JWST COSMOS-Web DR1: Identifying z~9–10 protocluster candidates through photometry

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Introduction:

It is important to find and study protoclusters in the distant Universe during their formative stages in order to understand the formation and evolution of present-day galaxy clusters. In the pre-JWST era, protocluster candidates were primarily identified up to $z \lesssim 7$, limited by optical wavelength coverage and survey area. With deep JWST near-infrared surveys such as CEERS and JADES have enabled the identification of protocluster candidates at $z > 7$. By taking advantage of JWST COSMOS-Web's near-infrared sensitivity, spatial resolution, and wide survey area, Wu et al. (2025) identified seven $z \approx 9–10$ protocluster candidates using COSMOS-Web DR0.5 (FOV: 0.27 deg^2). In this work, we present an extended search for high-redshift ($z \approx 9–10$) protocluster candidates using the full DR1.0 dataset (FOV:0.54 deg^2). We apply F115W-dropout color selection and spectral energy distribution (SED) fitting to isolate high-redshift galaxy candidates, and compute local overdensities to identify protocluster regions. The identification of protoclusters at $z > 9$ provides new constraints on the formation and early evolution of the most massive structures in the Universe.

Data:

Previous JWST Deep Surveys (CEERS/JADES):
Near-infrared NIRCam imaging over 134 arcmin^2

JWST COSMOS-Web:
Ultra-wide 1944 arcmin^2 field (~15× CEERS) with NIRCam filters F115W, F150W, F277W, F444W and a 5σ limiting magnitude of 28.0 mag in the F444W filter. In Fig.1a, the green highlighted region corresponds to the area analyzed in Wu et al (2025), while the full COSMOS-Web field is analyzed in this work.

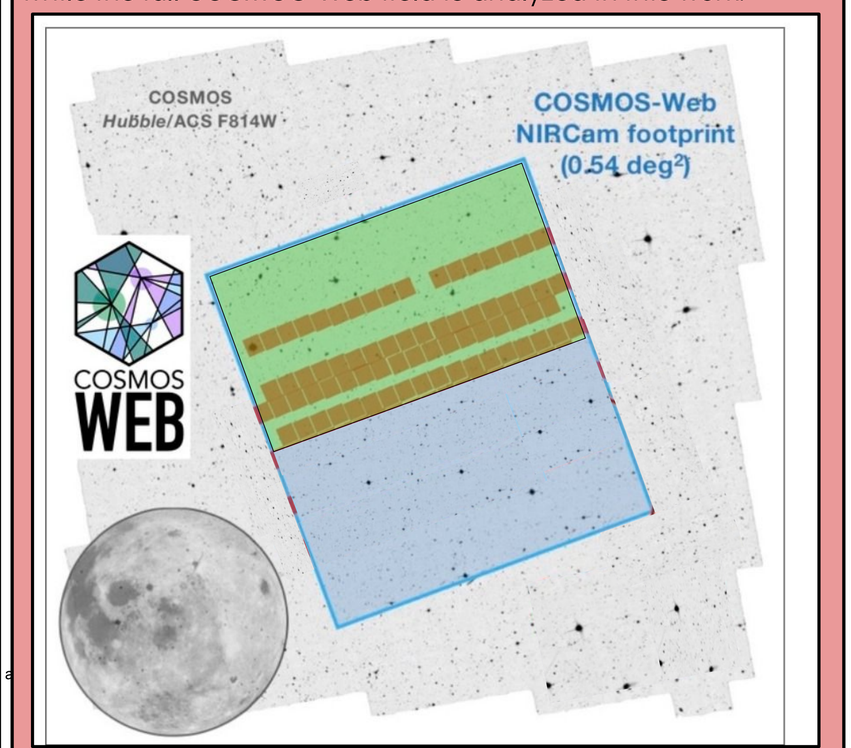


Fig 1a. Footprint of the COSMOS-Web program (Credits:NASA)

