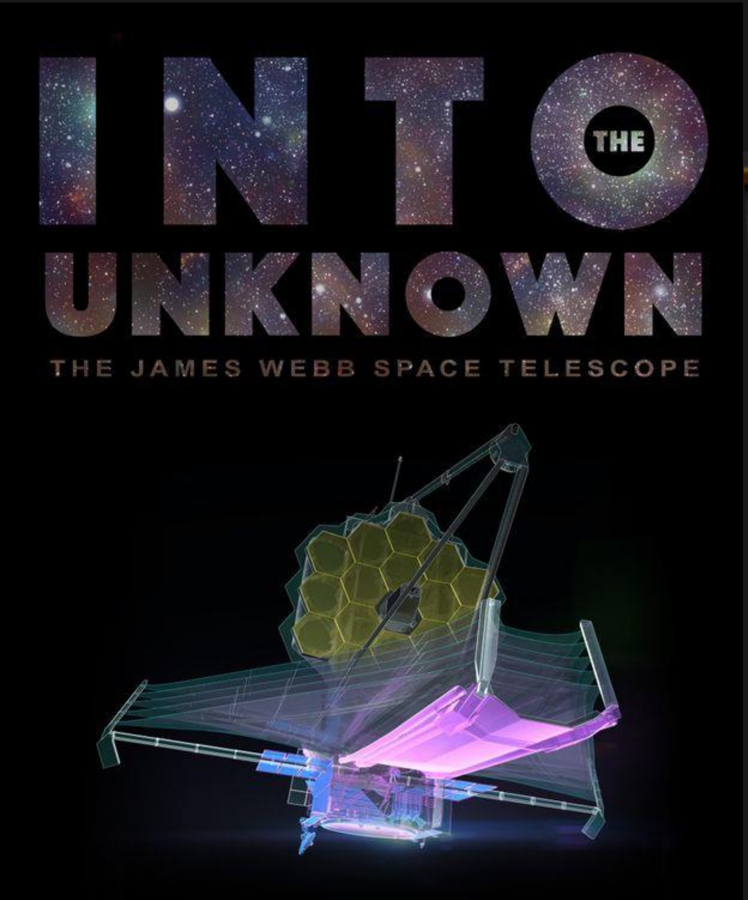
Webb's Science Themes
(© E. Wheatley)

Jeong Hwan Lee
(Seoul National Univ.)

JWST: The Most Powerful Space Telescope



- **James Webb Space Telescope (JWST)**
  - Launched on 2021 Christmas, Data released from July 2022
  - The largest (6.5m) space telescope
  - Covering near- to mid-infrared wavelengths



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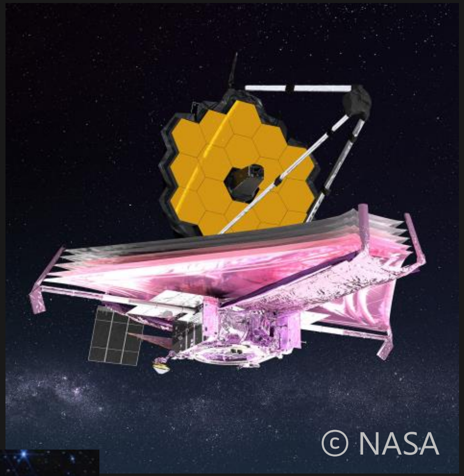

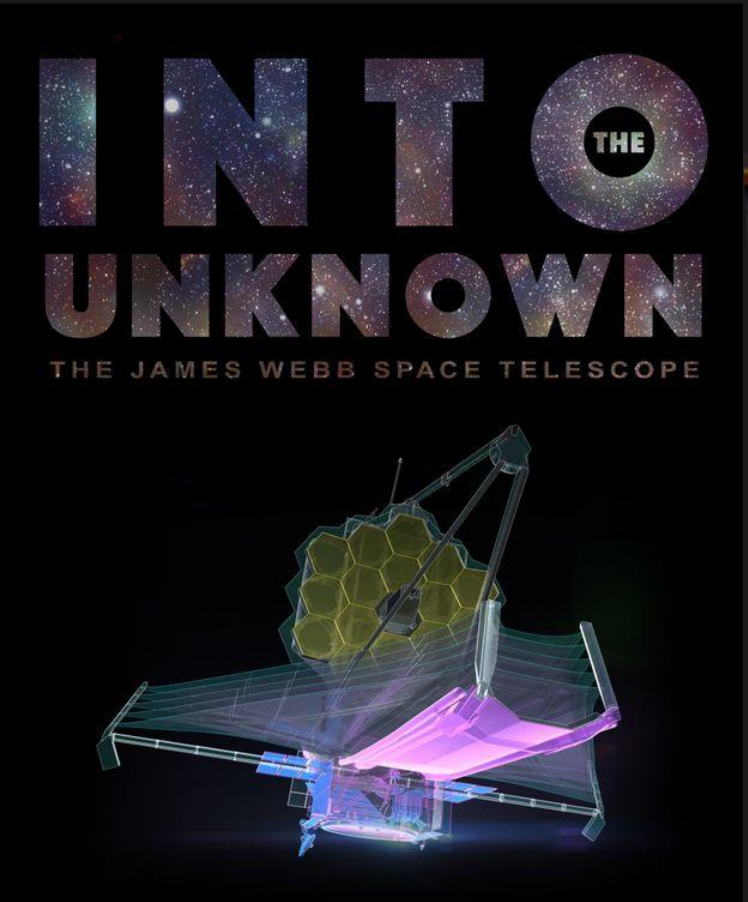

Instruments on JWST

❖ **Four main instruments on JWST:**

- Near Infrared Camera **(NIRCam)**
- Near Infrared Spectrograph **(NIRSpec)**
- Near Infrared Imager and Slitless Spectrograph **(NIRISS)**
- Mid Infrared Instrument **(MIRI)**

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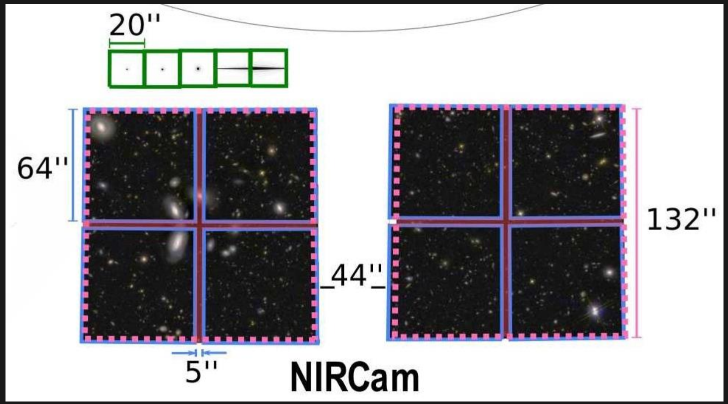

NIRCam

✓ Imaging
✓ Coronagraphic imaging
✓ Wide field slitless spectroscopy

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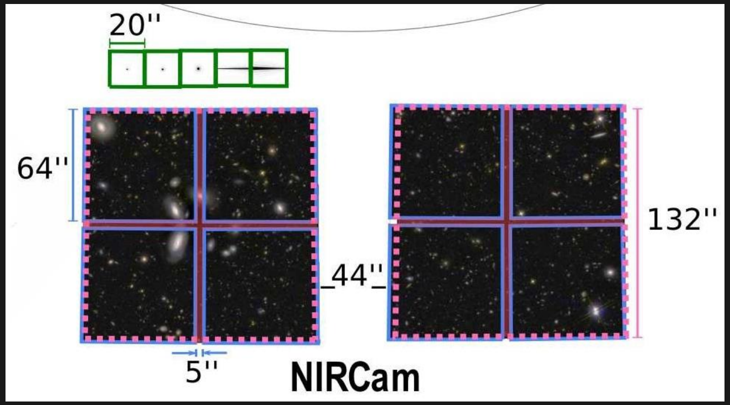

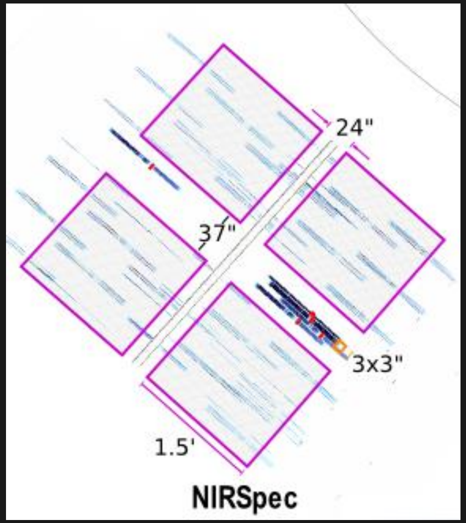

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- ✓ MOS spectroscopy
- ✓ IFU spectroscopy
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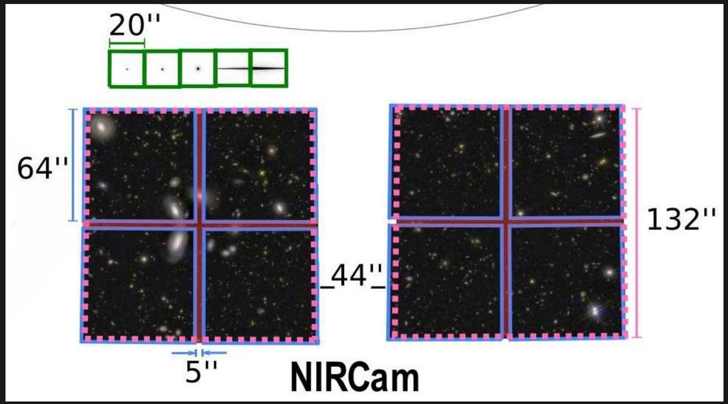

