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Data-driven galaxy morphology at $z > 3$ with contrastive learning and cosmological simulations

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Visual inspections of the first optical rest-frame images from JWST have indicated a surprisingly high fraction of disk galaxies at high redshifts. Here, we alternatively apply self-supervised machine learning to explore the morphological diversity at $z \geq 3$.

Our proposed data-driven representation scheme of galaxy morphologies, calibrated on mock images from the TNG50 simulation, is shown to be robust to noise and to correlate well with physical properties of the simulated galaxies, including their 3D structure. We apply the method simultaneously to F200W and F356W galaxy images of a mass-complete sample ($M_*/M_\odot > 10^9$) at $3 \leq z \leq 6$ from the first JWST/NIRCam CEERS data release. We find that the simulated and observed galaxies do not exactly populate the same manifold in the representation space from contrastive learning. We also find that half the galaxies classified as disks (either CNN-based or visually) populate a similar region of the representation space as TNG50 galaxies with low stellar specific angular momentum and non-oblate structure.

Although our data-driven study does not allow us to firmly conclude on the true nature of these galaxies, it suggests that the disk fraction at $z \geq 3$ remains uncertain and possibly overestimated by traditional supervised classifications.

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