A rest-frame near-IR study of clumps in galaxies at $1 < z < 2$ using JWST/NIRCam: connection to galaxy bulges

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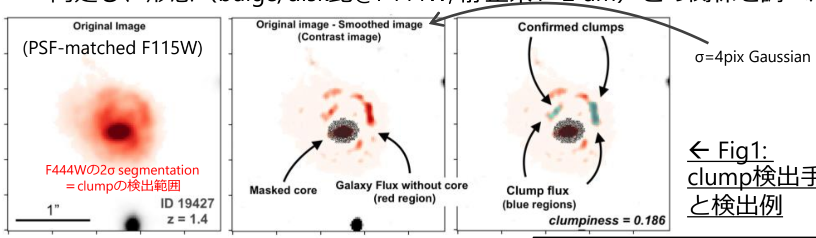
ABSTRACT

A key question in galaxy evolution has been the importance of the apparent 'clumpiness' of high redshift galaxies. Until now, this property has been primarily investigated in rest-frame UV, limiting our understanding of their relevance. Are they short-lived or are associated with more long-lived massive structures that are part of the underlying stellar disks? We use JWST/NIRCam imaging from CEERS to explore the connection between the presence of these 'clumps' in a galaxy and its overall stellar morphology, in a mass-complete ($log\,M_*/M_\odot > 10.0$) sample of galaxies at $1.0 < z < 2.0$. Exploiting the uninterrupted access to rest-frame optical and near-IR light, we simultaneously map the clumps in galactic disks across our wavelength coverage, along with measuring the distribution of stars among their bulges and disks. Firstly, we find that the clumps are not limited to rest-frame UV and optical, but are also apparent in near-IR with ∼ 60 % spatial overlap. This rest-frame near-IR detection indicates that clumps would also feature in the stellar-mass distribution of the galaxy. A secondary consequence is that these will hence be expected to increase the dynamical friction within galactic disks leading to gas inflow. We find a strong negative correlation between how clumpy a galaxy is and strength of the bulge. This firmly suggests an evolutionary connection, either through clumps driving bulge growth, or the bulge stabilizing the galaxy against clump formation, or a combination of the two. Finally, we find evidence of this correlation differing from rest-frame optical to near-IR, which could suggest a combination of varying formation modes for the clumps.

静止系近赤外線で（初めて）見る z>1 Clumpy銀河

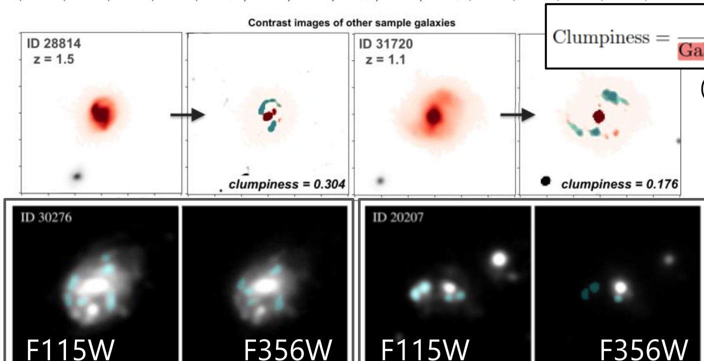
- Clumpy銀河は遠方の星形成銀河で多く見られるが、これまではほとんど静止系紫外で調べられてきた（HSTの観測波長による制限）。
  - Clumpは紫外（~可視）だけで見える短命でlow massな構造なのか、古い星も含んでいてhigh massで近赤外でも見えるのか？
  - Simulationではどちらも棄却できていない。
- JWST/NIRCamのF115W~F356Wを使ってz~1-2 静止系可視～近赤外でclumpを同定し、形態（bulge/disk比@F444W; 静止系1~2 um）との関係を調べた。



