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Early JWST imaging reveals strong optical and NIR color gradients in galaxies at $z \sim 2$ driven mostly by dust

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ABSTRACT

Recent studies have shown that galaxies at cosmic noon are redder in the center and bluer in the outskirts, mirroring results in the local universe. These color gradients could be caused by either gradients in the stellar age or dust opacity; however, distinguishing between these two causes is impossible with rest-frame optical photometry alone. Here we investigate the underlying causes of the gradients from spatially-resolved rest-frame $U-V$ vs. $V-J$ color-color diagrams, measured from early observations with the *James Webb Space Telescope*. We use $1\,\mu m - 4\,\mu m$ NIRCam photometry from the CEERS survey of a sample of 54 galaxies with $M_*/M_\odot > 10$ at redshifts $1.7 < z < 2.3$ selected from the 3D-HST catalog. We model the light profiles in the F115W, F200W and F356W NIRCam bands using `imcascade`, a Bayesian implementation of the Multi-Gaussian expansion (MGE) technique which flexibly represents galaxy profiles using a series of Gaussians. We construct resolved rest-frame $U-V$ and $V-J$ color profiles. The majority of star-forming galaxies have negative gradients (i.e. redder in the center, bluer in the outskirts) in both $U-V$ and $V-J$ colors consistent with radially decreasing dust attenuation. A smaller population (roughly 15%) of star-forming galaxies have positive $U-V$ but negative $V-J$ gradients implying centrally concentrated star-formation. For quiescent galaxies we find a diversity of UVJ color profiles, with roughly one-third showing star-formation in their center. This study showcases the potential of *JWST* to study the resolved stellar populations of galaxies at cosmic noon.

Background & Motivation:

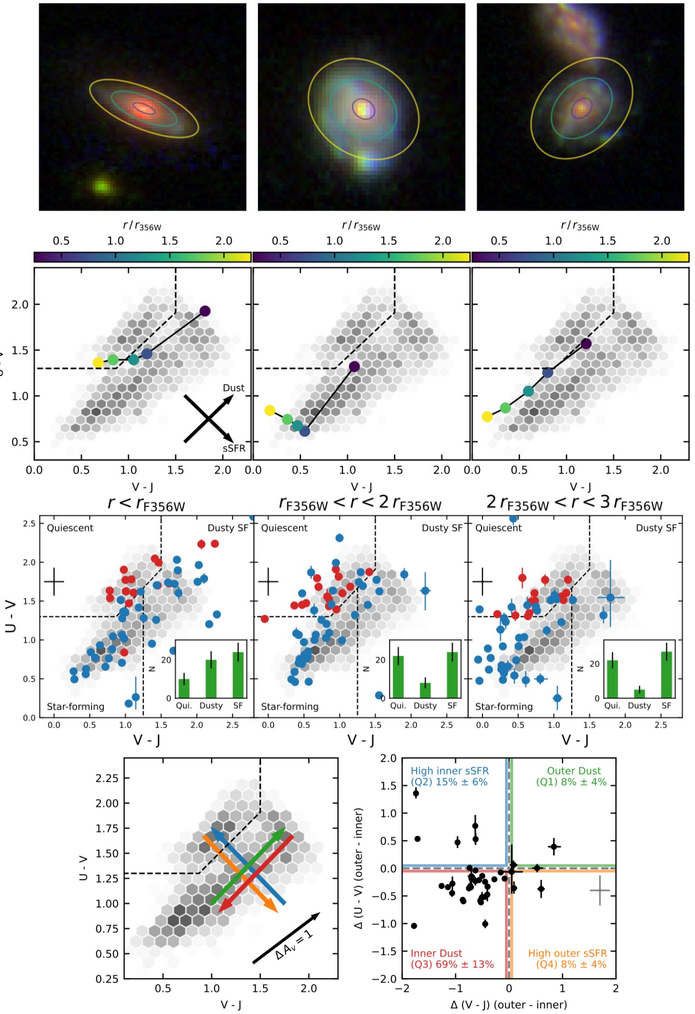
1. Galaxies: radial color profile → complex multicomponent SFH
SFGs, QGs: both redder in the center, bluer in the outskirts (negative optical color gradients)
z > 1: space-based resolution, e.g., HST (up to 1.6 μm, WFC3)
2. Optical color (rest-frame) are affected by variety of factors including dust, nebular emission lines
→ **UVJ** diagram (dust and SFH can be separated)
→ resolved UVJ diagrams of galaxies at z > 1