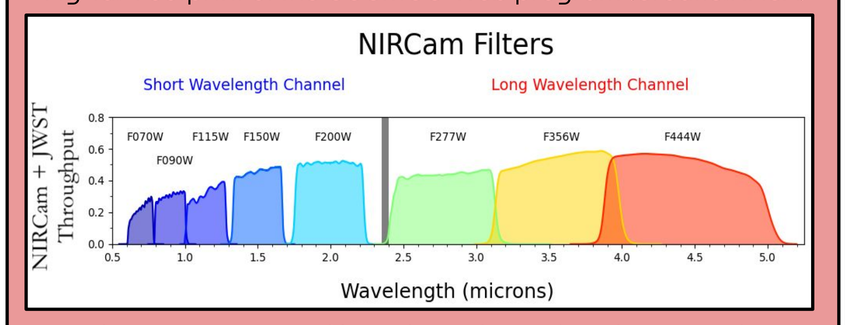


Fig 1b. JWST NIRCAM filters throughputs (Credits: NASA)

Methodology

Aperture Photometry

Lyman α break: galaxies at z > 9 show a sharp flux drop around ~1.2 μm.

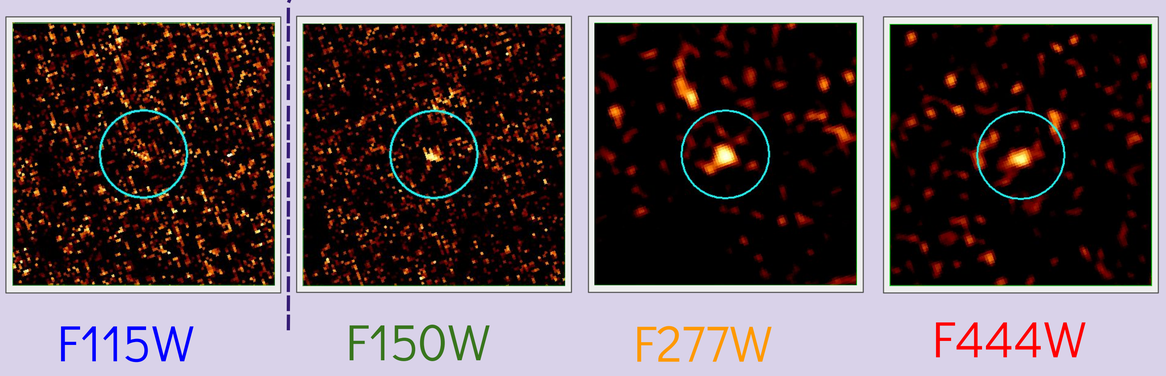


Fig. 2a: JWST NIRCam images of a Lyman-break galaxy

Color-Selection

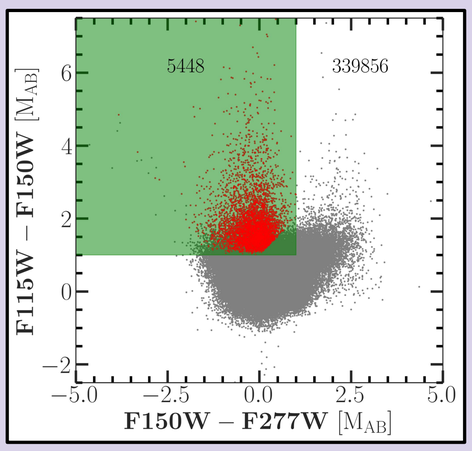
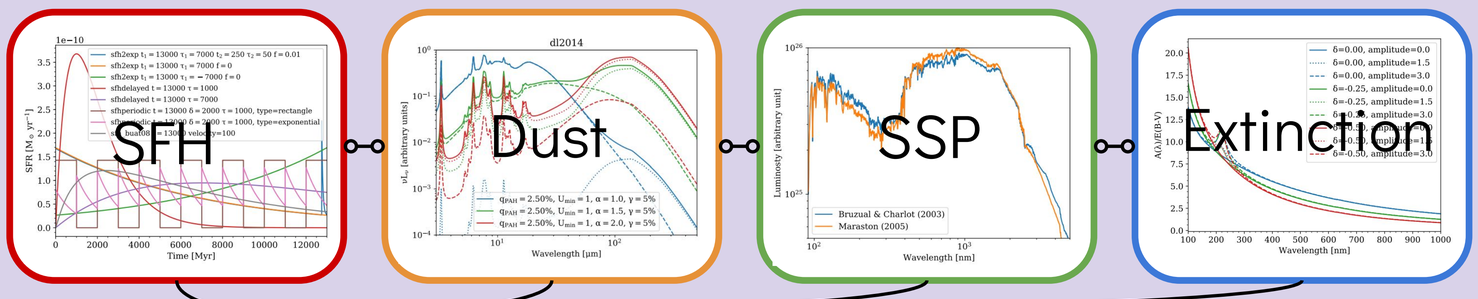


Fig. 2b: Color-color diagram of F115W-dropout candidates (red) and full catalog sources (grey); numbers show source counts.