← Fig1: clump検出手順と検出例

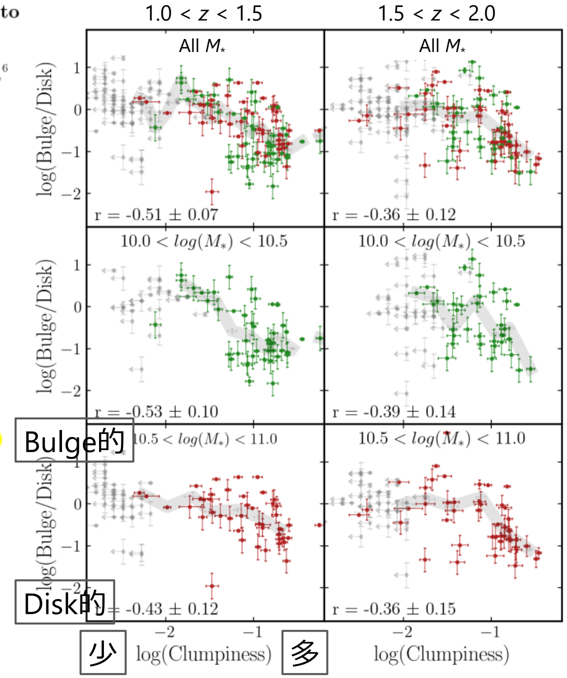
$$\text{Clumpiness} = \frac{\Sigma\,\text{Clump flux}}{\text{Galaxy Flux without core}}$$

(Clumpinessの定義)



↙ Fig3: 静止系可視と近赤外での見え方の比較

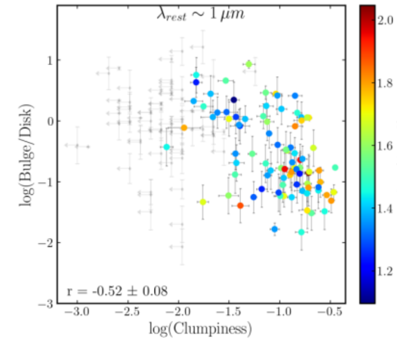
近赤外でもclumpは見えていて、~60%は可視と近赤外で同じ箇所を同定。
→ clumpはそこそこの質量をもっている＝**銀河の構造(形成)に関係**しているかもしれない。



↑Fig6: clumpiness (@rest 1um) と B/D比 (@F444W)

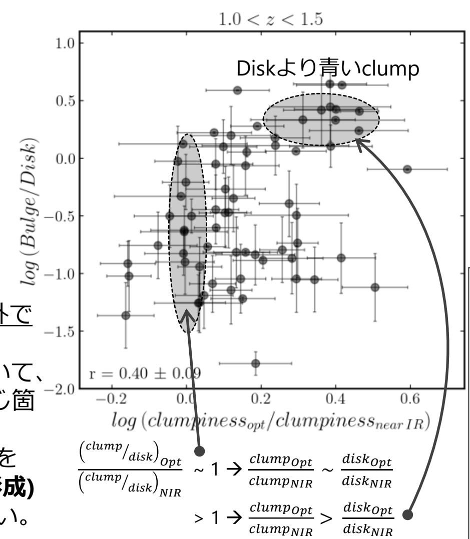
- B/D比: GALIGHTによるSersic n=1 & n=4の2成分fit（pure-bulge-likeや-disk-likeとedge-onは除外）
- Clump: PHOTUTILSによる5σピーク検出

Redshiftによらず、星質量によらず、**bulgeが発達しているほど、clumpが少ない（or 未検出）**という相関。D/T比にすると相関は見えない。



↑Fig12: SFRによる違いがあるか？
相関がSelection biasによるものかを確認するため、starburstiness (ΔMS) で色分け。
→ 相関を形成するサンプルに偏りは見られない。
→ **B/Dとclumpinessの相関はbulgeが関係**しているようだ。

Clumpy銀河の割合はminor mergerやdisk不安定性による割合と同程度
➔ clumpの形成メカニズムか



↙Fig7: B/D比とclumpiness比

- **Clumpが（近赤外と比べて）可視で明るいほどbulgeが顕著。**
- Fig.6は横軸をclumpiness_optにするとよりsteepになる。
- In-situ clumpは青く(若く)、ex-situ (infalling) clumpは赤い (古い) (？)
  - 各ClumpのSED解析が必要。

解釈：銀河(bulge)進化とclumpの関係
- ☐ Minor merger等によりclump形成 → 周りのガスを巻き込んで銀河中心に落ちる → bulge成長 → stellar feedbackによりclump破壊？
- ☐ 逆に、bulge成長 → disk安定化 → clump形成抑制？
- ☐ Clumpのcolorの幅広さは複数の形成メカニズムの存在を示唆か。