ALMA reveals rapid formation of a dense core for massive discs at z~2

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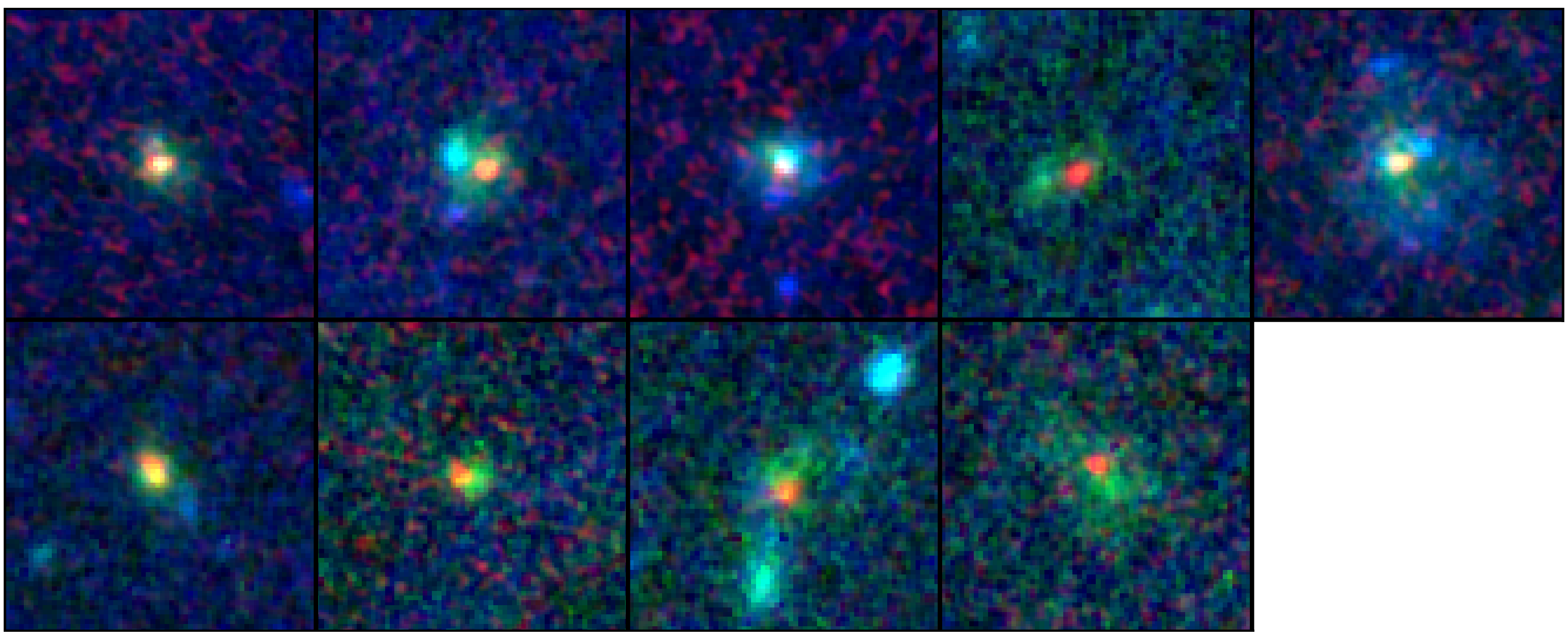
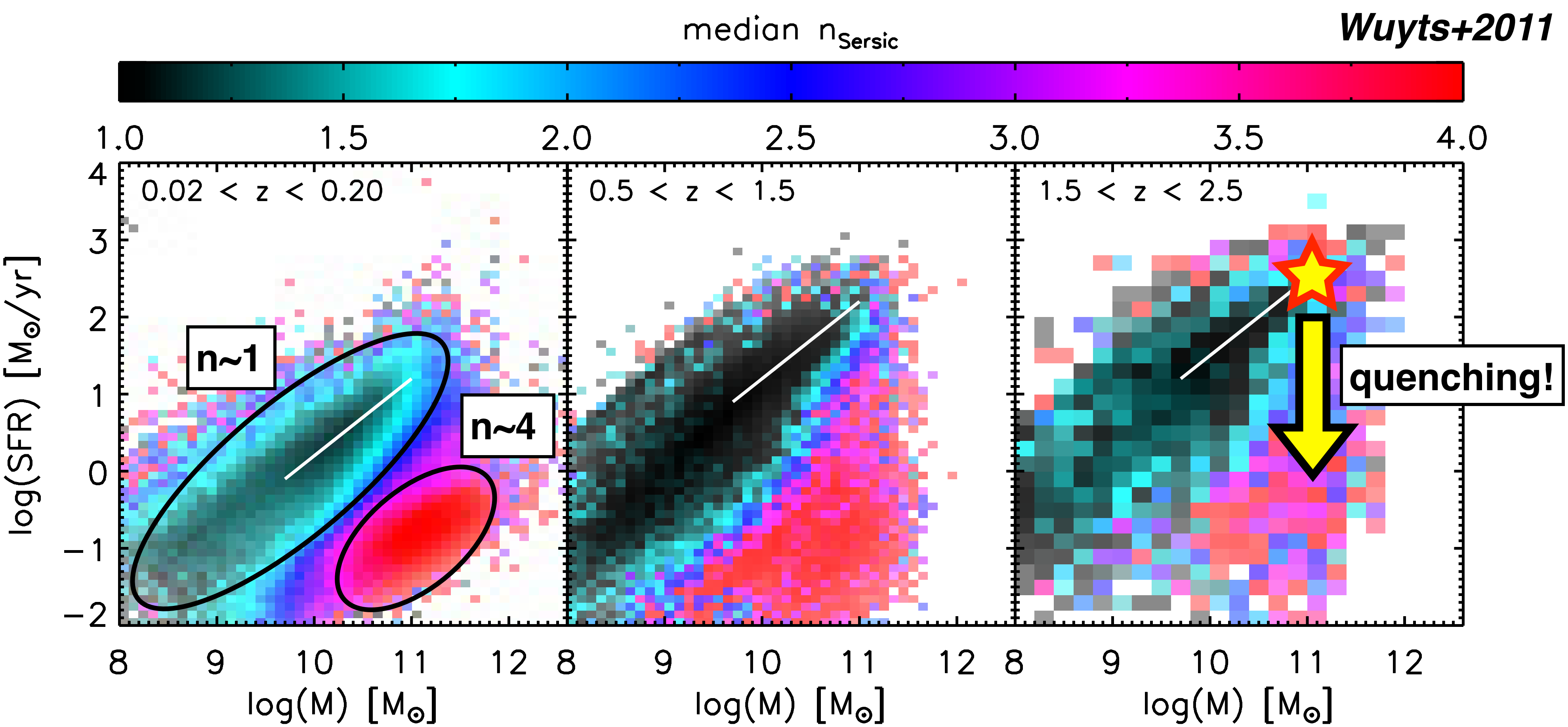
Bulge-forming galaxies



