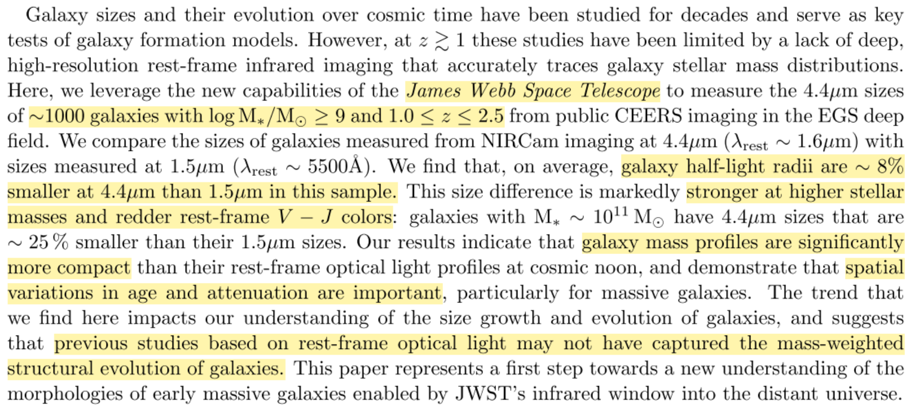
Rest-frame near-infrared sizes of galaxies at cosmic noon: objects in JWST's mirror are smaller than they appeared

Suess et al. 2022, arXiv:2207.10655



Galaxy sizes and their evolution over cosmic time have been studied for decades and serve as key tests of galaxy formation models. However, at $z \gtrsim 1$ these studies have been limited by a lack of deep, high-resolution rest-frame infrared imaging that accurately traces galaxy stellar mass distributions. Here, we leverage the new capabilities of the *James Webb Space Telescope* to measure the 4.4μm sizes of ~1000 galaxies with $\log \mathrm{M}_*/\mathrm{M}_\odot \geq 9$ and $1.0 \leq z \leq 2.5$ from public CEERS imaging in the EGS deep field. We compare the sizes of galaxies measured from NIRCam imaging at 4.4μm ($\lambda_{\rm rest} \sim 1.6\mu$m) with sizes measured at 1.5μm ($\lambda_{\rm rest} \sim 5500$Å). We find that, on average, galaxy half-light radii are ~ 8% smaller at 4.4μm than 1.5μm in this sample. This size difference is markedly stronger at higher stellar masses and redder rest-frame $V-J$ colors: galaxies with $\mathrm{M}_* \sim 10^{11}\,\mathrm{M}_\odot$ have 4.4μm sizes that are ~ 25 % smaller than their 1.5μm sizes. Our results indicate that galaxy mass profiles are significantly more compact than their rest-frame optical light profiles at cosmic noon, and demonstrate that spatial variations in age and attenuation are important, particularly for massive galaxies. The trend that we find here impacts our understanding of the size growth and evolution of galaxies, and suggests that previous studies based on rest-frame optical light may not have captured the mass-weighted structural evolution of galaxies. This paper represents a first step towards a new understanding of the morphologies of early massive galaxies enabled by JWST's infrared window into the distant universe.

銀河のサイズ進化 ← HSTによる調査

(1) 重い銀河はより大きい

(2) Cosmic noon (z~1-2)の銀河は近傍の銀河より小さい

(3) 一定の質量ではSFGがQGより大きい

➔ light-weighted sizeはmass-weighted sizeは異なり得る

➔ mass distributionを理解するにはrest-IRの高空間分解能データ

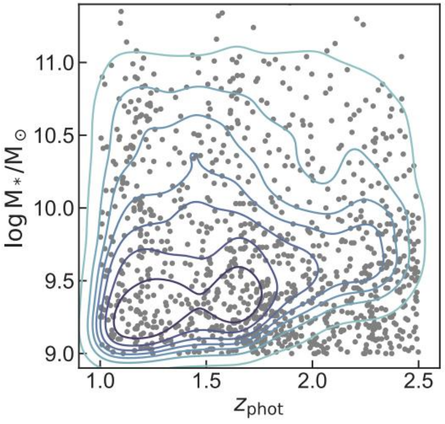
➔ JWST/NIRCamの撮像データ

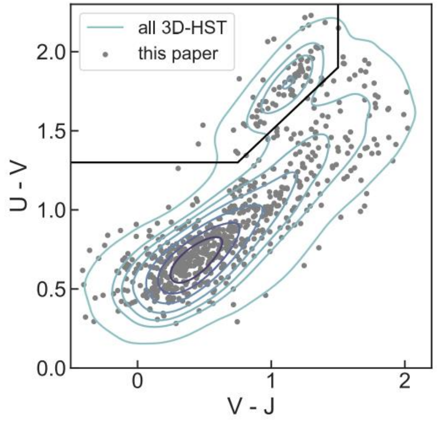
Sample : CEERS program AEGIS field

- F444W & F150W (~1.6-6.3 hours/pointing)
- 3D-HSTから星質量と赤方偏移(z_best)

