

# **A Large Number of Candidate Galaxies at Redshifts of 11 — 20 as Revealed by JWST ERO Data in SMACS 0723-73**

**Haojing Yan<sup>1</sup>, Zhiyuan Ma<sup>2</sup>, Chenxiaoji Ling<sup>1</sup>,  
Cheng Cheng<sup>3</sup>, Jia-Sheng Huang<sup>3</sup>**

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Amherst; (3)National Astronomical Observatories of China

241st AAS Meeting, Seattle, WA  
January 9, 2023



# **First Set of JWST Deep Data Revealed a Large Number of Candidate Galaxies at 200-400 Million Years after the Big Bang**

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# Redshift (“z”), Distance, Age of the Universe

- ❖ Expanding universe: galaxies beyond our Milky Way are moving away from us; the further they are, the larger their receding speeds are

**large receding speed = large distance**

- ❖ Light-emitting source moving away from observer — its light is “redshifted” (its blue light appears red to observer)

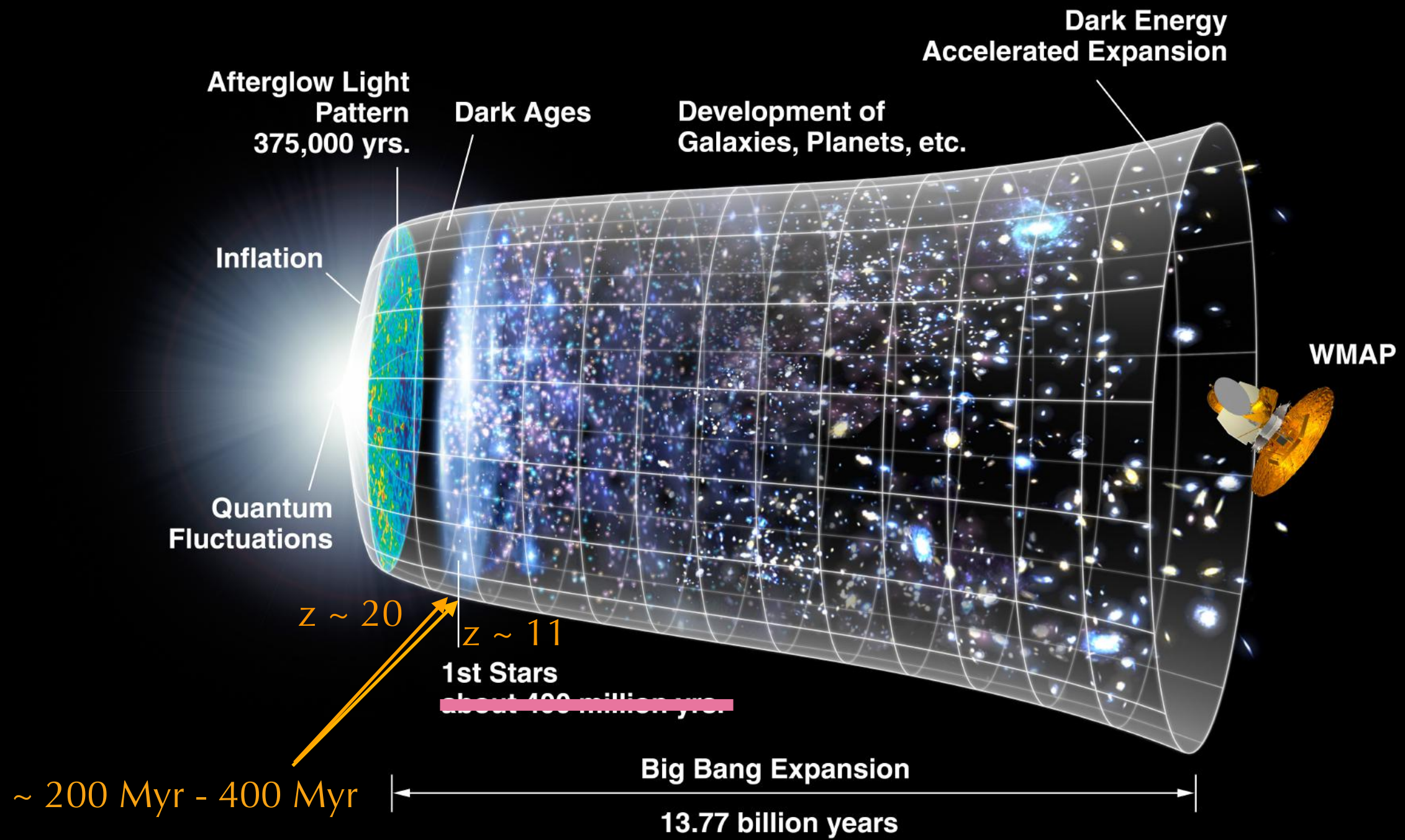
**large receding speed = high redshift (high-z)**