Origin of the Hubble sequence

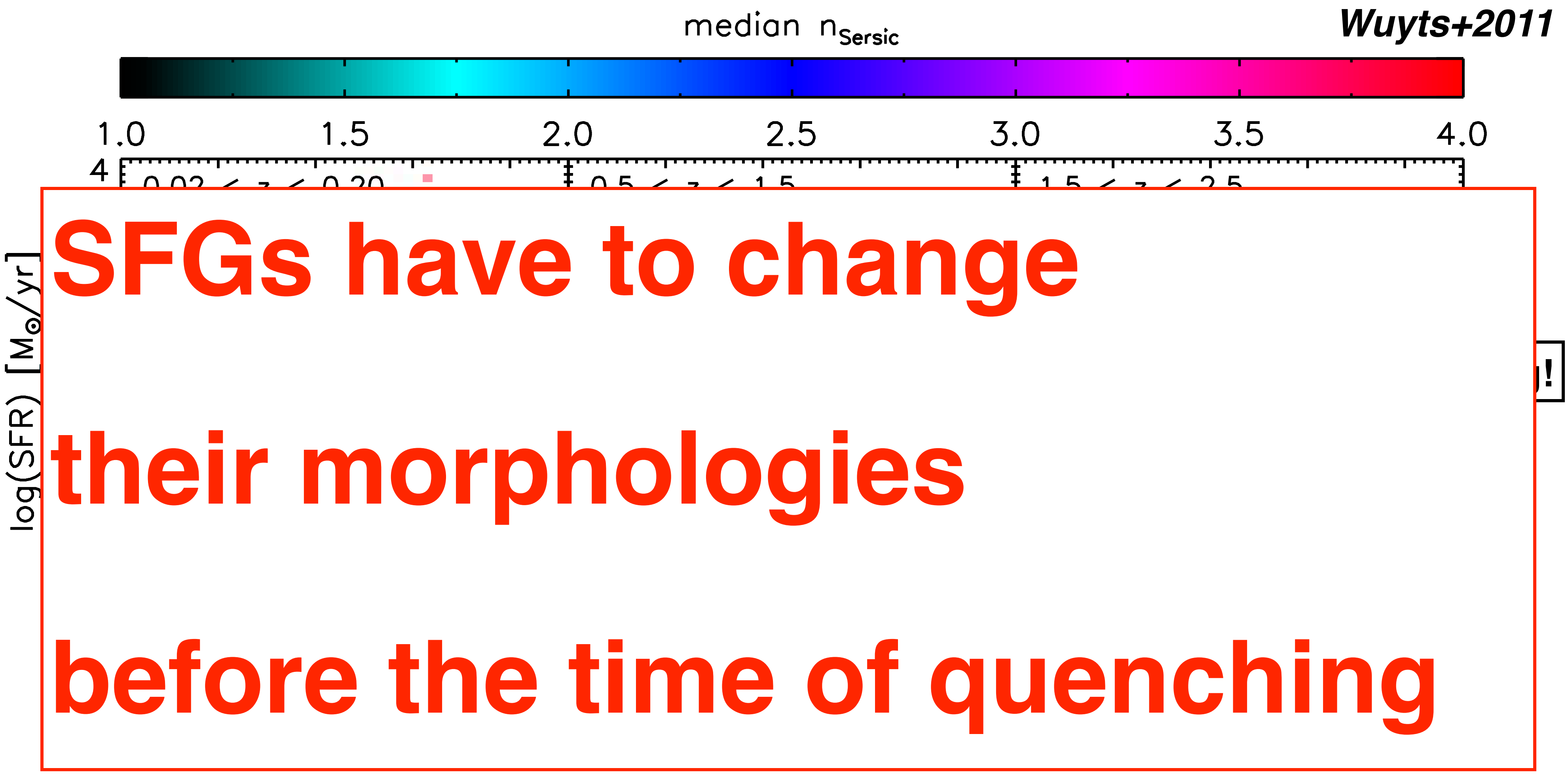


Star-forming galaxies -> disc-dominated (n~1)

Quiescent galaxies -> bulge-dominated (n>2)