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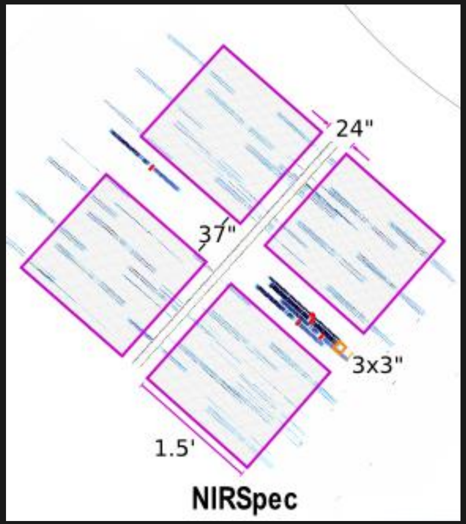

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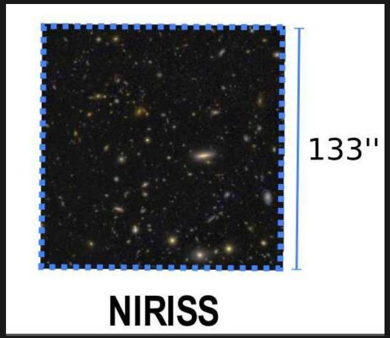
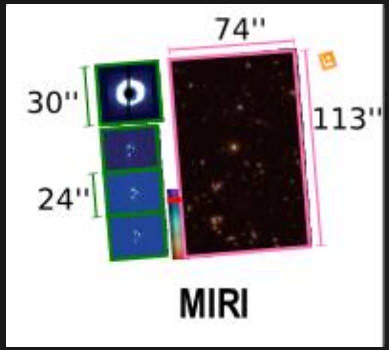


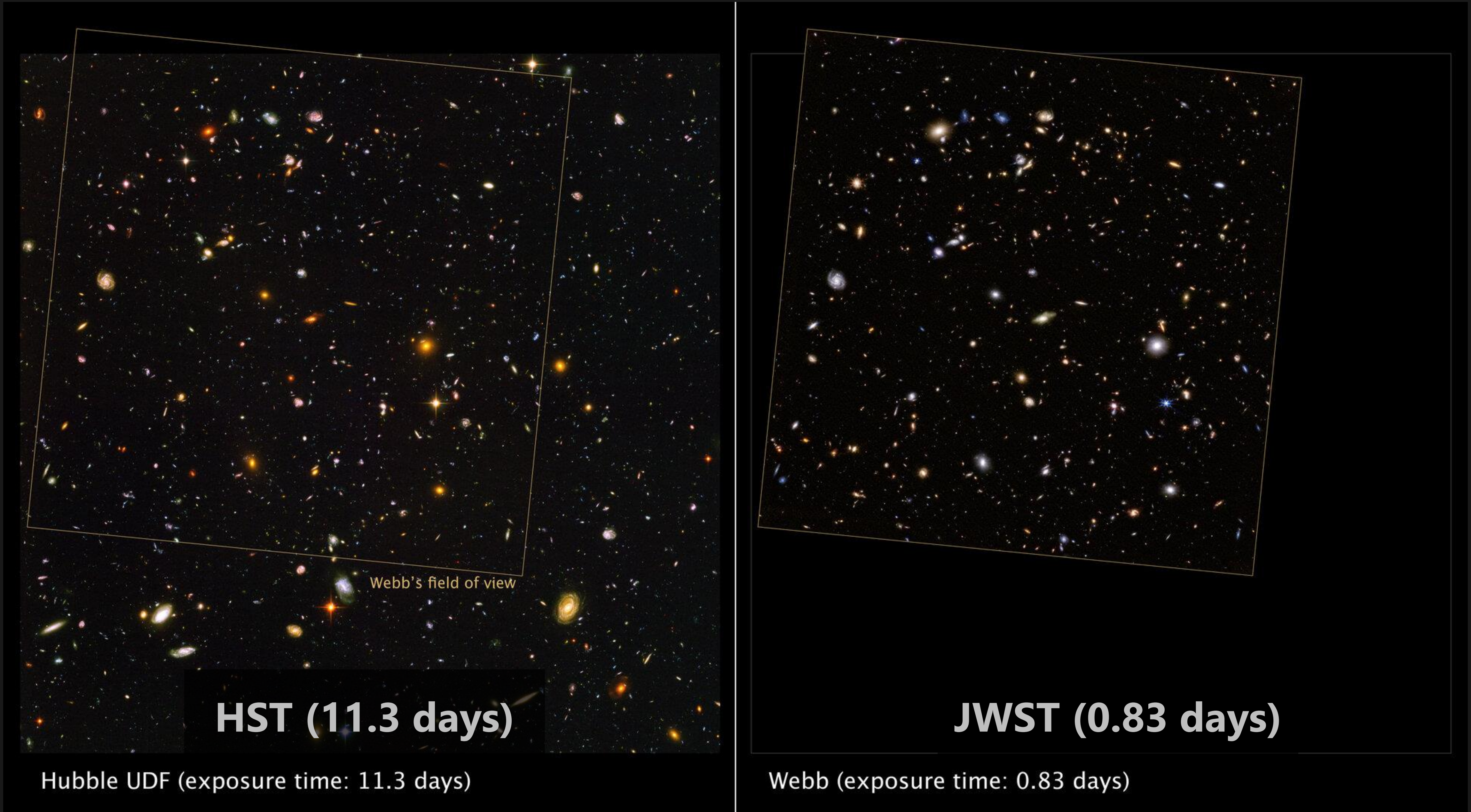
NIRISS
- ✓ Imaging
- ✓ Single spectroscopy
- ✓ Wide field spectroscopy



MIRI
- ✓ Imaging
- ✓ Low-R spectroscopy
- ✓ Mid-R spectroscopy

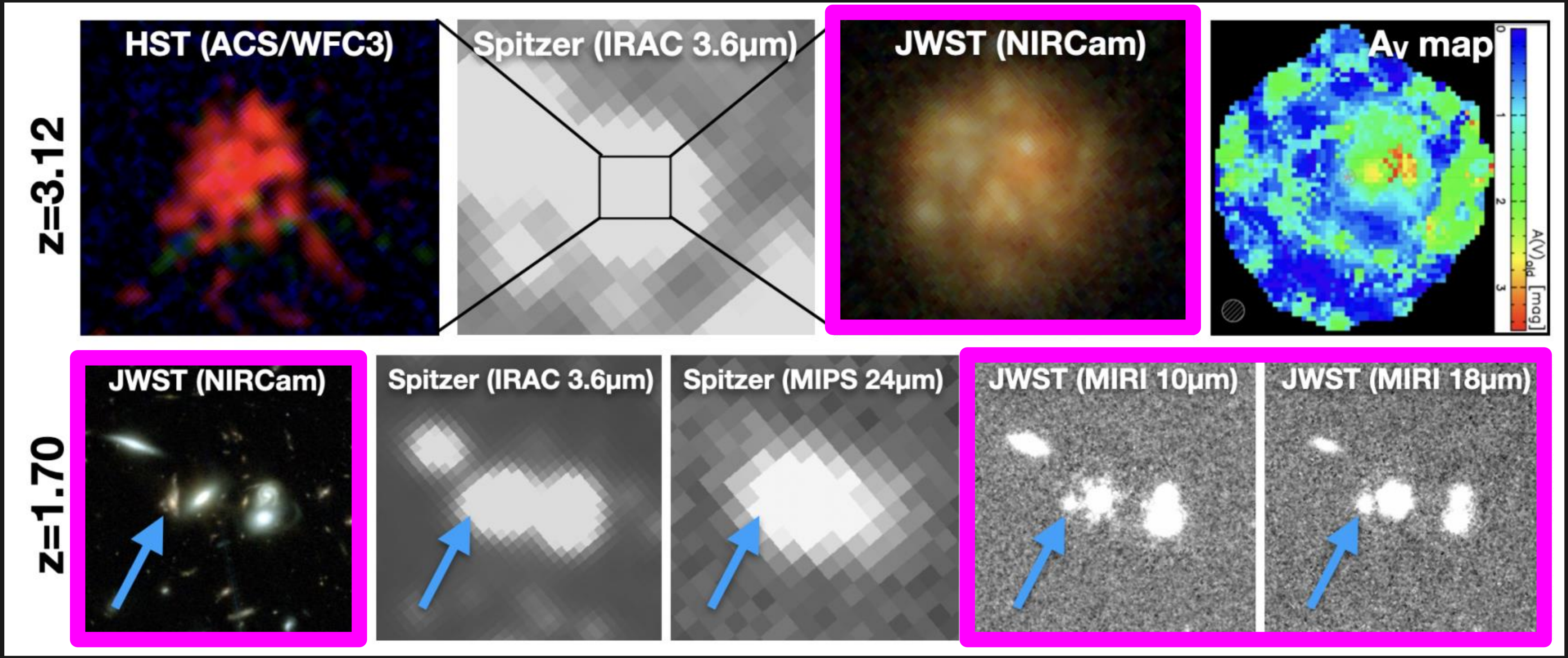
Performance of JWST: Hubble UDF

Hubble Ultra Deep Field
(NASA, ESA, CSA, and J. DePasquale)