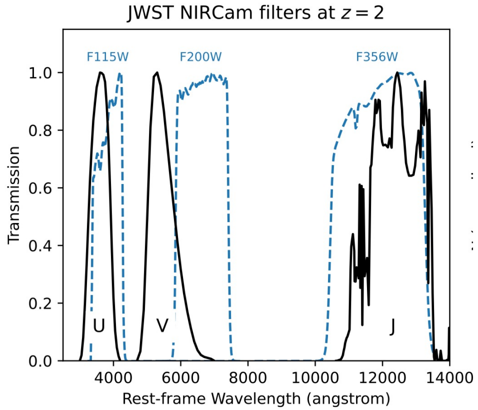
Data, Sample and Method

JWST-CEERS (Cosmic Evolution Early Release Science): EGS field
Galaxies from 3D-HST catalog: $M_* > 10^{10} M_\odot$, 1.7 < z < 2.3 (119)
imcascade: Fit the light distribution as a mixture of Gaussians
Fitting 10 Gaussian components to model each galaxy
Quality check: exclude ill-converged fit, large axis-ratio, no concentrated flux → 54/119 (X: too crowded, over–masked)

Filter Conversion: Simulation of mocked galaxies in PROSPECTOR

$$(U-V)_{RF} = 0.971\,(m_{115W} - m_{200W}) + 0.056 - 0.969\,(z-2)$$
$$(V-J)_{RF} = 1.310\,(m_{200W} - m_{356W}) + 0.168 - 0.268\,(z-2)$$





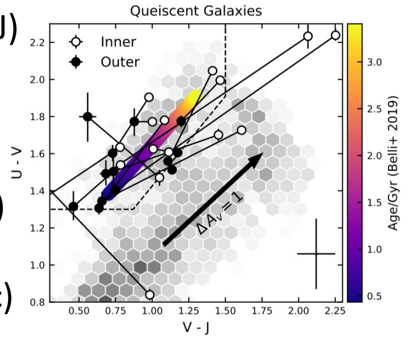
The ability of JWST to study the resolved structure of galaxies at cosmic noon

Result 1: Integrated colors from 0.5 to 2.5 r_{F356W}
Disky morphology with a red center in these sample, radially decreasing dust attenuation

Result 2: UVJ colors measured at different r_{F356W}
Total flux: 39/54 SFs, 15/54 QGs
Small radius: very strong dust attenuation (dust SF)
Ouskirts: these population disappear
The entire population of SFGs appears to shift towards the bottom left.

Result 3: SFGs Δ(U − V) − Δ(V − J) plane
Q1 & Q3: Higher dust content in the center compared to the outskirts ($\Delta A_V = -0.45$), 70% inner $A_V > 1$
Q2 & Q4: No detailed discussion (MW is Q4)

Result 4: QGs Δ(U − V) − Δ(V − J)
Age gradient + Dust vector:
Interpretation of QGs becomes more complicated
6/15: inner classifies to SFGs (a)
4/15: mild UVJ gradients (b)
5/15: QGs along age gradient (c)



What is the underlying cause of color gradients at cosmic noon?

Previous studies: Dust is the main cause of color gradients at z < 1.5
This work: confirming dust is the cause of negative color gradients out to z = 2.3, suggest even at higher redshift, dust continues to play a large role
This result is qualitatively different to what is observed in the local universe (Q3 v.s Q4).
Classical bulge have not yet formed at z ∼ 2.
Q2+Q4=23%: 2/3 are Q2 + (a), the growth of bulges in the center;
1/3 are Q4, in the process of inside-out quenching. (Complicated transitional phases)
For QGs, Resolved MIR/FIR measurements could help differentiate between the effects of dust and stellar age. (a): early stage of quenching; (b),(c): multiple quenching pathways