Hubble sequence

Wuyts+2011

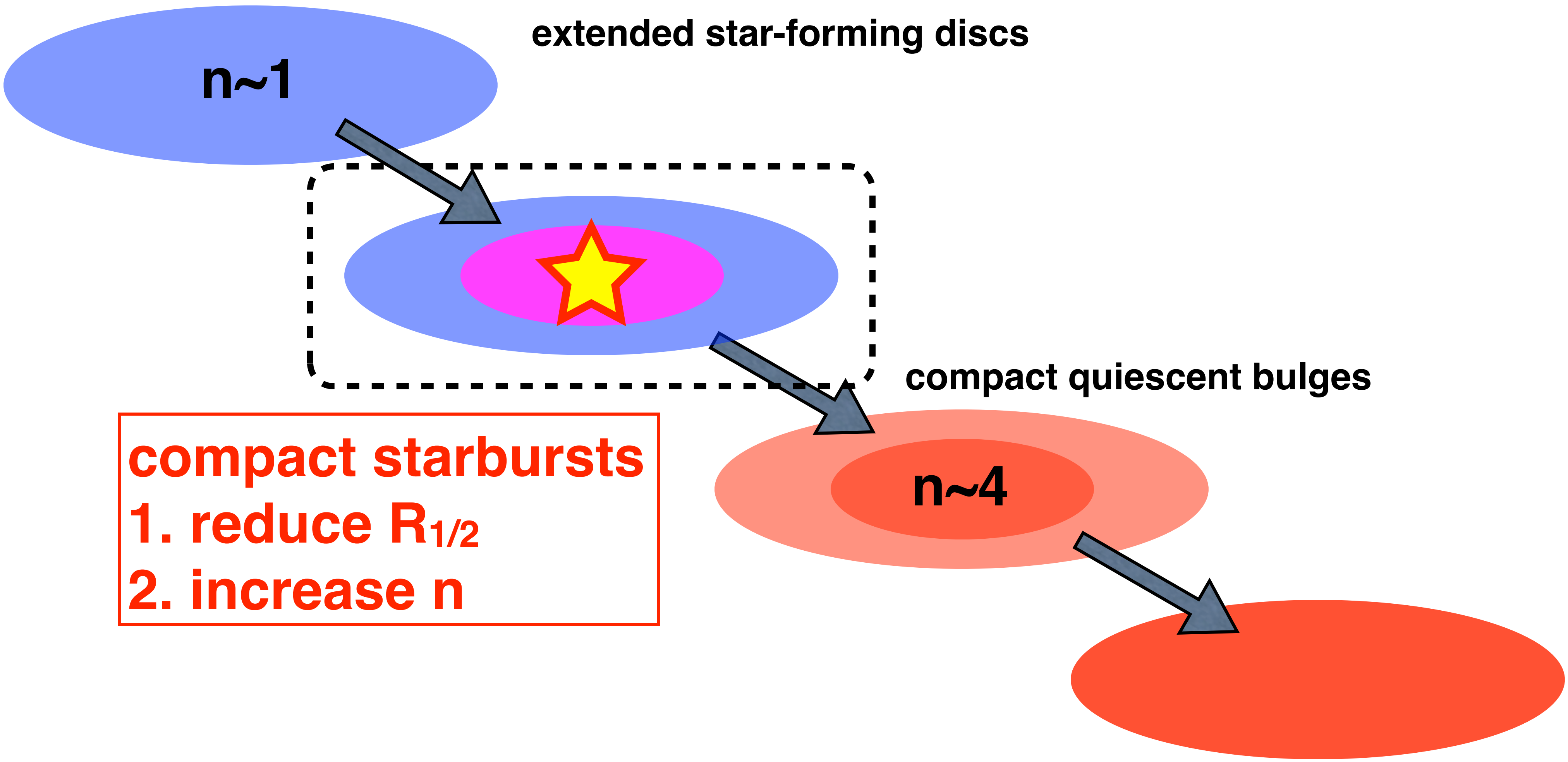


SFGs have to change their morphologies before the time of quenching

Star-forming galaxies -> disc-dominated (n~1)

Quiescent galaxies -> bulge-dominated (n>2)

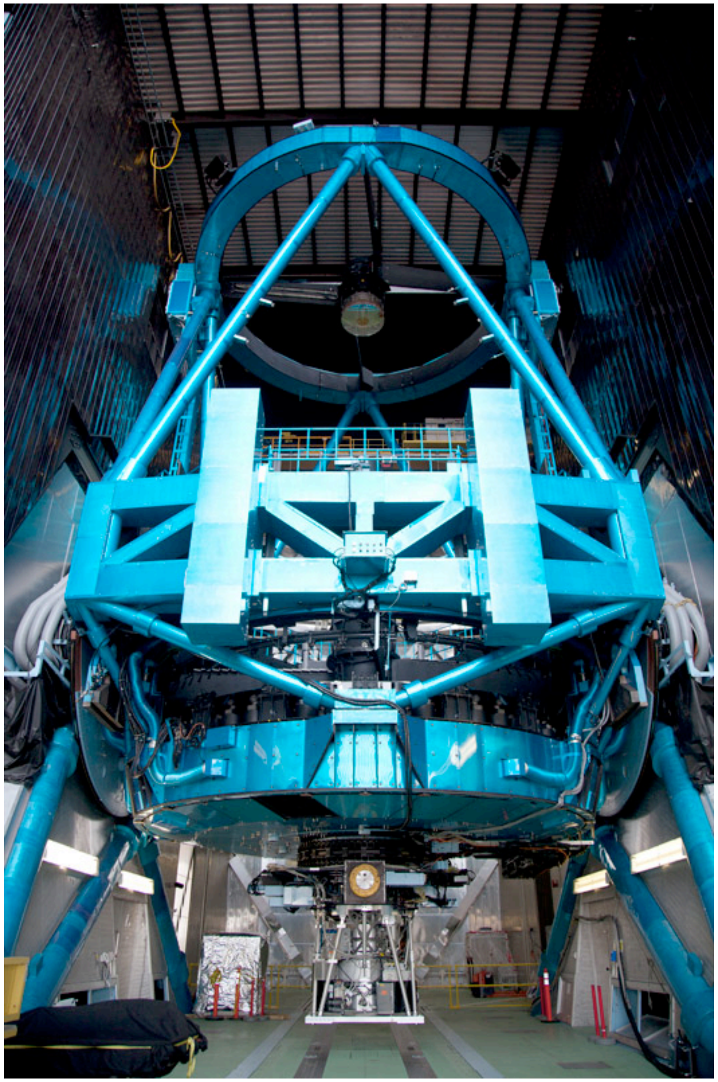
From disc-nominated to bulge-dominated



Our goal is
``to study the spatial distribution of star formation within SFGs at z~2''