Performance of JWST: CEERS

Finkelstein et al. (2025)



- ❖ Sensitivity of JWST: Unprecedentedly higher than other space telescopes
- ❖ Spatial resolution of JWST: Similar to HST, much better than Spitzer
- ❖ Advantage in wavelength coverage (NIR to MIR) compared to HST (up to 1.6 μm)

  → **Beneficial for studying the high-z universe!**

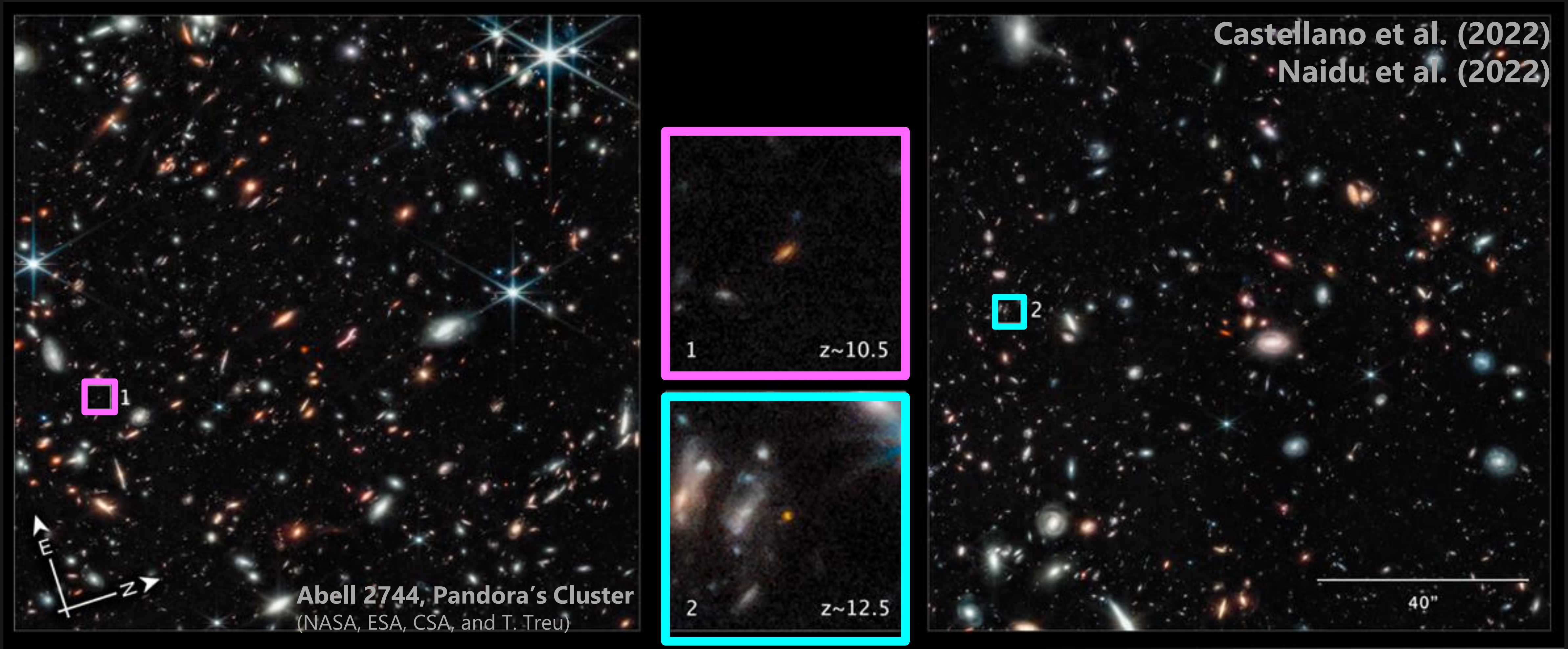
High-redshift Studies with JWST Instruments

- Systematic Search for Galaxies in the “Cosmic Dawn” $(z \gtrsim 10)$
- Morphological Distributions of Galaxies in the “Cosmic Morning” $(z \sim 4-8)$
- Detailed Properties of AGNs in the High-z Universe
- Detection of Lensed Stars, Star Clusters, and Galaxies
- Emission-line Galaxies in the Cosmic Reionization Era

1. Cosmic Dawn Galaxies

- ❖ Extremely bright and massive galaxies at ~400 Myr after Big Bang
- ❖ Helpful to understand early galaxy formation!