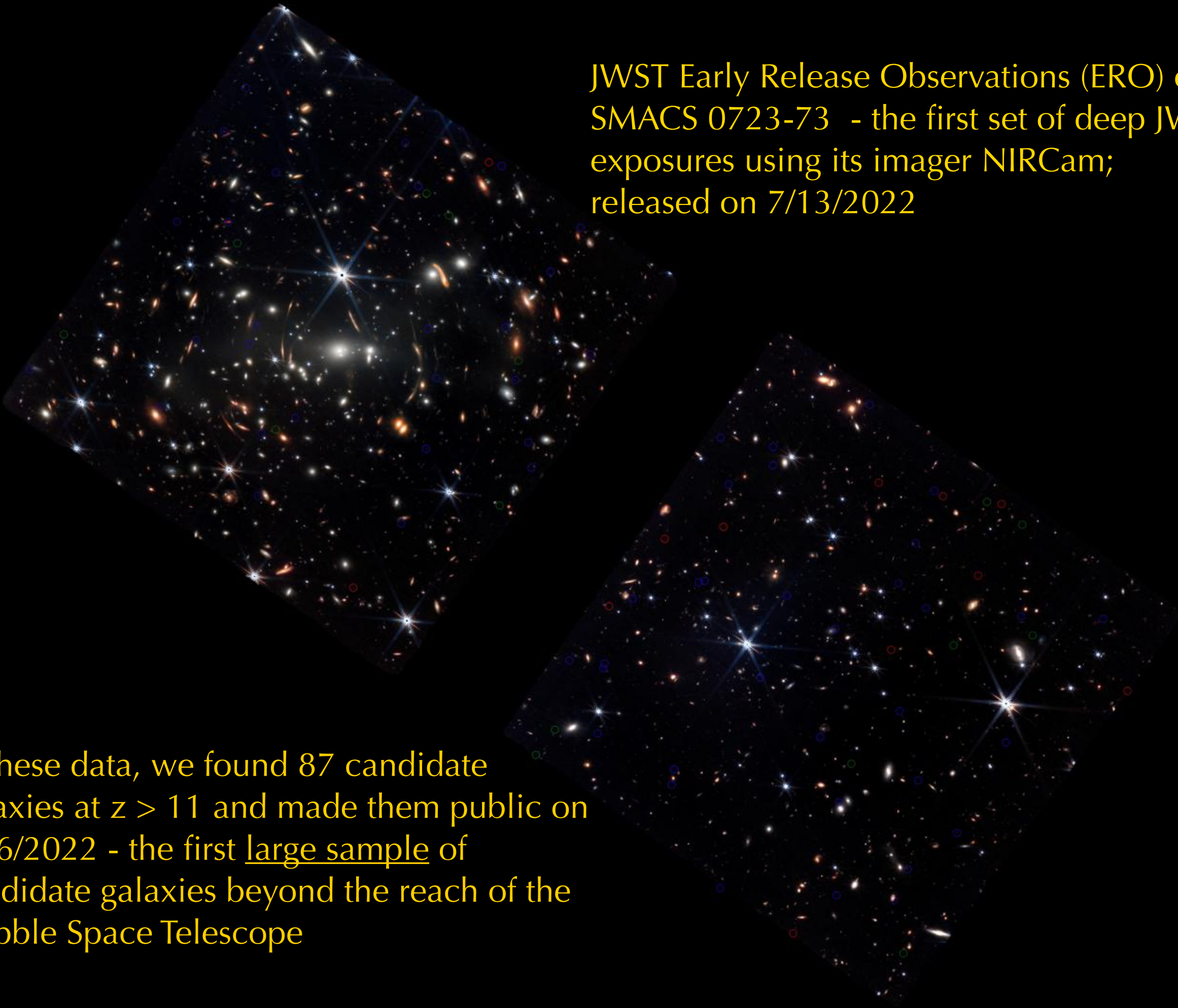
- ❖ **High z = large distance**

- ❖ Speed of light is finite

**large distance = long light-traveling time**

- ❖ **High z = long light-traveling time = young universe**