➔ $1.0<z<2.5$, $\log(M_*/M_\odot)>9$

➔ 1500 galaxies

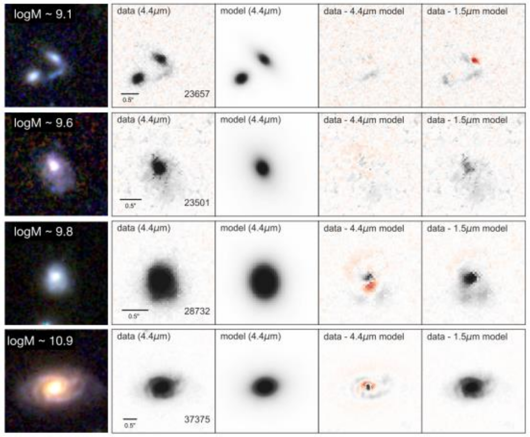




GALFIT

- WebbPSFでPSF作成
  (星はサチっているので使用できない)
- astropyとphotutilsでセグメンテーションマップ
  - 暗い天体をマスク
  - SExtractor方式でスカラー背景除去
- GALFITでF150WとF440Wの形態フィット
  (Sersic profile)

➔ 1080 galaxies



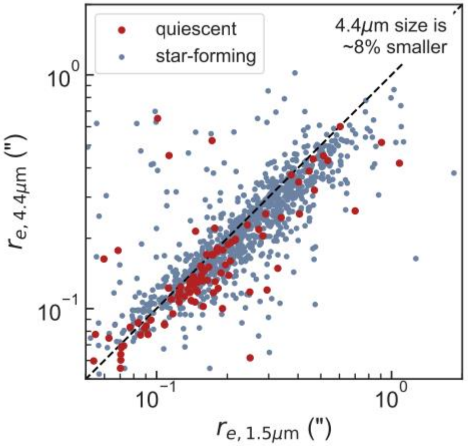
1.5umと4.4umのサイズ比較

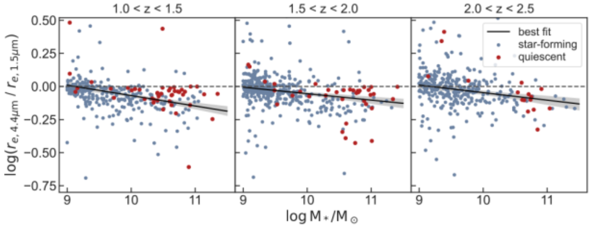
➔ 4.4umの方が8%だけ小さい

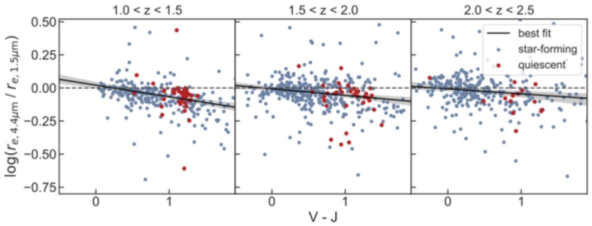
サイズ変化の星質量、V-J color依存性

➔ 高質量、赤いほどサイズの違いが大きい

- 近傍で知られた結果(Kelvin+2012, Lange+2015)と一致 ➔ この時代にすでに複雑な構造
- stellar population synthesisでhalf-light radiiとhalf-mass radiiを比較した研究と定性的には一致







既存の結果に対する疑問 (正しくmass sizeで調べると)

- 高質量銀河ほど$r_{4.4um}/r_{1.5um}$が違う ➔ 大質量でもサイズが大きくないかも
- $r_{4.4um}/r_{1.5um}$が赤方偏移進化したら ➔ Cosmic noonの銀河は小さくないかも
- SFGとQGで$r_{4.4um}/r_{1.5um}$が違ったら ➔ QGの方がSFGより小さくないかも

Light-weighted sizeがバイアスされていて、SFGとQGが同じような大きさだとしたら、劇的な形態の変化(Zolotov+2015)や厳しい先祖子孫の関係(van Dokkum+2015)が緩むかもしれない