  → **Rapid mass growth? Top-heavy IMFs due to Pop III stars?**



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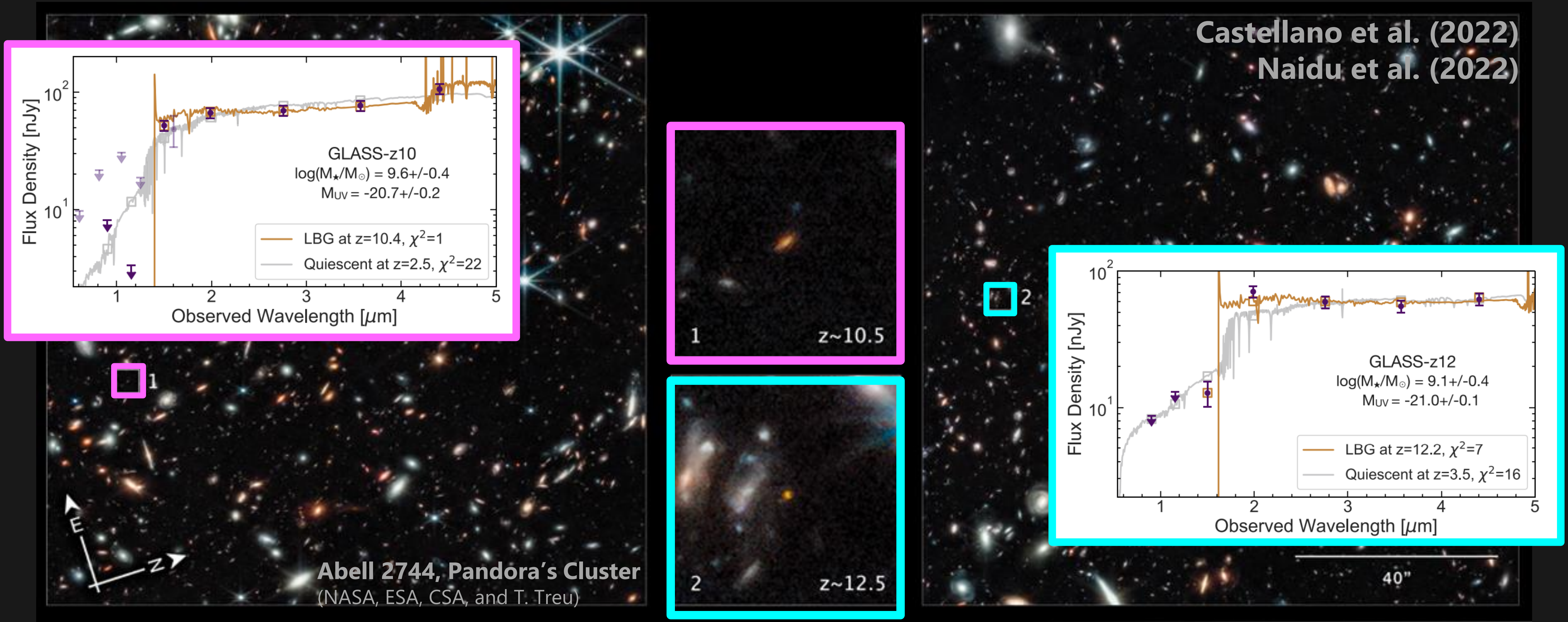
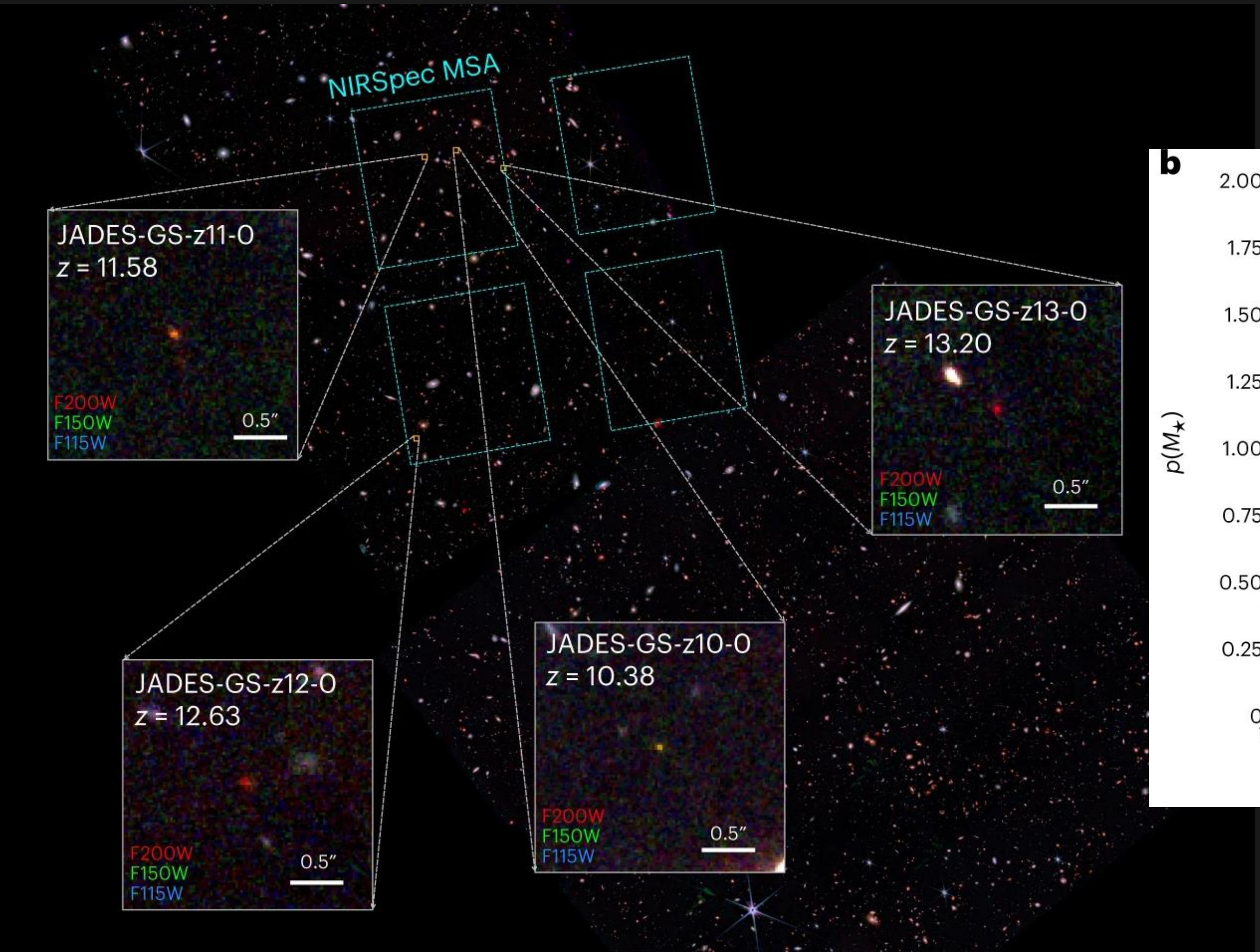
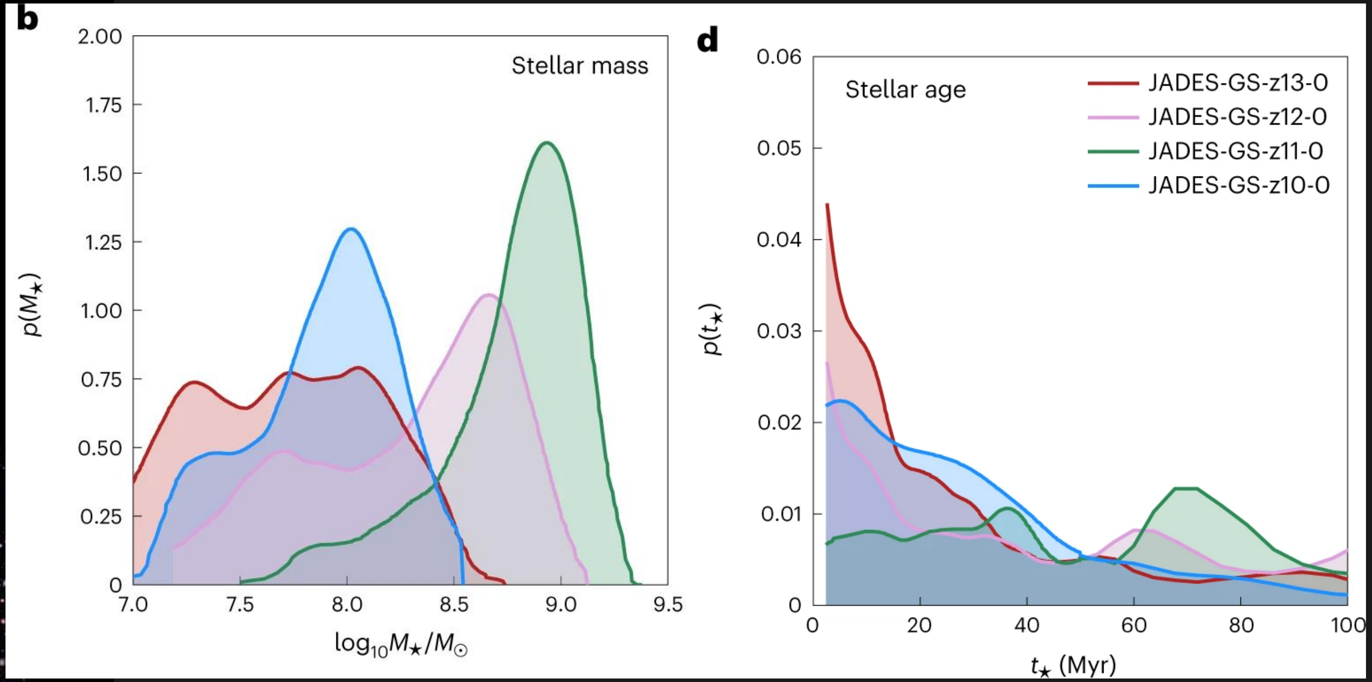


1. Cosmic Dawn Galaxies

- ❖ Spectroscopic confirmation of cosmic dawn galaxies with JWST/NIRSpec
- ❖ Metal-poor, young ages, and stellar masses with $10^7 - 10^9\ M_\odot$

  → **Emergence of the first stars & Large contribution to cosmic reionzation**



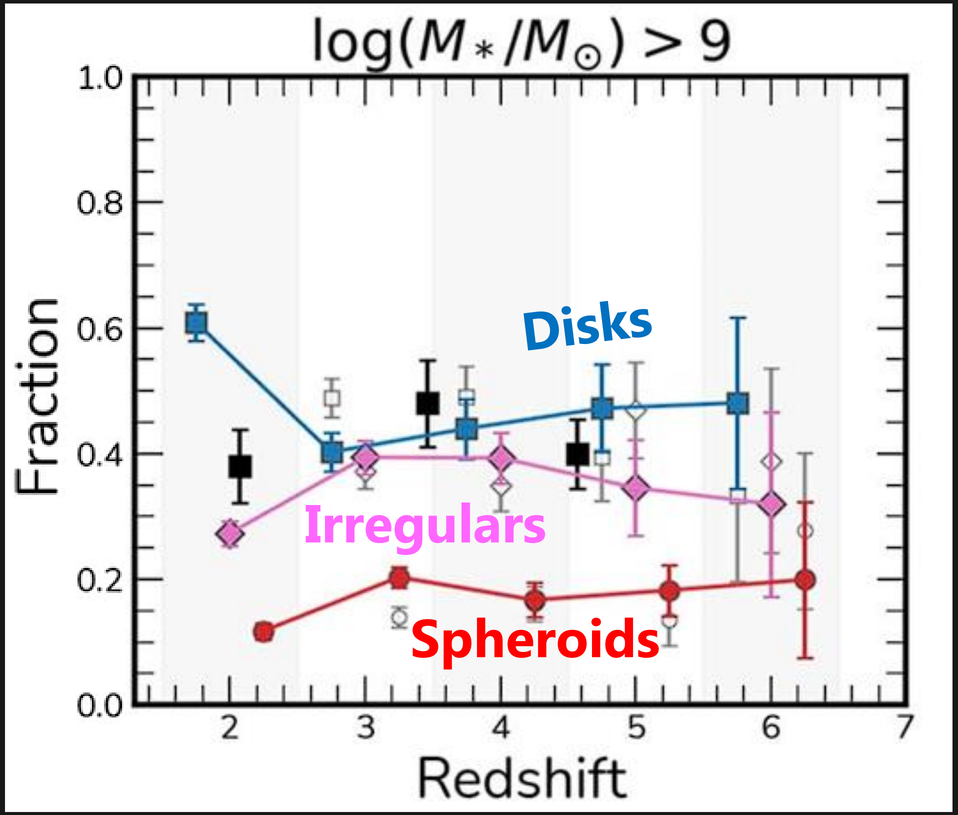


Curtis-Lake et al. (2023)
Robertson et al. (2023)