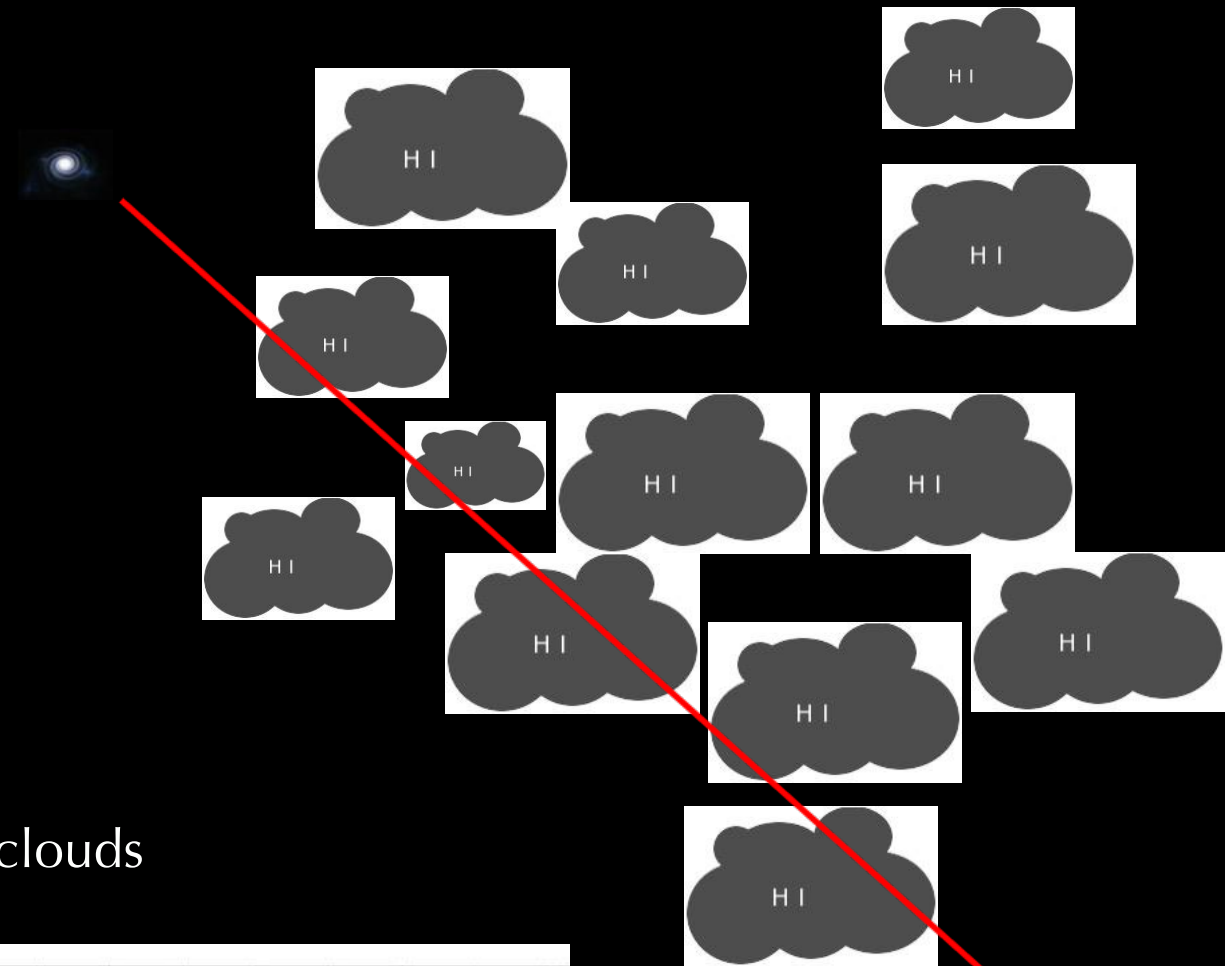
JWST Early Release Observations (ERO) on  
SMACS 0723-73 - the first set of deep JWST  
exposures using its imager NIRCam;  
released on 7/13/2022

