A JWST investigation into the bar fraction at redshifts $1 \leq z \leq 3$

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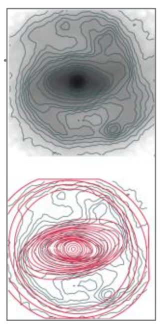
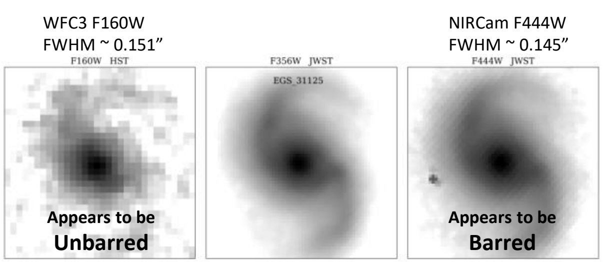
ABSTRACT

The presence of a stellar bar in a disc galaxy indicates that the galaxy hosts a dynamically settled disc and that bar-driven processes are taking place in shaping the evolution of the galaxy. Studying the cosmic evolution of the bar fraction in disc galaxies is therefore essential to understand galaxy evolution in general. Previous studies have found, using the Hubble Space Telescope (HST), that the bar fraction significantly declines from the local Universe to redshifts near one. Using the first four pointings from the James Webb Space Telescope (JWST) Cosmic Evolution Early Release Science Survey (CEERS) and the initial public observations for the Public Release Imaging for Extragalactic Research (PRIMER), we extend the studies on the bar fraction in disc galaxies to redshifts $1 \leq z \leq 3$, i.e., for the first time beyond redshift two. We only use galaxies that are also present in the Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS) on the Extended Groth Strip (EGS) and Ultra Deep Survey (UDS) HST observations. An optimised sample of 768 close-to-face-on galaxies is visually classified to find the fraction of bars in disc galaxies in two redshift bins: $1 \leq z \leq 2$ and $2 < z \leq 3$. The bar fraction decreases from $\sim 18.9^{+9.7}_{-9.4}$ per cent to $\sim 6.6^{+7.1}_{-5.9}$ per cent (from the lower to the higher redshift bin), but is $\sim$ 3 – 4 times greater than the bar fraction found in previous studies using bluer HST filters. Our results show that bar-driven evolution commences at early cosmic times and that dynamically settled discs are already present at a lookback time of $\sim$ 11 Gyrs.

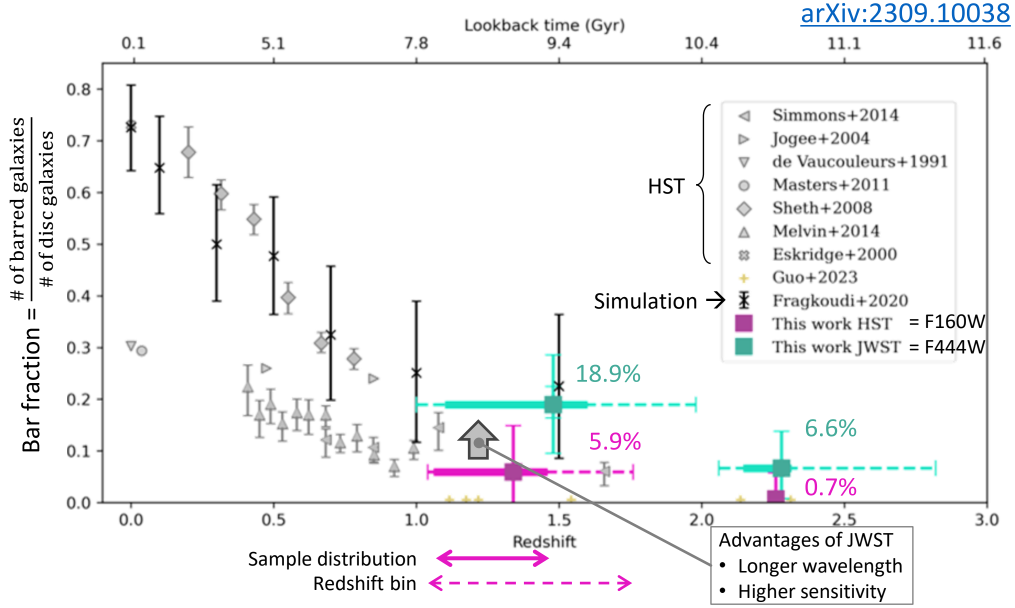
Fraction of barred galaxies at z > 1 through rest-frame NIR