Spectral Energy Distribution (SED) Modeling using CIGALE



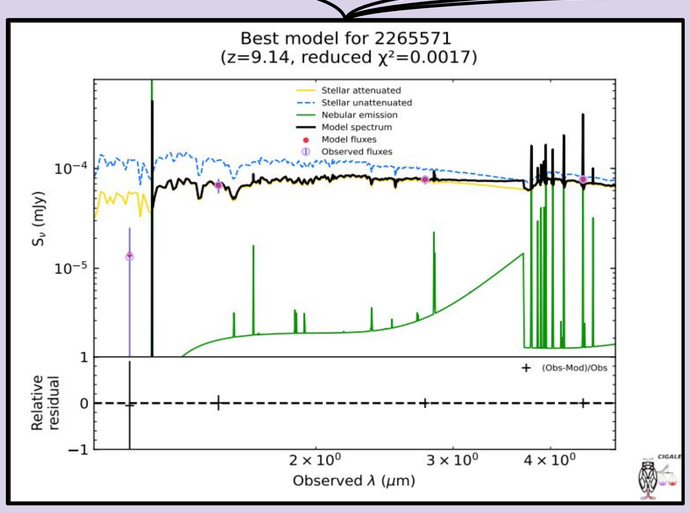


Fig. 2c: Best-fit SED for an example galaxy.

Distribution of galaxies across redshifts z>9

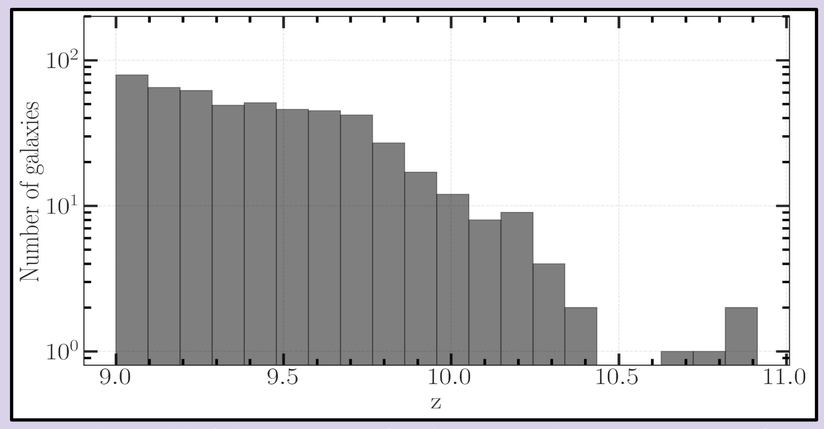
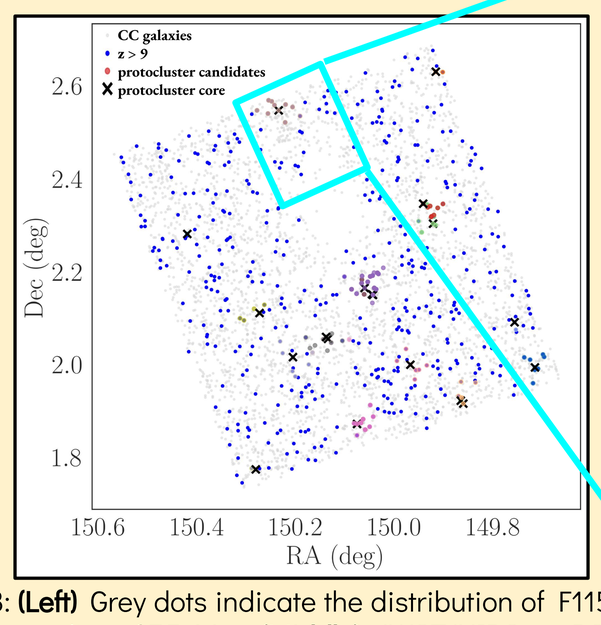