In these data, we found 87 candidate  
galaxies at  $z > 11$  and made them public on  
7/26/2022 - the first large sample of  
candidate galaxies beyond the reach of the  
Hubble Space Telescope

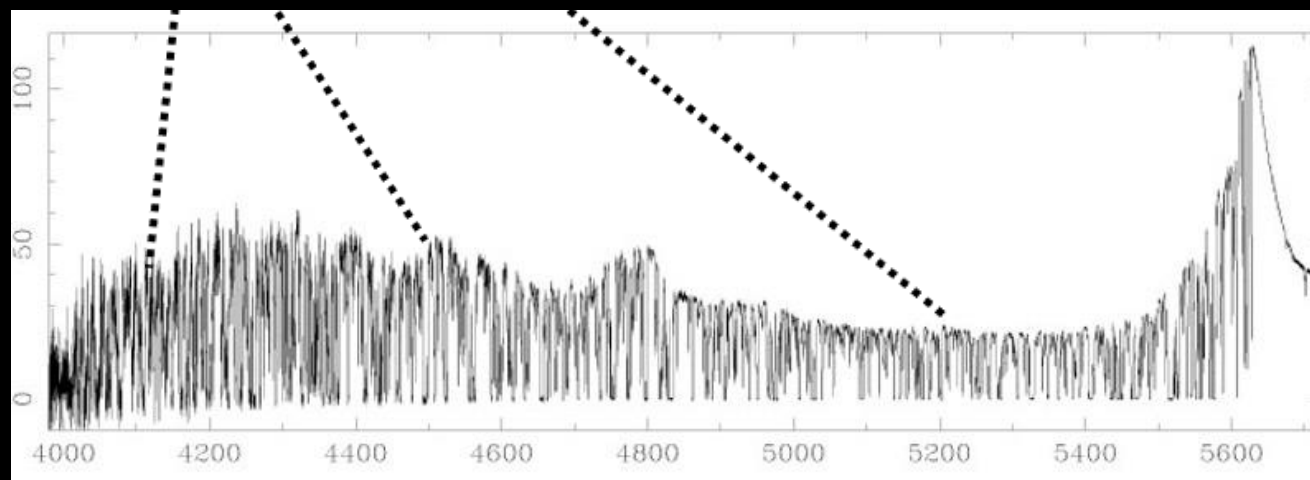


# High-redshift signature: Lyman break

- ❖ Absorption due to the line-of-sight neutral hydrogen clouds creates strong “Lyman-break” signature in spectra of objects at  $z > 3$  (Steidel & Hamilton 1992)



