Dust-obscured star-forming phase at the origin of the galaxy bimodality

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Abstract :

The combined capabilities of the *James Webb* Space Telescope/NIRCam and the *Hubble* Space Telescope/ACS instruments provide enhanced spatial resolution imaging from the UV-to-NIR wavelengths that offer unprecedented insights into the internal structure of star-forming galaxies (SFGs) even when they are shrouded in dust.
In particular, a population of highly attenuated and massive SFGs, faint in the optical, named optically-faint galaxies (OFGs) can now be spatially resolved and studied in the rest-frame optical/near infrared. These OFGs represent a crucial population for unraveling the mechanisms driving the transition from vigorous star formation to quiescence, as they probably are the progenitors of the massive and passive galaxies already in place at cosmic noon.
We used the outstanding spatial resolution of the JWST images from the CEERS survey in the Extended Groth Strip (EGS) field combined with HST data to investigate the spatial distribution of $\Sigma_{\star}$, Σ_{SFR}, A_V^{ISM}, sSFR and mass-weighted age within a mass-complete sample of massive galaxies at z=3–4 while also emphasizing the peculiarity of OFGs relative to SFGs and quiescent galaxies (QGs) at these early redshifts.

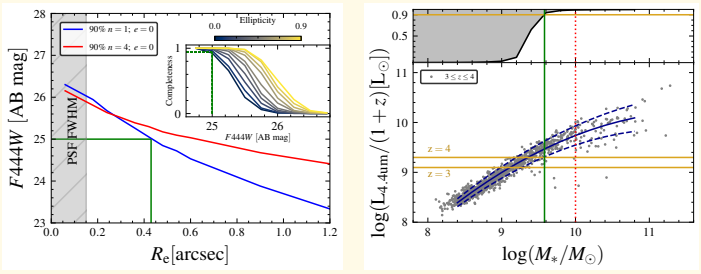
This work reveals a primeval bimodality between extended blue SFGs and red, compact and strongly attenuated SFGs that have undergone a phase of major gas compaction. We show evidence that this primeval bimodality leads to the bimodality observed between blue SFGs and red QGs in the local Universe.

Aim

Study and compare the morphology of blue and red SFGs to the one of QGs in a mass-complete sample at 3<z<4.

A mass-complete sample in the CEERS field

We performed injection-recovery of 1000 Sérsic profiles in the CEERs field to derive the limiting magnitude of the survey. We then translated this into a mass-limit empirically using the the evolution of the mass-to-light ratio and its dispersion. Our sample is 90% complete for $\log(M_\star/M_\odot)$>9.6 and contains 190 galaxies.



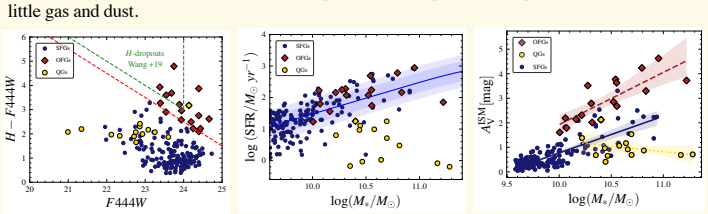
(a) Limiting magnitude determination **(b) Mass completeness determination**

Fig 1. **(a)** Evolution of the limiting magnitude for extended objects with various Sérsic profiles. **(b)** Illustration of the method used to obtain the 90% mass-limit. The sample of low mass-to-light galaxies at high mass are the OFGs and is complete for $\log(M_\star/M_\odot)$>10.

Optically-Faint Galaxy population

To identify this massive and highly obscured population, we used the [1] color selection criteria. These galaxies were missed by the Lyman break selection and only the most massive of them were detected as H-dropout by the [2] criteria. This population is located in the Star-Forming Main Sequence.