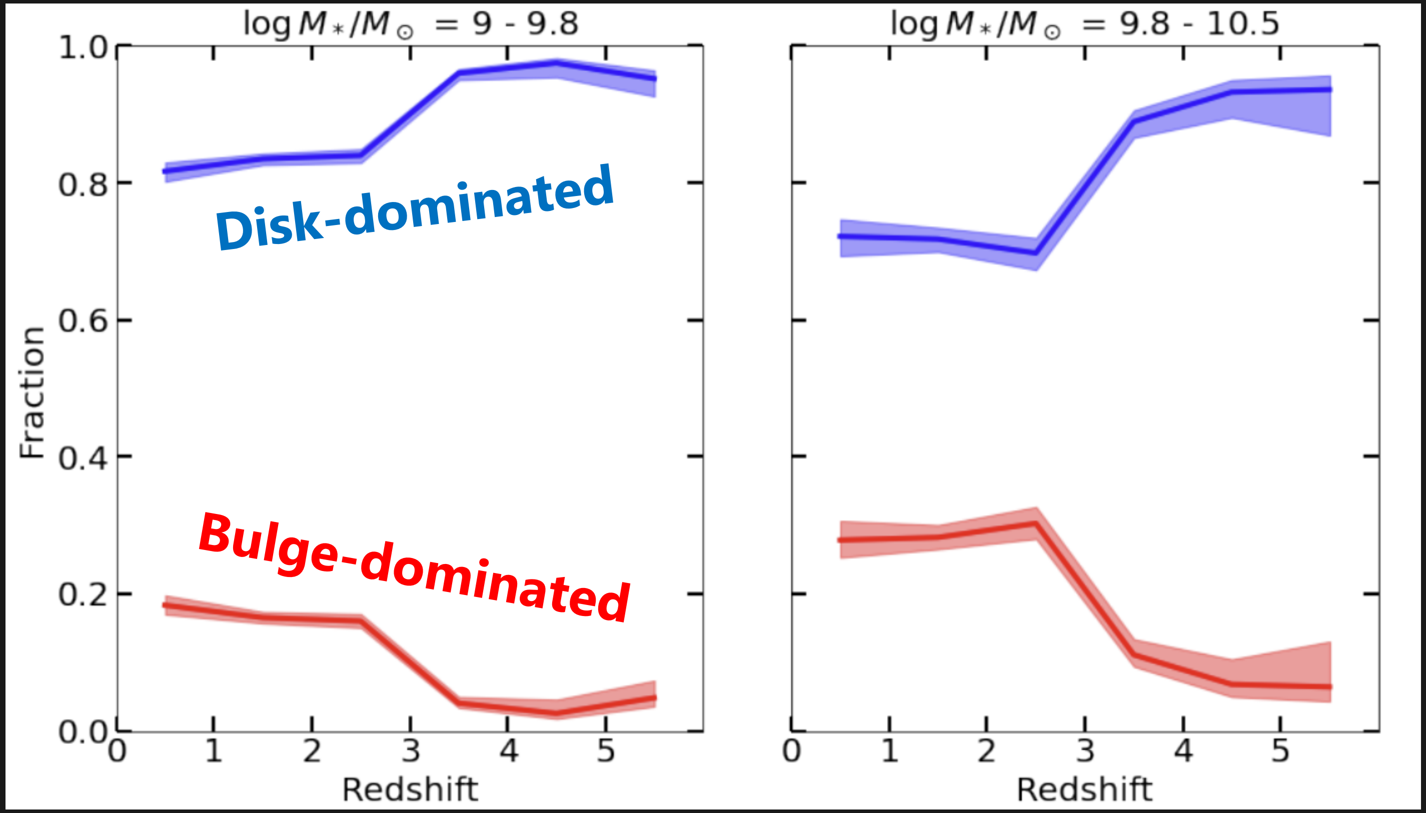
2. Morphologies of High-z Galaxies

❖ JWST is able to explore rest-frame optical galaxy morphologies beyond z>3!

CEERS field (visual classification)
Ferreira et al. (2023)



CEERS field (CNN + Visual classification)
Huertas-Company et al. (2023)



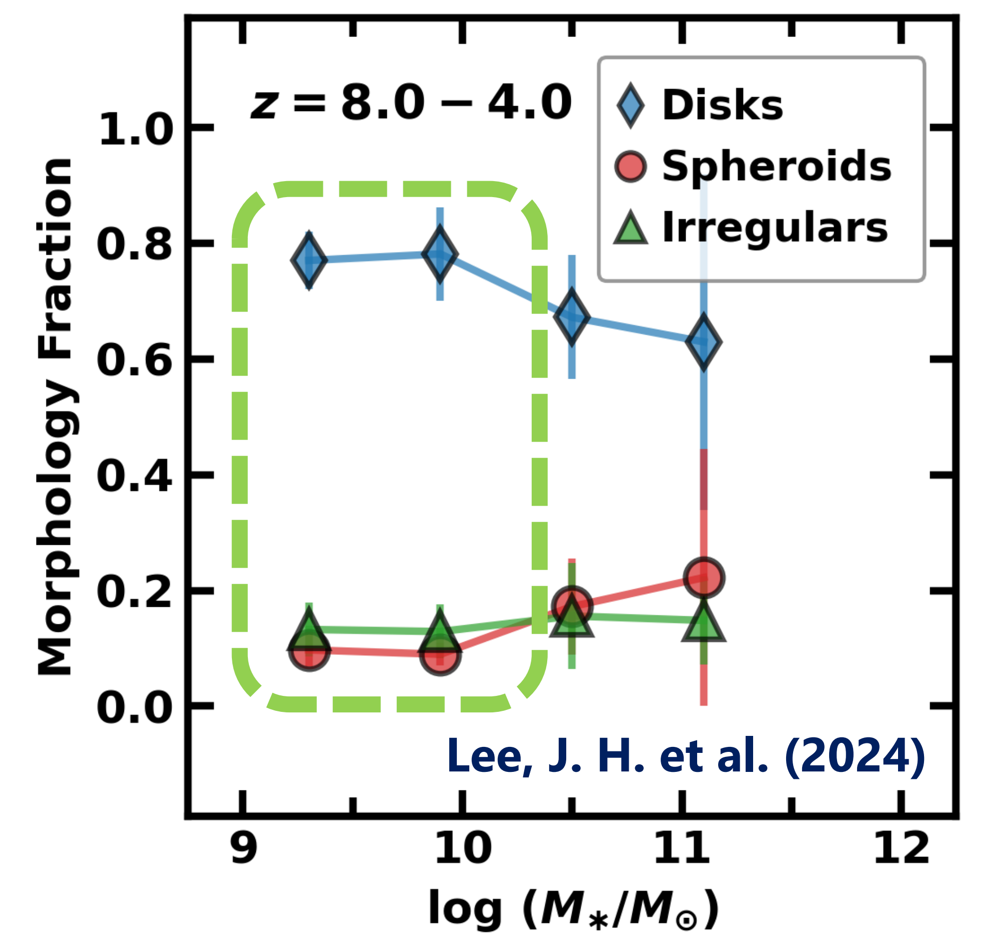
❖ Most JWST studies agree the disk dominance in the early universe.