Absorption due to hydrogen clouds

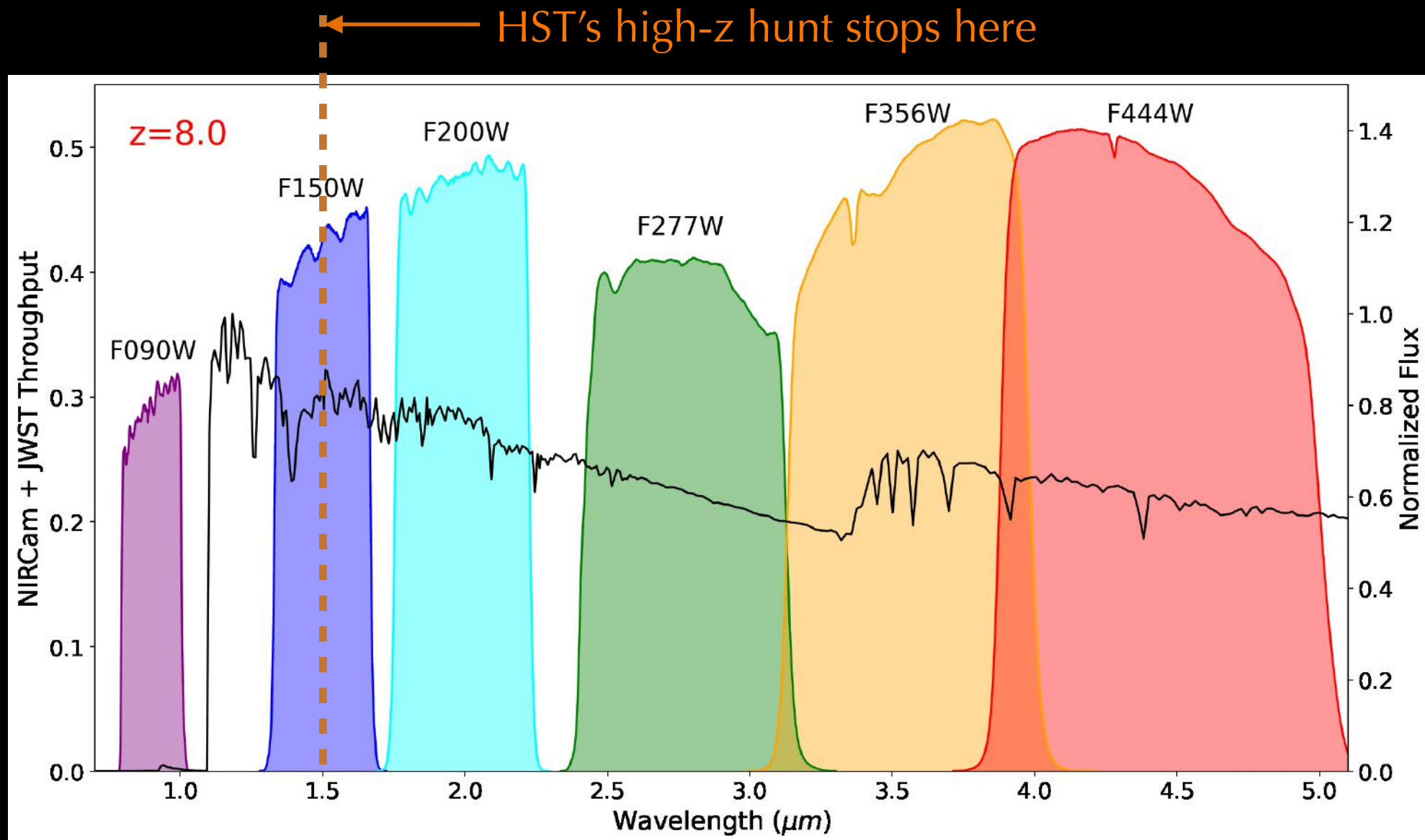


Spectrum of a  $z=3.6$  quasar revealing the line-of-sight Ly $\alpha$  absorption