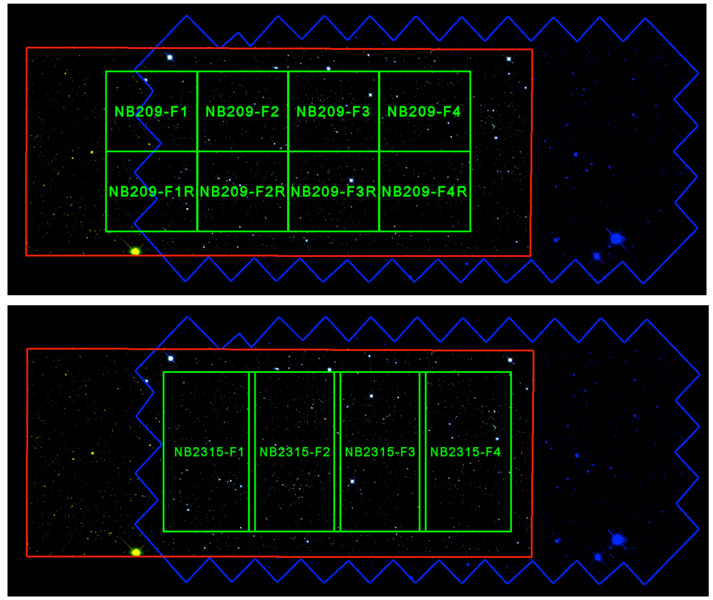
Sample: Subaru narrow-band imaging

Subaru telescope



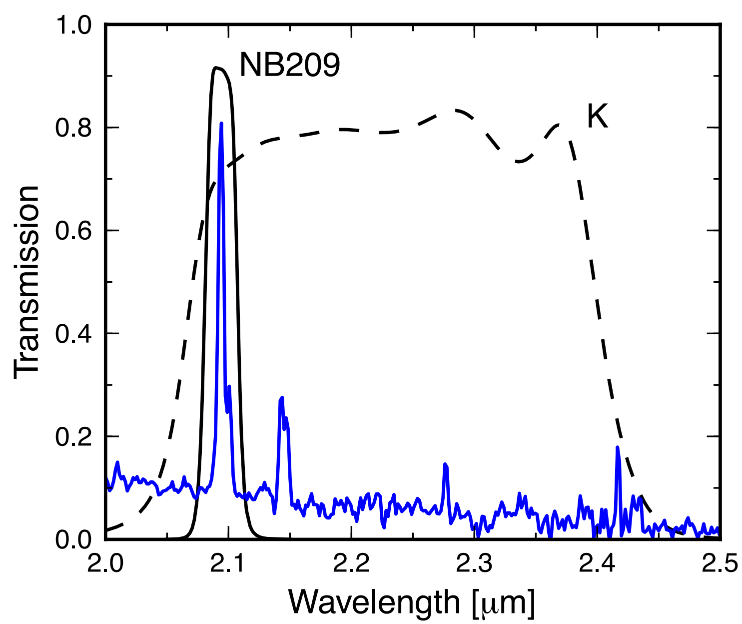
credit NAOJ

CANDELS-SXDF-UDS field



NB209:
Hα line at z=2.19

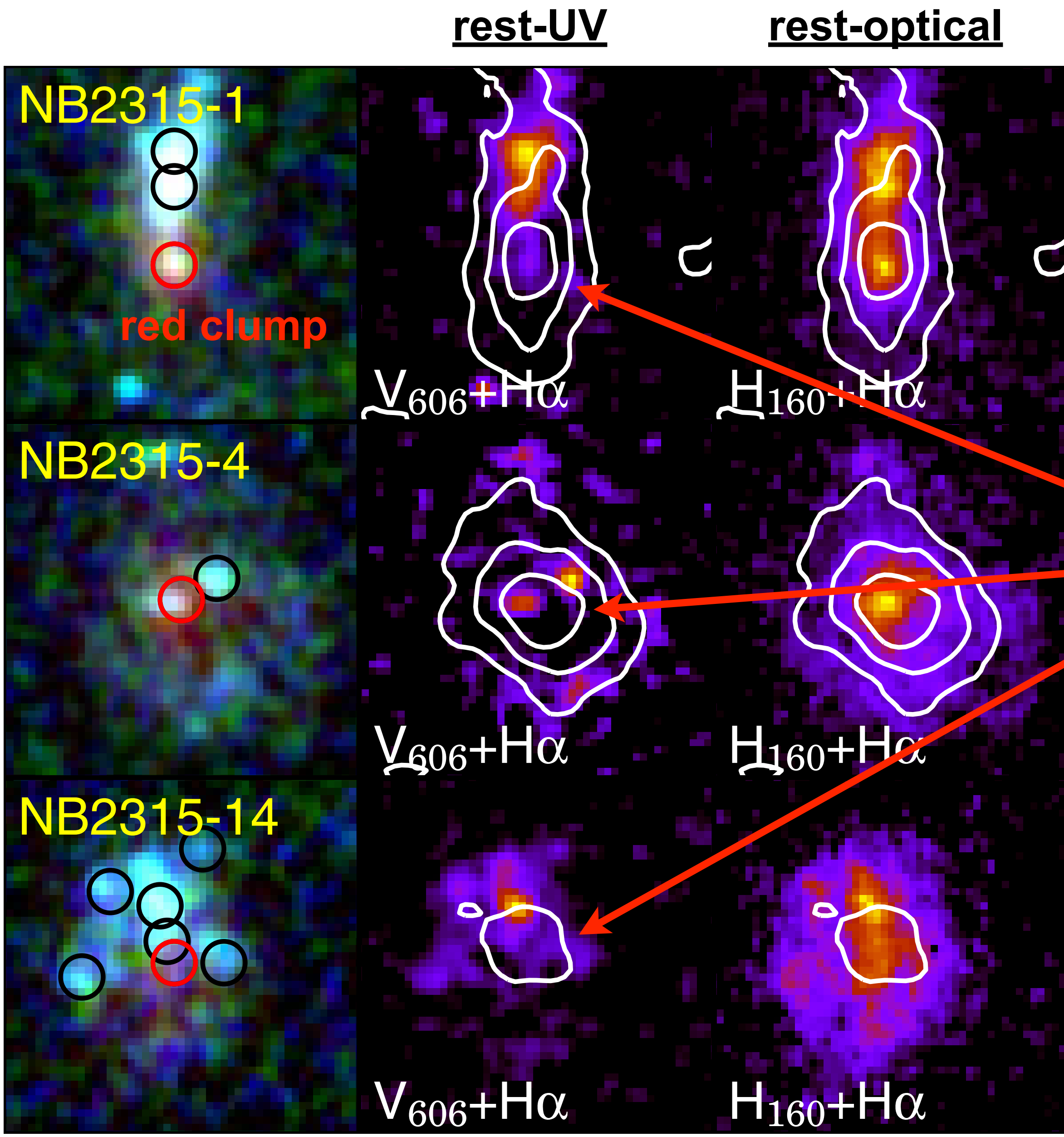
NB2315:
Hα line at z=2.53



~100 SFGs at z~2

Tadaki et al. 2013
Kodama et al. 2013

Indirect evidence of central dusty star formation



white contour: Hα map
○: central red clump