Fig. 2d: Redshift histogram of galaxies with $9 < z < 11$ satisfying the F115W-dropout criteria

Analysis & Results:

To find overdense regions we find the over-density (δ), defined as the ratio of the difference between local-density $\varrho(x)$ and the field average $\bar{\rho}$ minus 1 within a aperture radius (R = 2.5 cMPc).

$$\delta = \frac{\rho(x) - \bar{\rho}}{\bar{\rho}} = \frac{\rho(x)}{\bar{\rho}} - 1$$



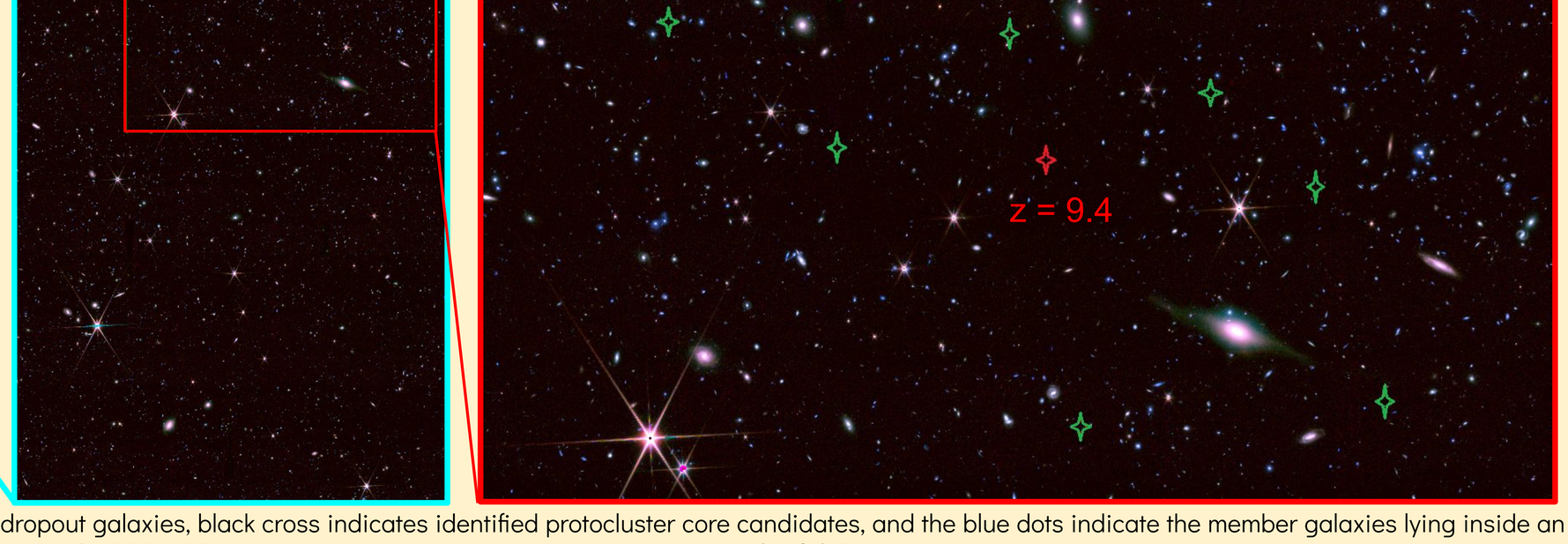


Fig 3: **(Left)** Grey dots indicate the distribution of F115W dropout galaxies, black cross indicates identified protocluster core candidates, and the blue dots indicate the member galaxies lying inside an cluster radius of 7.5 Mpc. **(Middle)** JWST/NIRCam RGB image of a COSMOS tile containing a protocluster candidate at z = 9.4. **(Right)** Zoomed in image centered on the protocluster candidate.

Conclusion:

- **15 protocluster core candidates at z > 9** have been identified, whereas only a few were previously known at 7 < z < 8.
- We found one at z=10.7, possibly the **most distant protocluster** candidate.

References:

Harikane et al. (2019,2023), Lapotre et. al., Larson et. al. (2022), Chen et. al. (2024), Cossas K.-W. Wu et. al (2025), Casey et al. 2023, Maximilien Franco (2025), M Boquien et al. (2019)