→ **Early disk formation due to initial angular momentum**

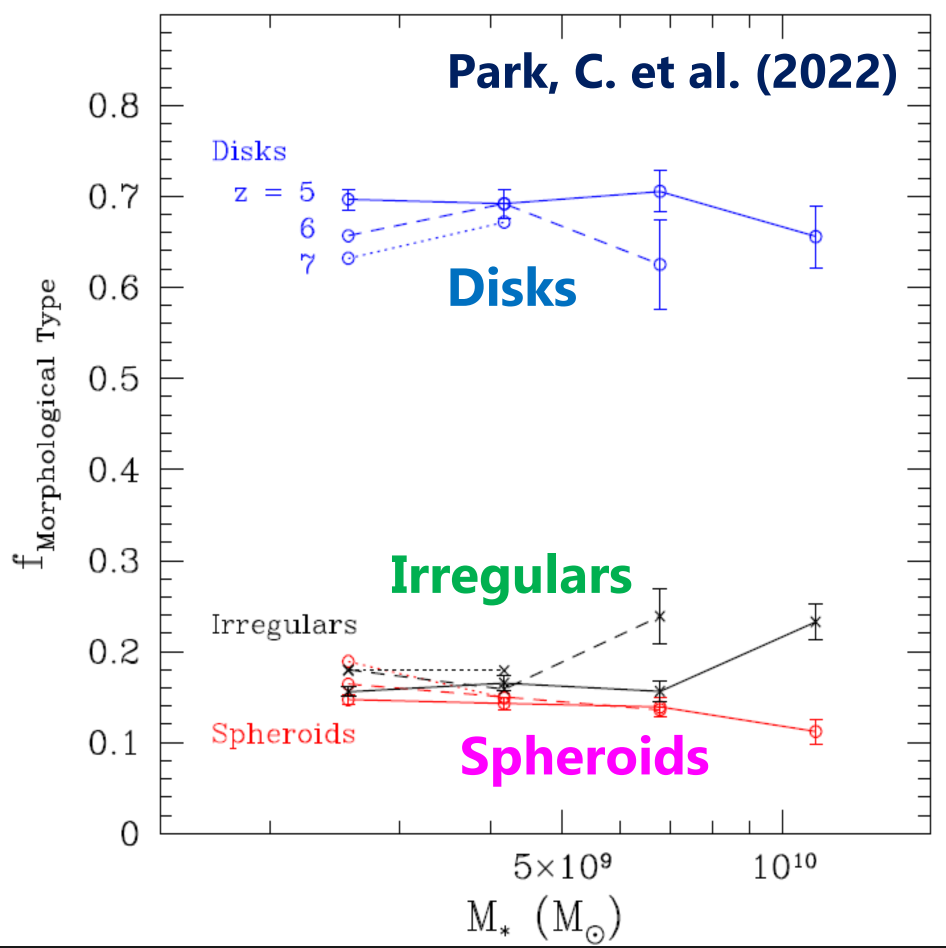
2. Morphologies of High-z Galaxies

❖ JWST observational results are consistent with HR5 cosmological simulation!

JWST (observation)



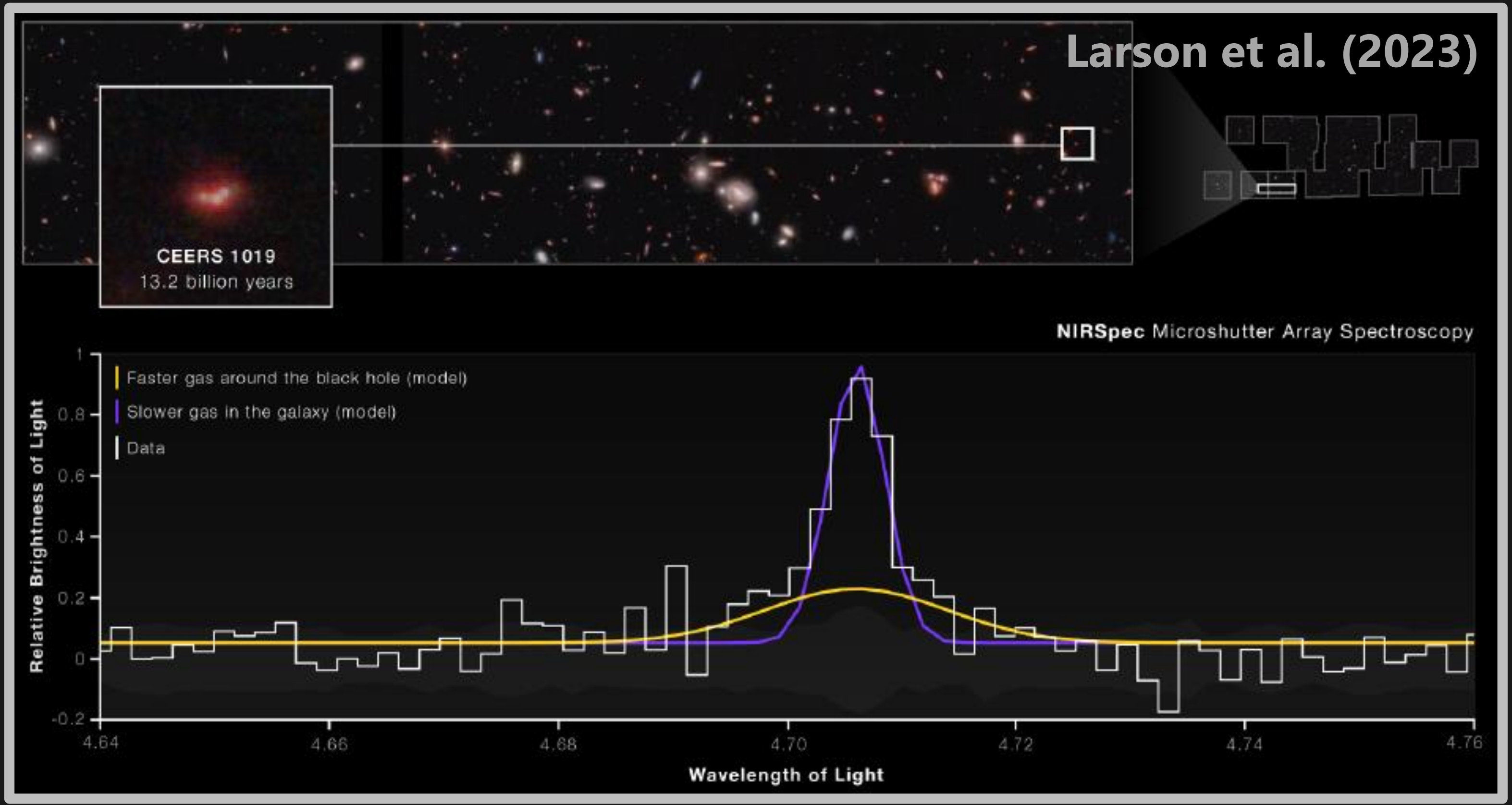
HR5 (simulation)



3. Detailed AGN Properties at High Redshifts

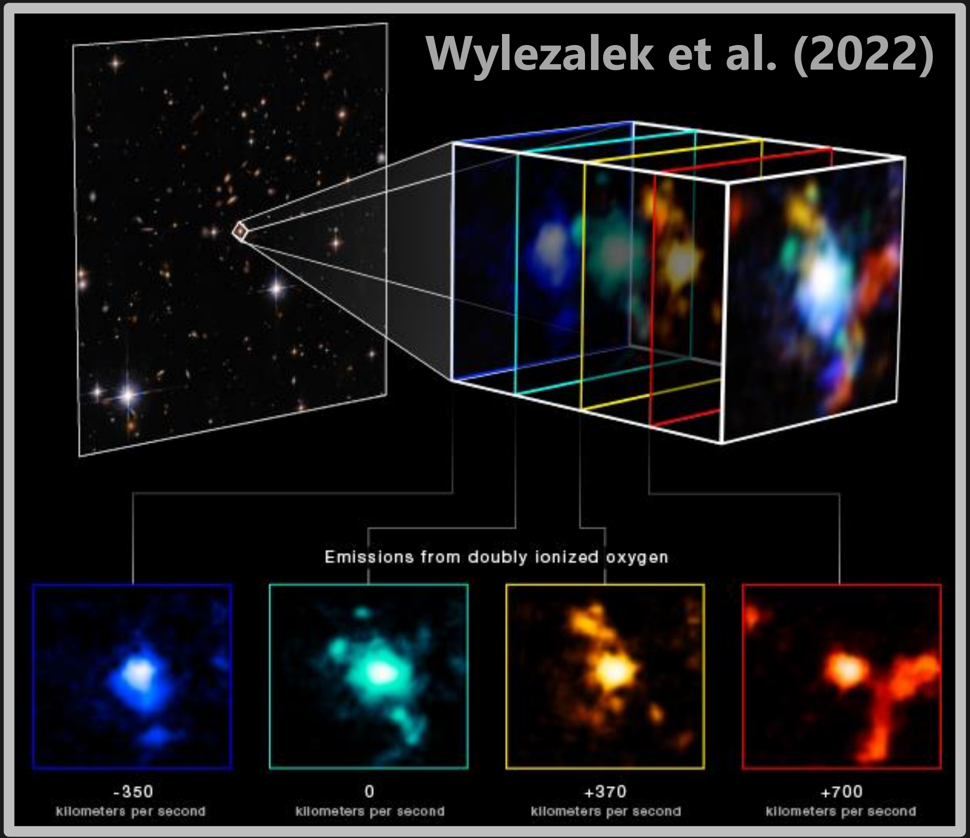
❖ Combining JWST imaging and spectroscopy reveals the physics of high-z AGNs.