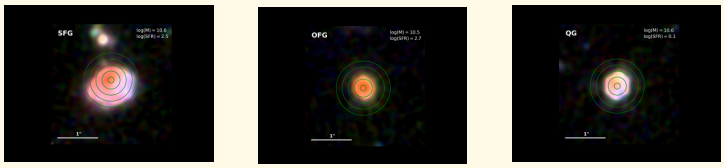
There is a correlation between the dust attenuation and the stellar mass for both the obscured and unobscured SFGs. At a given mass, red SFGs (OFGs) are systematically more attenuated than blue SFGs while dust attenuation of QGs does not evolve with mass as it is the case for SFGs and OFGs. They contain similar dust attenuation as SFGs with $\log(M_\star/M_\odot) \sim 10.2$. This low A_V^{ISM} demonstrates that despite being compact and cuspy these galaxies have little gas and dust.



(a) Color selection **(b) Main Sequence relation** **(c) Dust attenuation**

Fig 2. **(a)** OFGs color selection criteria (red dotted line) from [1]. OFGs are shown as red squares. Blue and yellow circles are the UVJ selected blue SFGs and QGs. **(b)** Location of these three populations in the SFR- $M_\star$ plane. The [3] main sequence is displayed as a solid blue line with its 1σ scatter. **(c)** Dust attenuation as a function of stellar mass. The regression lines for each population are displayed as solid and dotted lines.

Resolved SED-fitting



We binned each galaxy in five concentric annuli with a width = F444W FWHM and ran the SED code CIGALE on their respective UV-to-NIR photometry.

Bulge formation and compaction event

We renormalized the median radial profiles to the median stellar mass of the SFGs. For the radius, we used the mass-size relation from [4]. For Σ_{SFR} we rescaled to the main sequence from [3]. For A_V^{ISM} we used the relation traced by the SFGs in **Fig 2. (c)**.

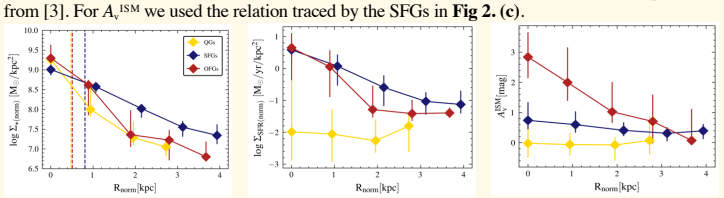


Fig 3. OFGs and QGs show similar stellar profiles and in terms of Σ_{SFR} OFGs are more concentrated than SFGs. The dust attenuation is particularly concentrated in OFGs, explaining their high attenuation compared to SFGs. These observations suggest a compaction event occurring *in-situ* within OFGs that is building the bulge of massive quiescent galaxies.

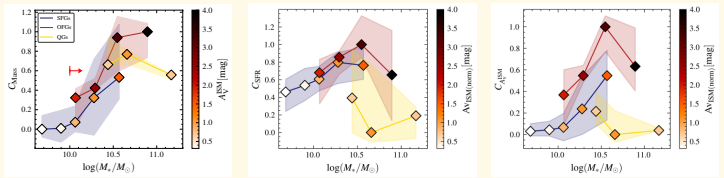


Fig 4. OFGs mass profiles are more concentrated than SFGs at all mass and become analog to the one of QGs for $\log(M_\star/M_\odot)$~10.5. The SFR concentration of OFGs and SFGs are alike up to this mass. The dust concentration in OFGs being significantly higher at a given mass than the one of SFGs, suggests a real bimodality between SFGs and OFGs that takes its seed in the compaction event that OFGs undergo.

Origin of the galaxy bimodality

For $\log(M_\star/M_\odot)$>10.5 the concentration of SFR and dust decays significantly. This suggests that above this mass, the bulge formation is over thanks to a major gas compaction event and that star formation happens majoritarily in the outer part of these OFGs. Therefore OFGs might start inside-out quenching in their future. We connect our finding with the galaxy evolution of (e.g [5], and [6]) which predict such a major compaction phase near this « critical mass ». Observations in the local Universe such as [7] have highlighted this mass as being the mass defining the bimodality between SFGs and QGs.

To conclude, we unveiled in this work the nature of the OFG population as the link between the morphological transition of SFGs into QGs.

References

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