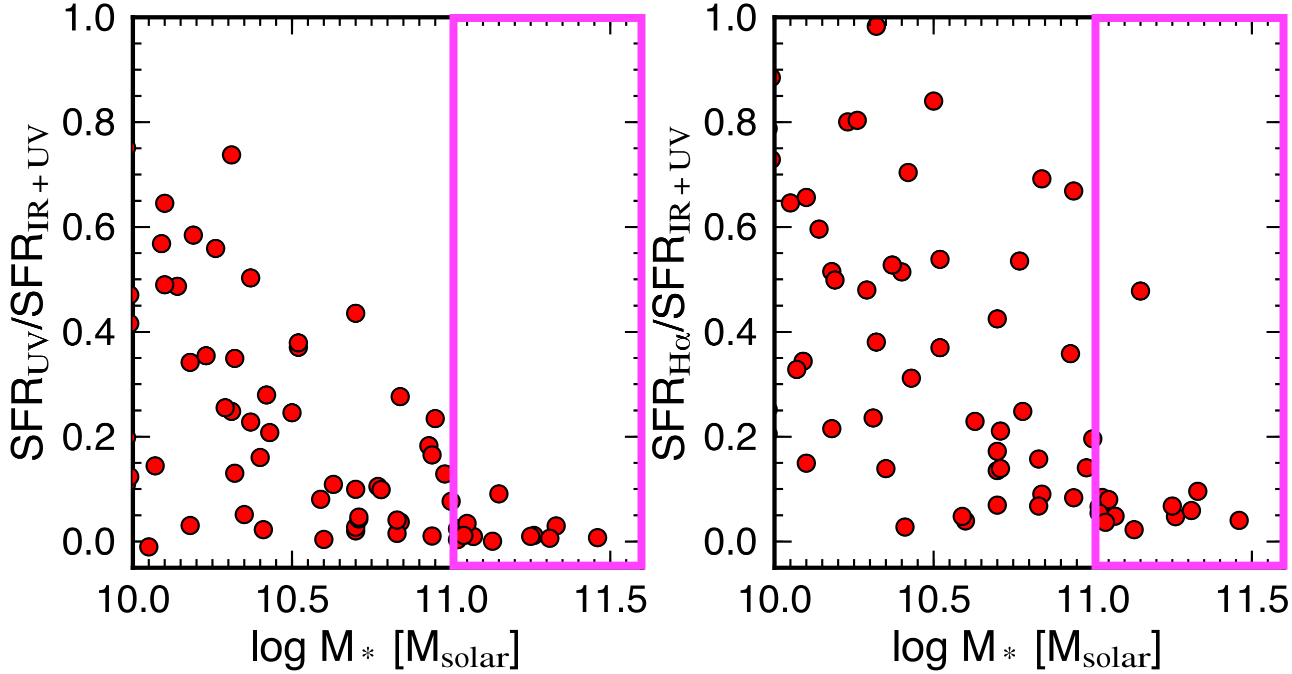
the central red clump has high Hα/UV ratio

dusty star formation in galaxy center

Tadaki et al. 2014

A serious problem is dust extinction

Galaxy properties for Hα-selected SFGs at z~2



UV can trace only ~1% of total star formation

even with Hα emission, A(Hα)~3 mag

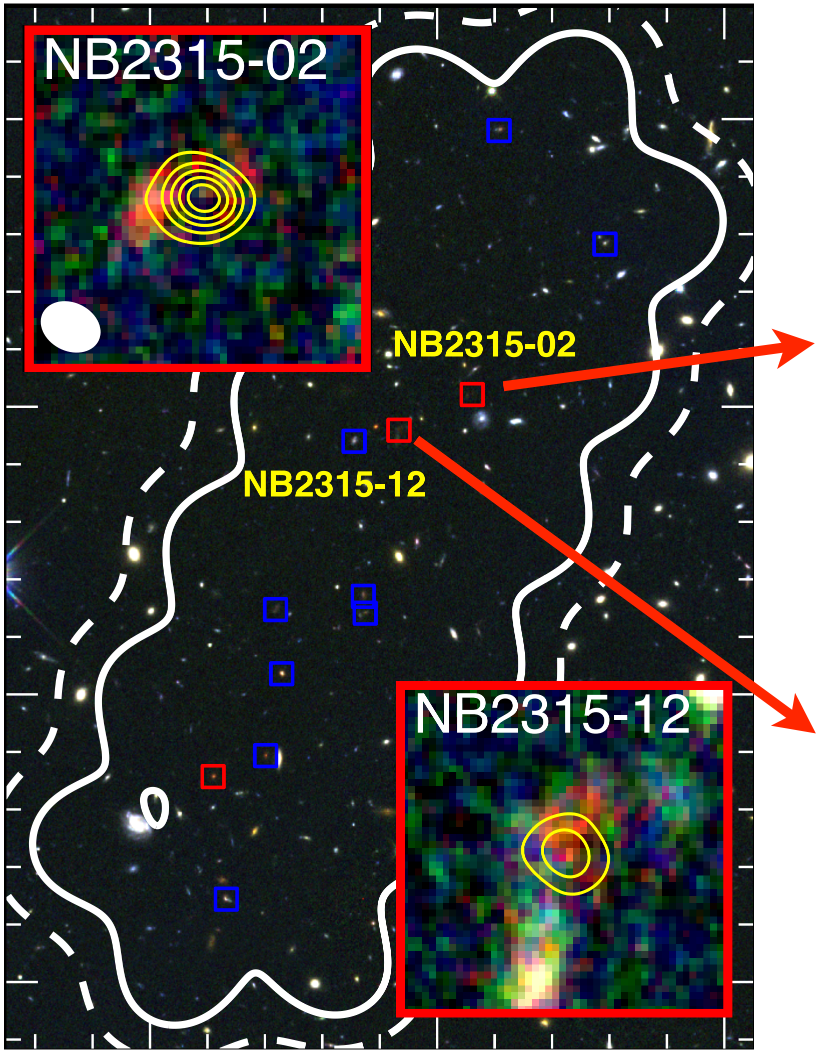
what we want to know is the spatial distribution of star formation within galaxies

