Euclid Quick Data Release (Q1)

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A first look at the fraction of bars in massive galaxies at $z < 1$★

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Stellar bars are key structures in disc galaxies, driving angular momentum redistribution and influencing processes such as bulge growth and star formation. Quantifying the bar fraction as a function of redshift and stellar mass is therefore important for constraining the physical processes that drive disc formation and evolution across the history of the Universe. Leveraging the unprecedented resolution and survey area of the *Euclid* Q1 data release combined with the Zoobot deep-learning model trained on citizen-science labels, we identify 7711 barred galaxies with $M_* \gtrsim 10^{10} M_\odot$ in a magnitude-selected sample ($I_E < 20.5$) spanning 63.1 deg^2. We measure a mean bar fraction of 0.2 – 0.4, consistent with prior studies. At fixed redshift, massive galaxies exhibit higher bar fractions, while lower-mass systems show a steeper decline with redshift, suggesting earlier disc assembly in massive galaxies. Comparisons with cosmological simulations (e.g., TNG50, Auriga) reveal a broadly consistent bar fraction, but highlight overpredictions for high-mass systems, pointing to potential over-efficiency in central stellar mass build-up in simulations. These findings demonstrate *Euclid*'s transformative potential for galaxy morphology studies and underscore the importance of refining theoretical models to better reproduce observed trends. Future work will explore finer mass bins, environmental correlations, and additional morphological indicators.

Barred galaxies fraction at z < 1 revealed with Euclid

- **Stellar bars** are a fundamental component of disk galaxies' (secular) evolution.
- Quantifying the fraction of barred galaxies at various redshifts is essential to understand the growth of disk galaxies and baryon assembly history.
- Identifying bars requires high spatial resolution imaging.
- Sharp images from HST and JWST have significantly advanced the study of barred galaxies.
  - It was previously thought that high gas content and turbulent conditions in the early universe prevent bar formation. ↔ JWST has found barred galaxies up to z ~ 4.
- However, their survey area and the sample size are relatively small.
- **Euclid** provides us both the **high resolution** and the very **wide** (space-based) coverage.
- This study uses the Euclid **Q1** data to measures the bar fraction in massive (Ms > 1e10 $M_\odot$) galaxies up to z ~ 1.
  - The number of barred galaxies is increased by more than an order of mag.
  - Bars are identified on I_E+Y_E images using a deep-learning model (**Zoobot**) trained on Galaxy Zoo labelling.
  - Bar fraction: $f_{bar} = \frac{N_{bar}}{N_{gal}}$, where $N_{gal} = |\{p_{feature} > 0.5\} \cap \{p_{edge\ on} < 0.5\}|$

    Galaxies with clear internal structure — Not edge-on galaxies

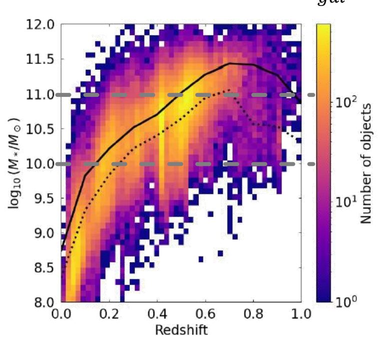

Fig. 1. Photo-z vs. stellar mass diagram showing the completeness limits for the Euclid Q1-GZ data set. The 90% and 50% stellar mass completeness limits are derived following Pozzetti et al. (2010) and are indicated by the solid and dotted black lines respectively.

↑ Fig1: Stellar mass completeness

90% complete at 1e10 $M_\odot$ (@z~0) and 1e11 $M_\odot$ (@z~1).

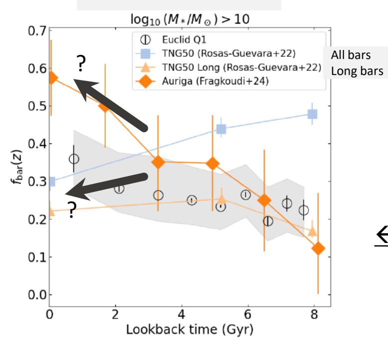

Fig. 7. Comparison of the observed bar fraction in our *Euclid* sample (large empty circles) with cosmological simulations. The cyan squares and pink triangles show the results from the TNG50 simulation when all bars and only long bars are included respectively. The orange diamond shows the Auriga simulation. The grey shaded region indicates the effect of varying the probability threshold for bar selection between 0.4 and 0.6. The mean bar fraction is globally well reproduced by the simulations.

← Fig7: Comparison with simulations

- Both simulations produce average f_{bar} ~ 0.2—0.4, that is **consistent with observations** (Fig 6).
- But show lower f_{bar} at lower z.
- Also, the trend **depends on selection criteria of bars**.