# Finding High-z Galaxies: “dropout” selection

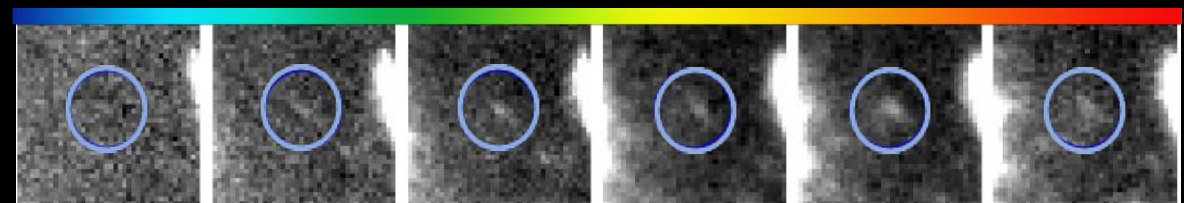
- ❖ A high-z galaxy is weak or even invisible in (“drops out”) blue-band imaging; but still appears in red bands
- ❖  $z > 11$  is beyond the reach of the HST; JWST for the job!





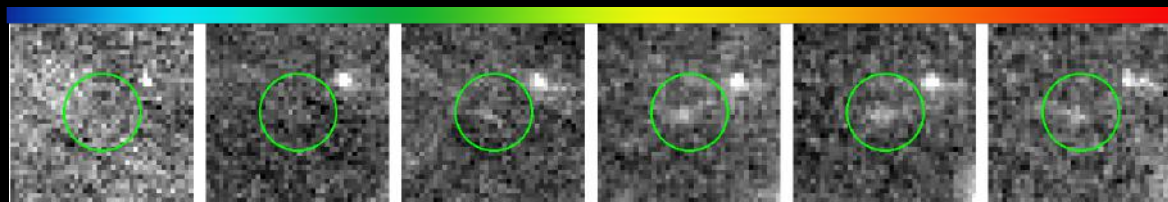
High- $z$  ( $z > 11$ )

60 total



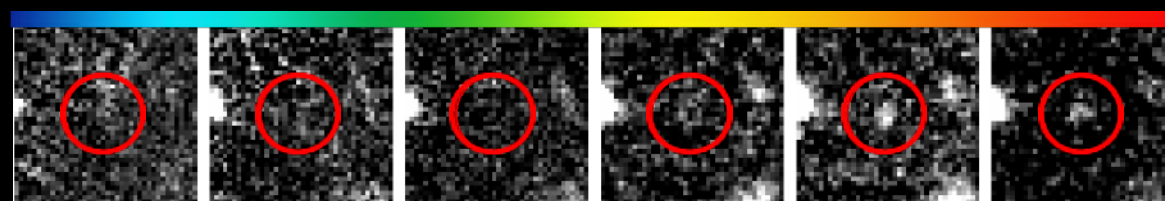
Very High- $z$  ( $z > 15$ )

15 total



Extremely High- $z$  ( $z > 20$ )

12 total





# JWST pushing to $z > 11$

- ❖ So it's all natural then to see JWST pushing beyond  $z \sim 11$  ?
- ❖ **Yes** : everyone expected JWST to find galaxies at  $z > 11$
- ❖ **No** : almost no one expected to see so many candidate galaxies at  $z \sim 11-15$  (let alone at approaching  $z \sim 20$  and beyond) within just one NIRCам pointing
- ❖ **Next** : What we found are still just “candidate galaxies” at  $z > 11$ ; JWST spectroscopy confirmation on such objects will be critical
- ❖ **Bottom line** : even if just a fraction of our candidates are confirmed at  $z > 11 \sim 15$ , our previous picture of galaxy formation in the early universe must be revised



- ❖ Based on *“First Batch of  $z \approx 11-20$  Candidate Galaxies Revealed by the JWST Early Release Observations on SMACS 0723-73”* by Yan, Ma, Ling, Cheng & Huang (2023), ApJ, 942, L9 (preprint posted at arXiv.org on 07/23/2022)
- ❖ See also iPoster 177.41