for massive galaxies with logM*>11

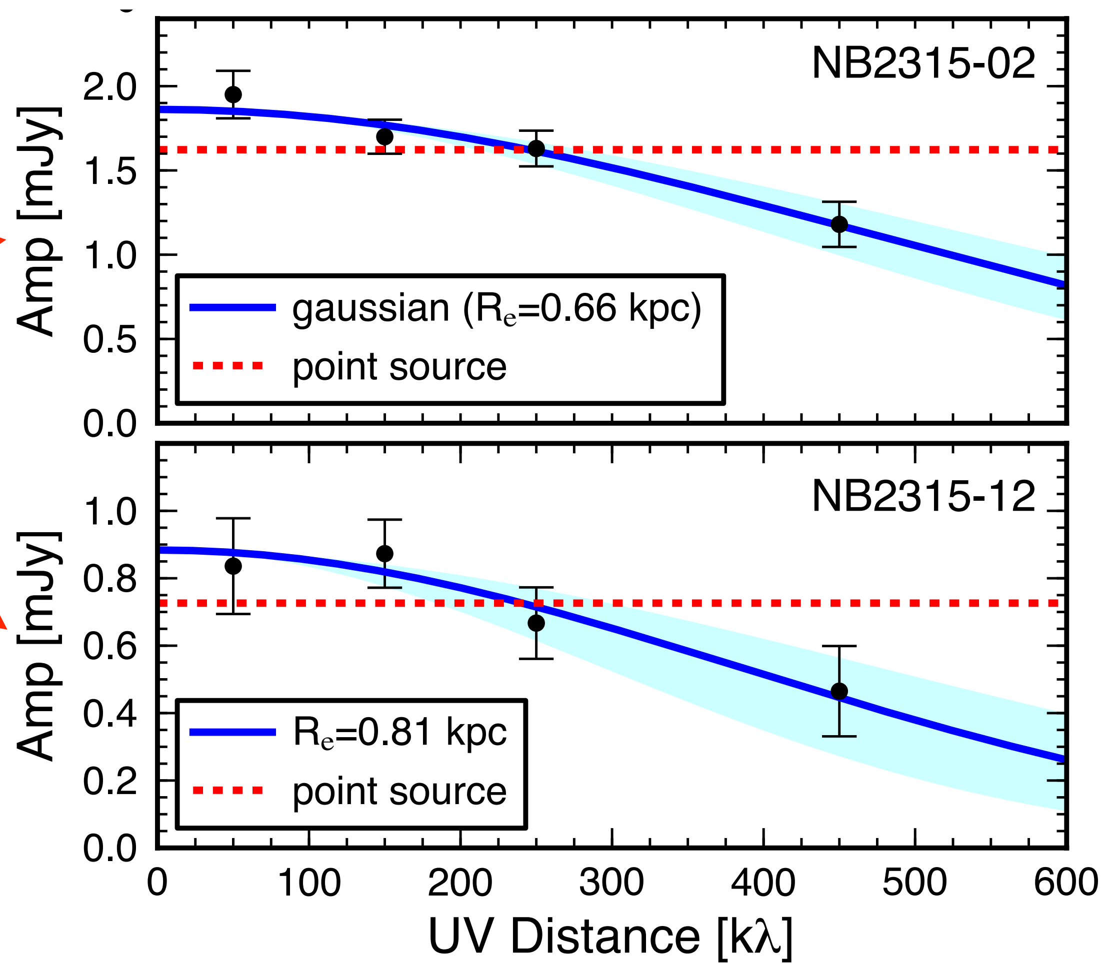
we need to spatially resolve the dust emission with ALMA

From indirect to direct evidence with ALMA

SXDF-ALMA 2 arcmin² deep survey at 1.1 mm
(*Tadaki et al. 2015, Kohno et al. 2015*)

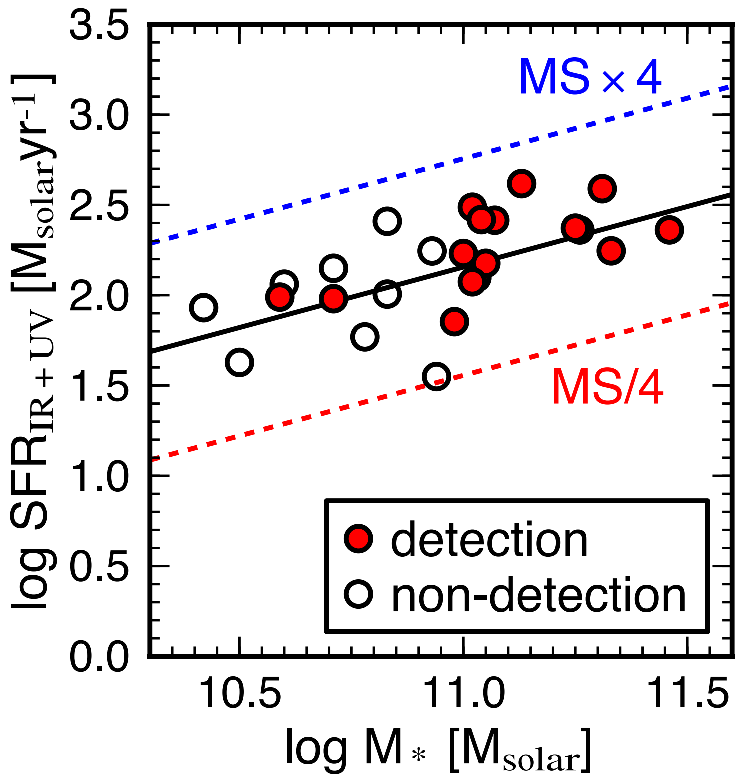


size measurements of dust emission



the dust emission is extremely compact ($R_{1/2}$~1 kpc)