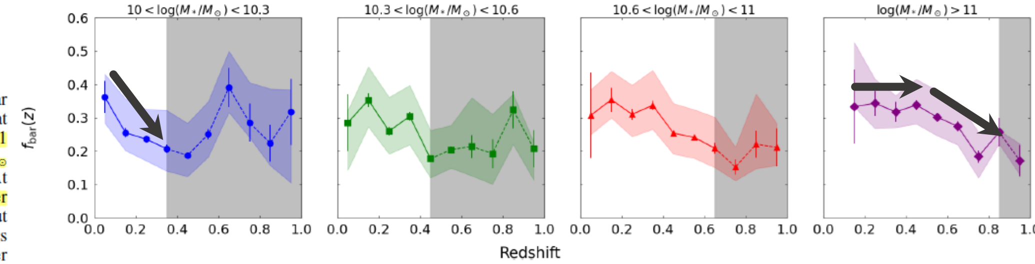

Fig. 5. Evolution of the bar fraction as a function of redshift. Each panel shows a different stellar mass bin as labelled. The coloured shaded regions indicate the effect of changing the threshold for selecting barred galaxies between 0.4 and 0.6. The grey shaded regions indicate the redshift ranges affected by incompleteness. Error bars indicate the 68% confidence interval under a beta-binomial posterior. The bar fraction shows a dependence with stellar mass, both in the normalisation and the evolutionary trends.

↑ Fig5: Evolution of the bar fractions

- In all mass bins, f_{bar} decreases at higher z.
- The decrease is pronounced in lower mass sample.
- Massive galaxies have higher f_{bar} at a given z.

Fig6: Comparison with HST/JWST studies (Ms > 1e10 $M_\odot$) →

- This work has significantly small statistical errors due to the large sample size (N=7711).
- Regardless of differences in selection and completeness, all studies show **consistent average f_{bar}** (0.1—0.3), including JWST/NIRCam result.
- Note that a luminosity-limited sample would produce artificially flatter trend, since at higher z, the sample is biased toward massive galaxies which have higher bar fraction.

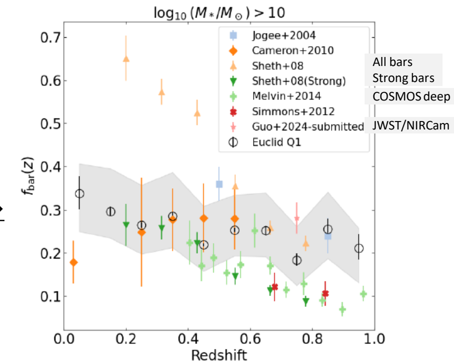

Fig. 6. Bar fraction as a function of redshift. The large black circles show the measurement from Q1 presented in this work. The grey shaded region indicates the effect of changing the threshold for selecting barred galaxies between 0.4 and 0.6. Different colours and symbols indicate previously published results from different space-based surveys as labelled. The *Euclid* measurements are in general agreement with previous works, but with significantly smaller statistical error bars.

Fig8: Comparison with simulations by Ms →

- **Simulations overpredict** f_{bar} for massive galaxies.
- Simulations would overproduce central star formation? (→ disk instability) → more efficient bar formation?

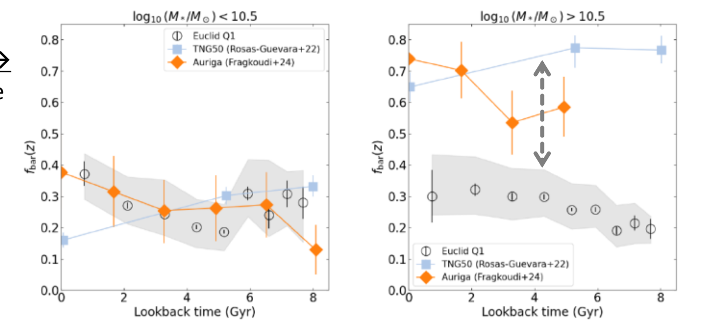

Fig. 8. Same as Fig. 7, but dividing galaxies in stellar mass bins. The left panel shows galaxies with stellar masses between 10^{10} and $10^{10.5}$ $M_\odot$. The right panel shows galaxies more massive than $10^{10.5}$ $M_\odot$. Simulations tend to over predict the bar fraction at the high mass end.

- Q1 demonstrates the ability of the Euclid sharp/deep/wide data to investigate the internal structure of disk galaxies.
- The final DR (100x the sample size) will allow exploration of environmental correlations and more detailed comparisons with simulations.