CEERS_1019 (z=8.679)



- Highest-redshift AGN
- $\log M_{BH} \sim 7$ with **super-Eddington accretion**

SDSSJ165202+172852 (z=2.94)

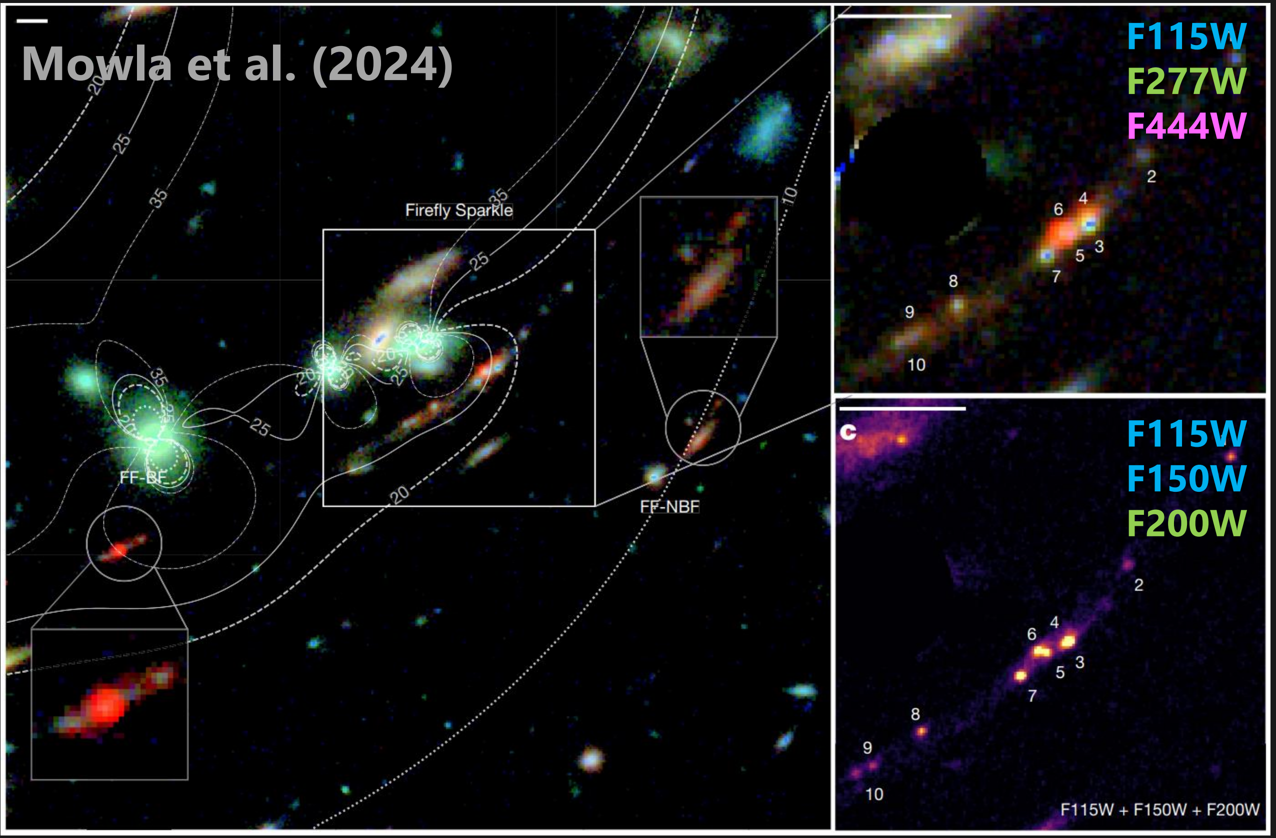


- Complex [OIII] gas kinematics
- **Dense environments**

4. Detection of Lensed Objects

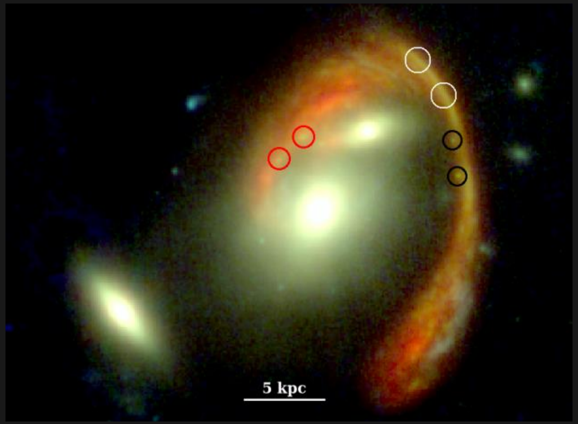
❖ Gravitational lensing provides good opportunity to study distant objects, by magnifying their appearance and brightness.

"Firefly Sparkle" (z=8.30)



- Progenitors of massive star clusters

Lensed objects in "El Gordo"



"En Anzuelo" (z=3.58)

- A lensed RSG star (z=2.19)

5. Emission-line Galaxies in the Reionization Era

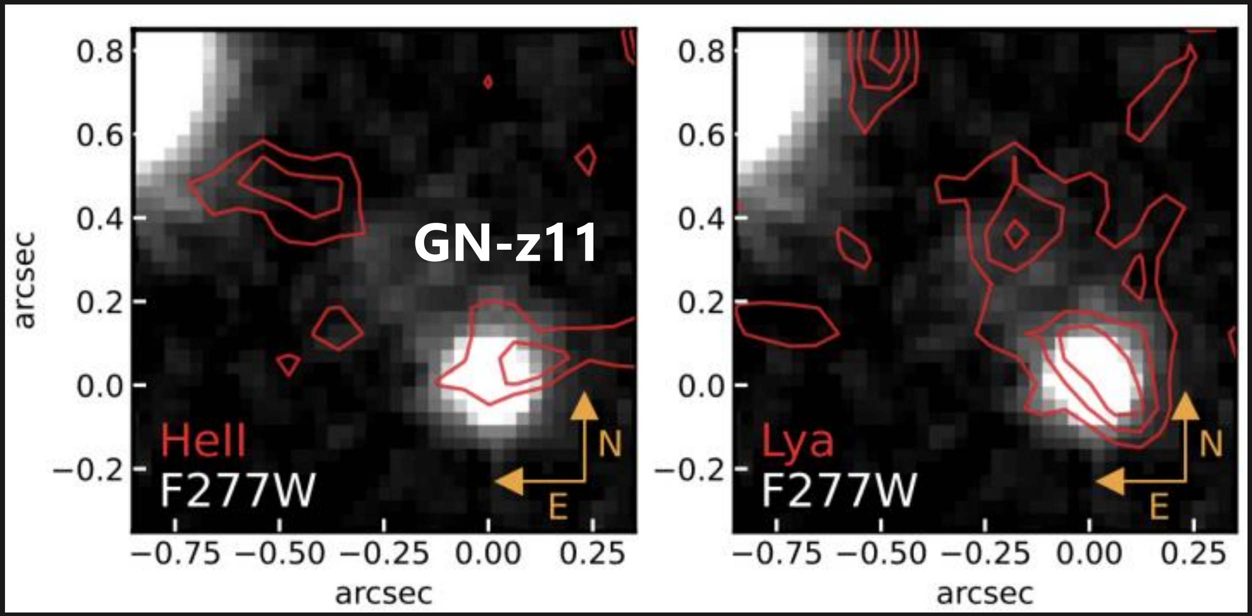
❖ Emission-line galaxies found by JWST/NIRCam and NIRSpec are main contributors to cosmic reionization.

EIGER Survey (NIRCam WFSS)

Matthee et al. (2023)

- 117 [OIII] emitters at z~5-7
- Young ages, High EWs, High U, Low A_V

Lyα Halo around GN-z11 (z=10.6)



Maiolino et al. (2024)