ALMA 870 μm observations in CANDELS-UDS

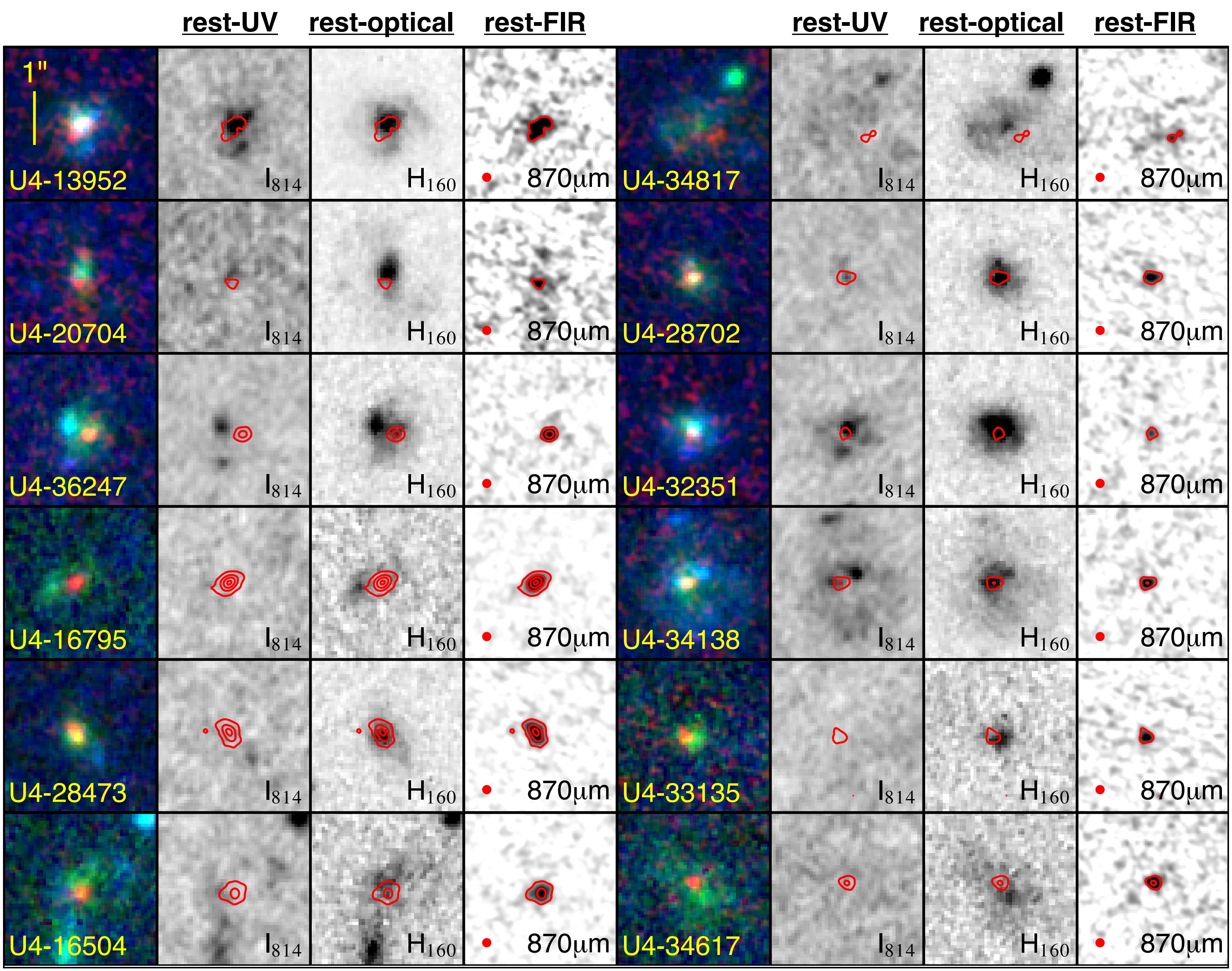


Target:
25 Hα-selected SFGs at z=2.2 or z=2.5
Observations:
ALMA/Band-7 (870μm), **0.2″ resolution**
Result:
16/25 are detected
12 have reliable size measurements

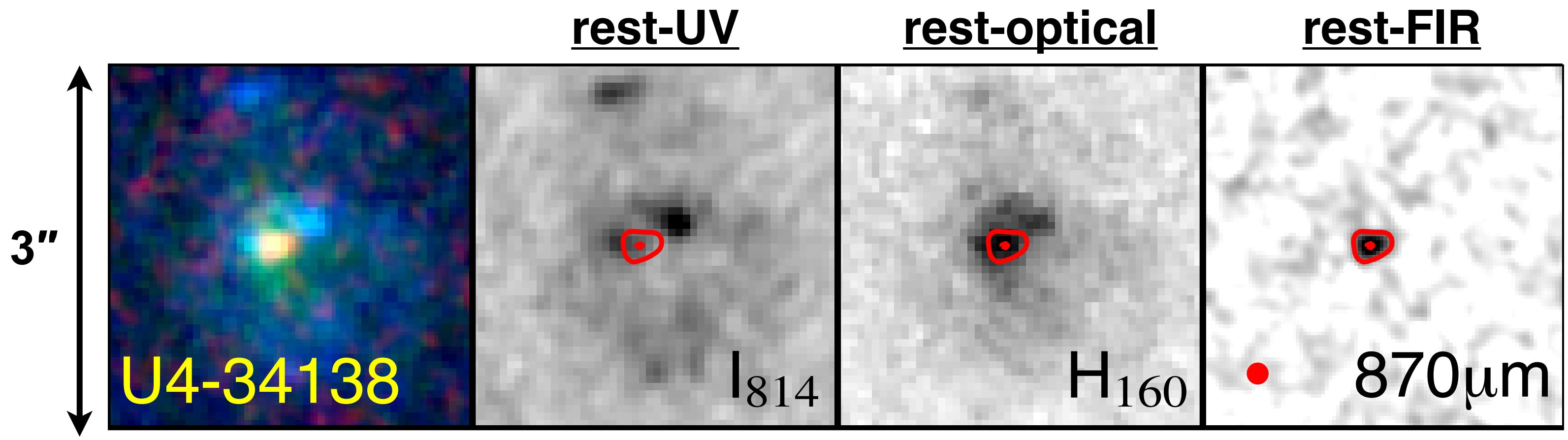
Credit: ALMA(ESO/NAOJ/NRAO)