- Stellar bar in a disc galaxy is an important structure as it drives the internal evolution of the galaxy by redistributing mass.
- Previous **HST** observations found the **declining bar fraction from z=0 to 1**.
  → Bar-driven galaxy evolution was thought to have started at least around z ~ 1.
- Because bars are dominated by older stellar populations, the **bars appear weaker in the optical** than in NIR.
  → The HST studies would be biased at higher redshift.
- However, the rest-frame NIR cannot be observed by HST beyond z ~ 1.
- JWST can extend the study of bars in the rest-NIR up to z ~ 3.
- Sample selection and bar identification
  1. CANDELS sample between **1 < z_phot < 3**
  2. Ellipse fit to isophotes
     (→ faint or poorly resolved sample removed)
  3. Selection of not-highly-inclined (***i*** **< 60**) galaxies
  4. Identification of bar structure **by eye**





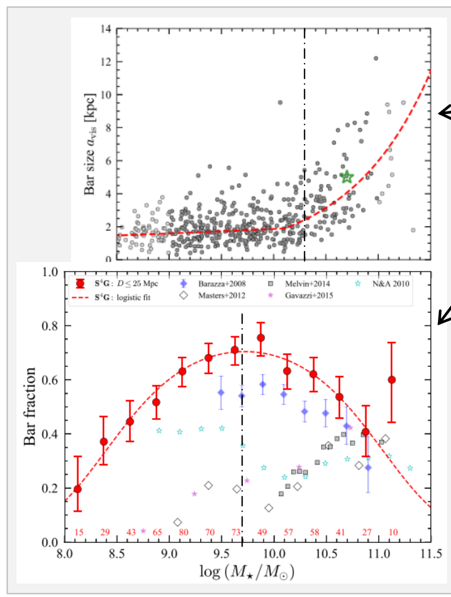
↑ Fig4: a z ~ 2 galaxy in F160W and F444W.
Classified as "unbarred" in WFC3, while "barred" in NIRCam, due to differences in wavelength and sensitivity.



↑Fig6: Bar fraction at z = 0—3 proved with HST and JWST.

- Bar fraction in F444W still shows a decline with increasing z, but at z ~ 1, 3x higher than in F160W.
  → Indicating that the detectability of bars depends on wavelength and sensitivity (and resolution).
- Bar fraction may not have changed as drastically as predicted by HST.
- Found 10 barred galaxies at z > 2.
  → The bar-driven galaxy evolution has happened beyond z ~ 2.5, not z ~ 1.

not a concern here since both are almost the same.



Possible issues/biases (at higher z)

Cf. ~8 kpc/arcsec @ z~1—2

- Bars longer than ~ 2 * PSF FWHM can be identified.
  → **Weak** (< 3 kpc) bars could be missed even with JWST.
- Bars become longer with increasing M_* (@ z=0).
  → Bars in **low-mass** galaxies could be missed.
  - On the other hand, bar fraction depends on M_s with a peak at $M_s \sim 10^{9.7}$ M_{sun} (@ z=0).
    - Low-mass barred galaxies would NOT be missed so much?

↓

Future papers will use wider NIRCam data to investigate:
- Bar fraction dependence on M_s
- Redshift evolution of bar length
- Relation between bar length and galaxy size

↖ Fig2 of Erwin 19: More stellar mass, the longer the bar (z=0).
← Fig5 of Erwin 18: Bar fraction peaks at $M_s \sim 10^{9.7}$ M_{sun} (z=0).