- High HeII EW, Weak metal lines
  → **Pop III star signature?**

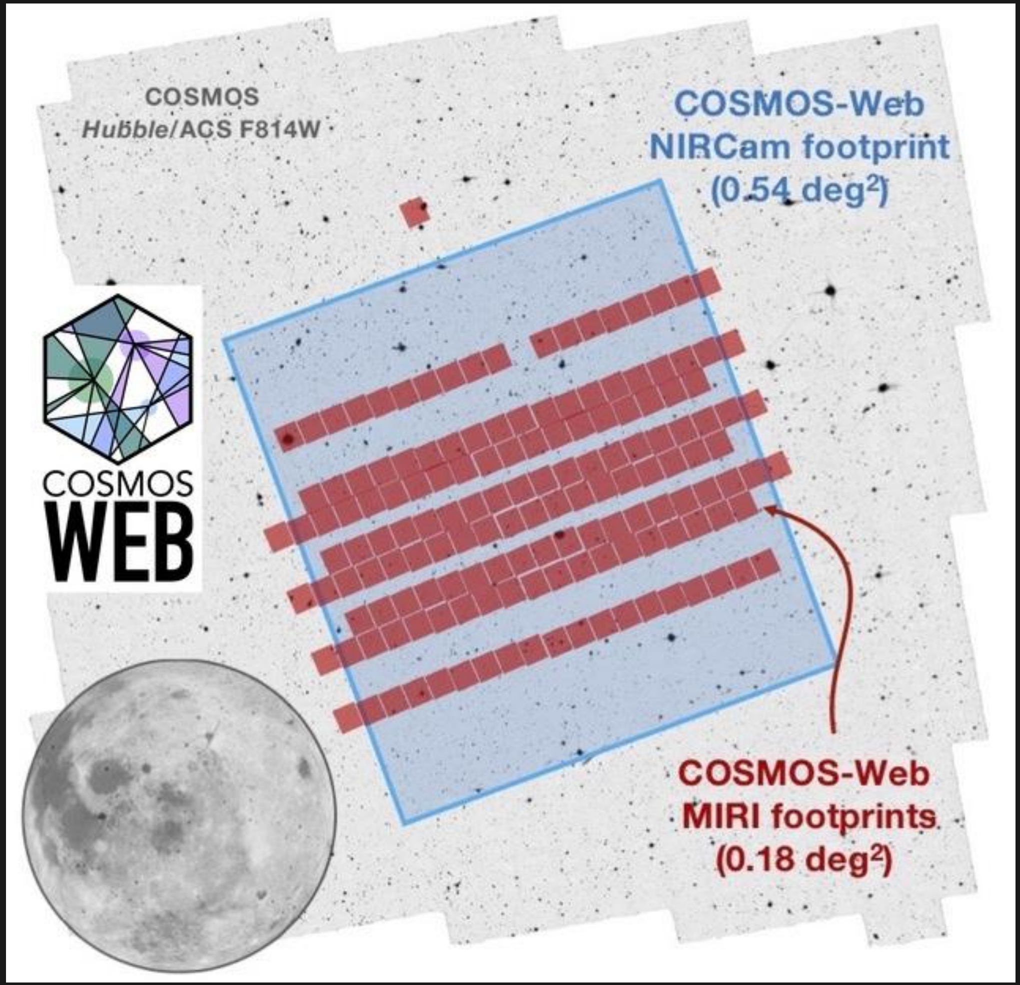
Future Researches using JWST: with COSMOS-Web

❖ **Limitation of JWST: narrow field of view**
→ Challenging to study the environmental effect of high-z galaxies

❖ **COSMOS-Web survey**
- Largest JWST field
  (**~0.54 deg^2** ↔ ~100 arcmin^2 for CEERS)
- Multiwavelength data from UV to IR

❖ Possible sciences
- Finding protoclusters at high redshifts
- Environment-Morphology relation
- Environment-SFR relation

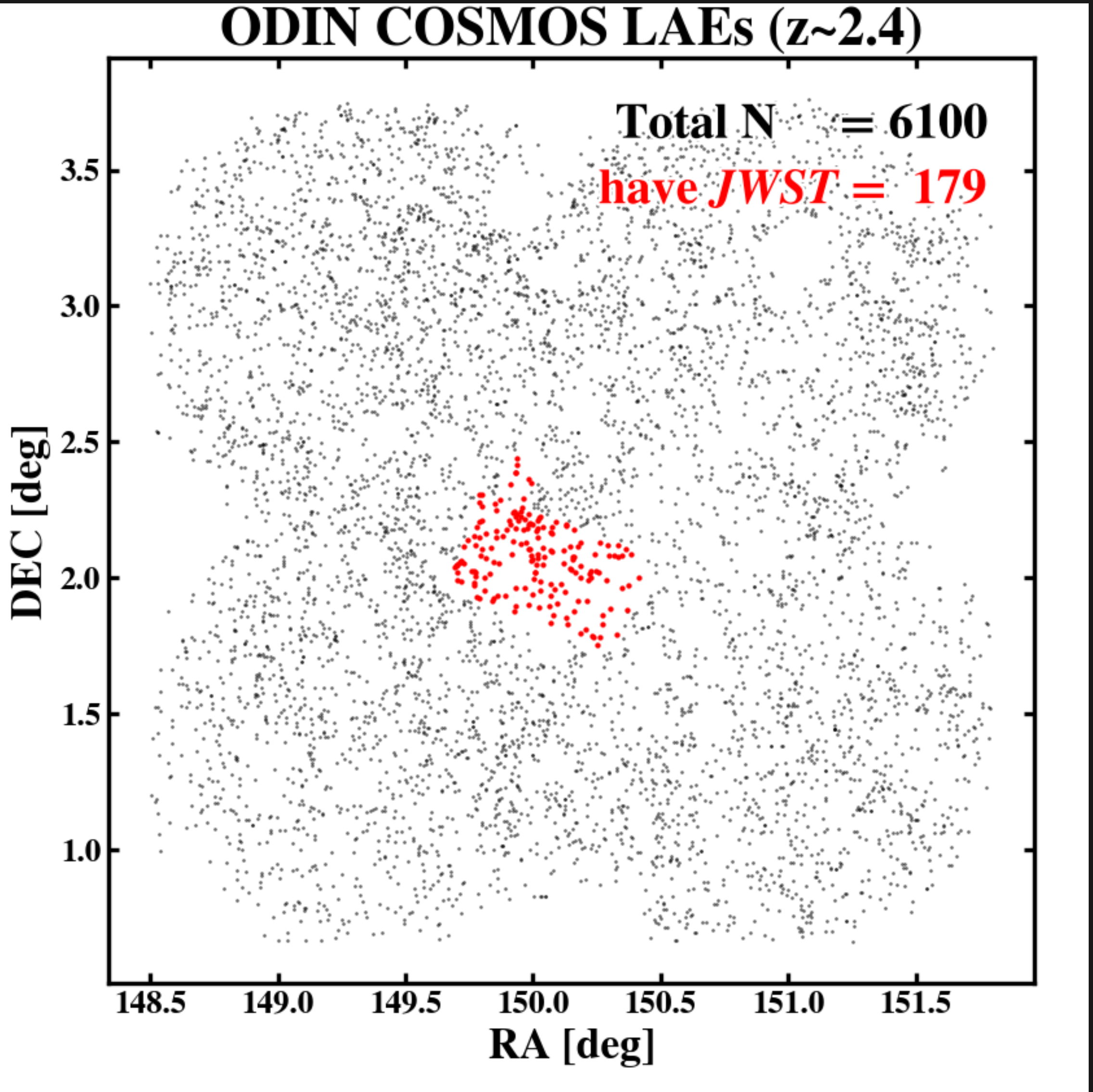
❖ Tuning for SED fitting is necessary…



Future Researches using JWST: with ODIN

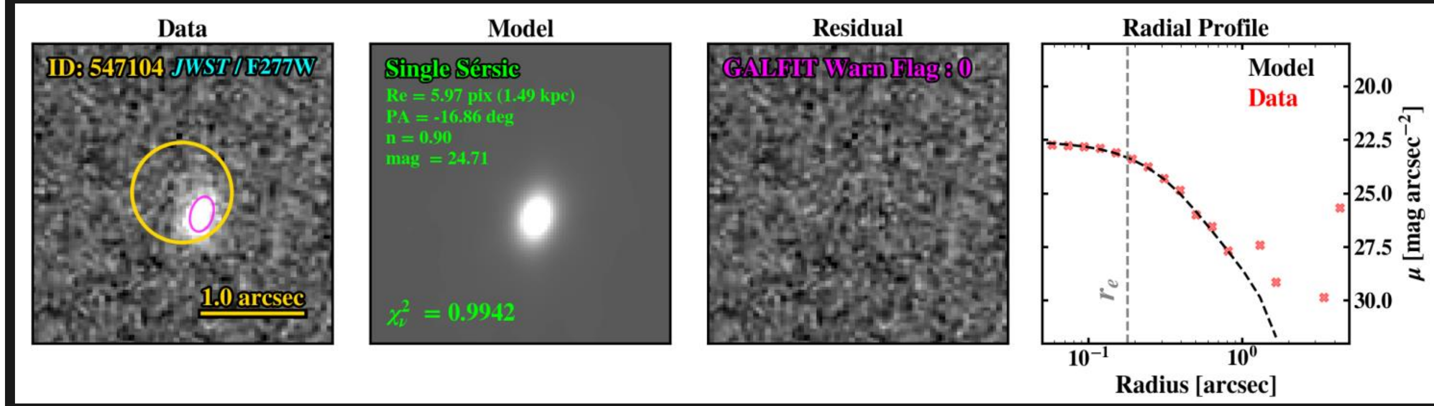
- **ODIN survey:** DECam narrow-band survey for finding LAEs at z=2.4, 3.1, and 4.5

Lee, Kyoung-Soo, et al. (2023)



- With JWST/NIRCam, **the rest-frame optical morphologies for high-z LAEs** can be investigated!

(Figures provided by **Sang Hyeok Im**)



GALFIT results

Future Researches using JWST: with K-GMT

❖ **With Gemini F2:** spectroscopic observations of high-z quiescent galaxies

- Fundamental plane (FP) relations: observation vs. simulation

→ **Great opportunity for making synergies with K-GMT program!**

(Figures provided by **Priya Goyal**)