Tadaki et al. in prep

HST & ALMA composite images



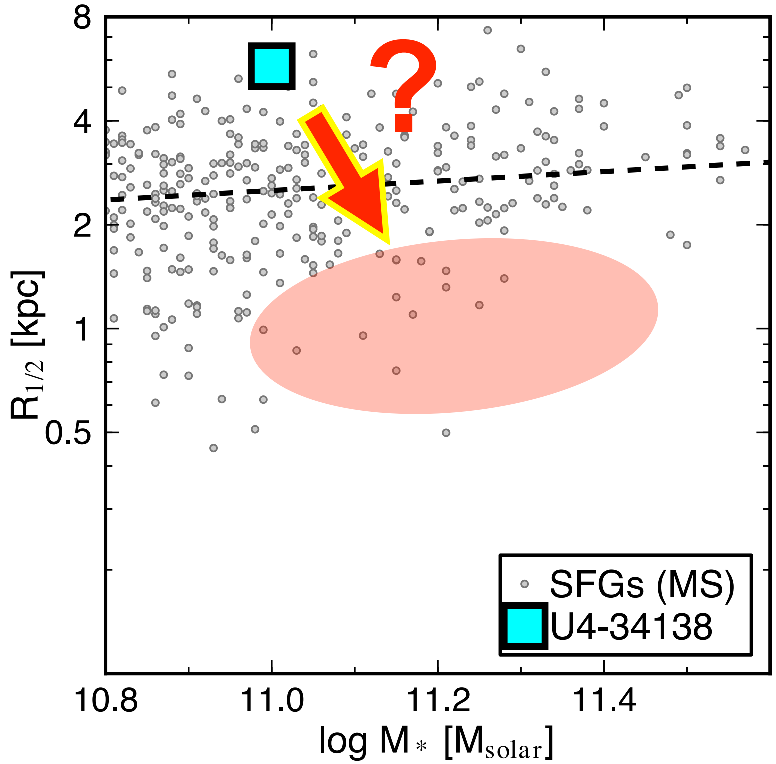
HST & ALMA composite images



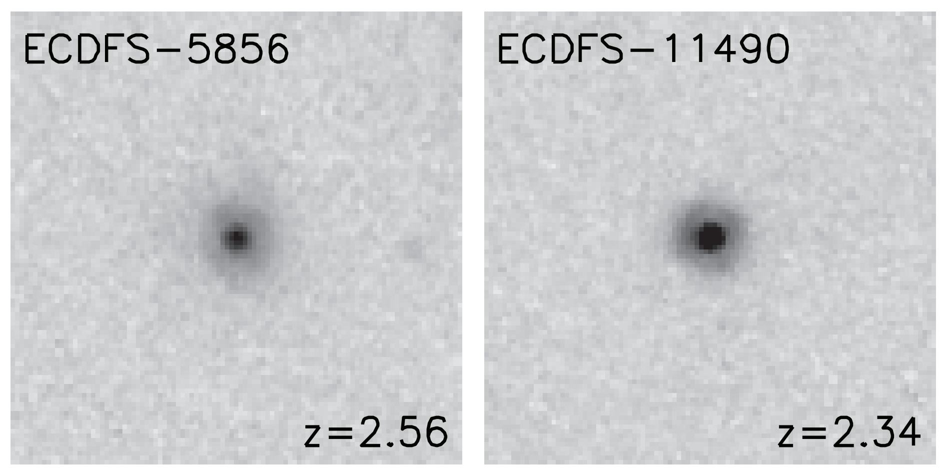
clumpy

extended disc
($R_{1/2}$=5.8 kpc, n=1.2)

centrally
concentrated!



compact quiescent galaxies
(van Dokkum+08)



Size measurements of 870 μm emission

exponential model

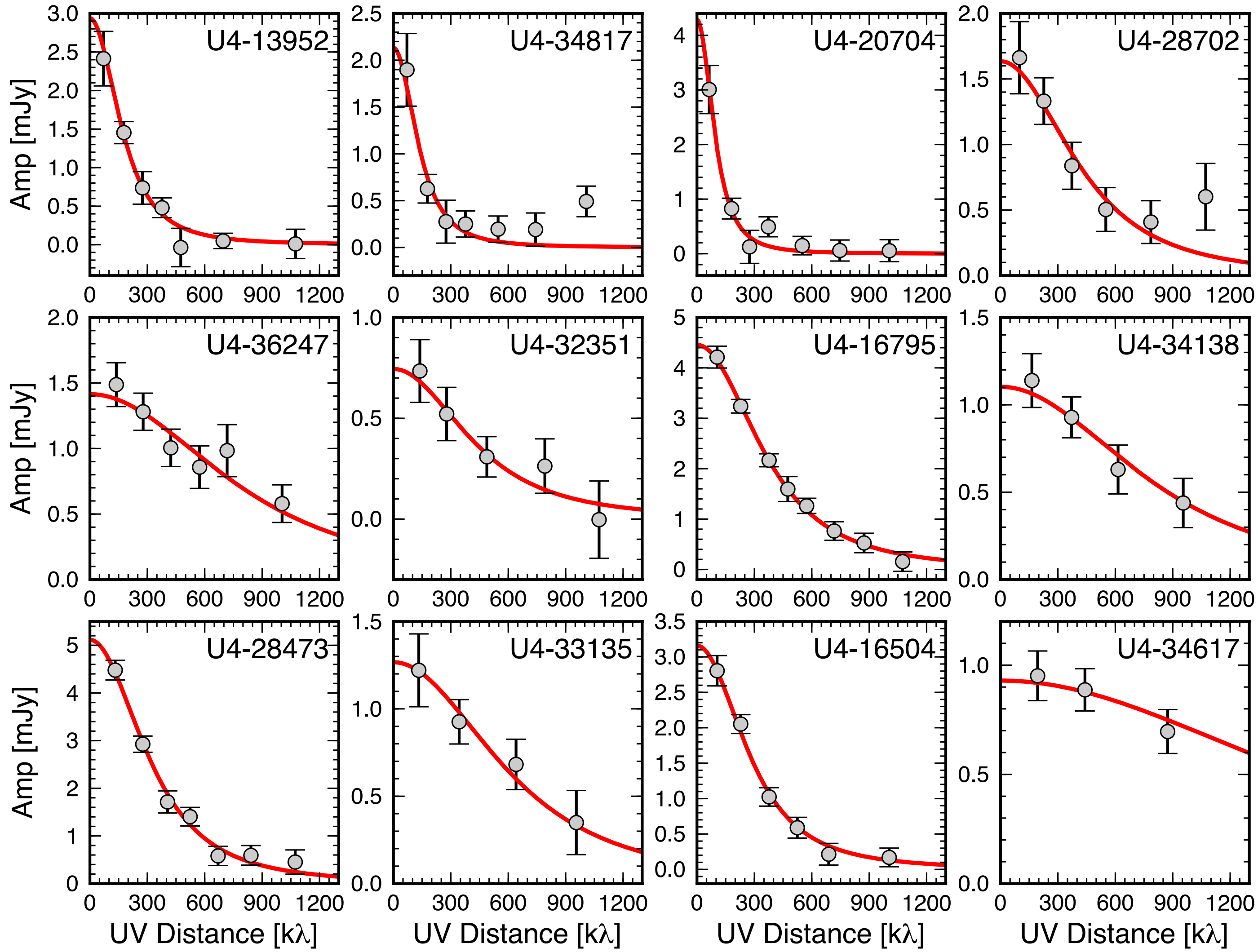


image plane:

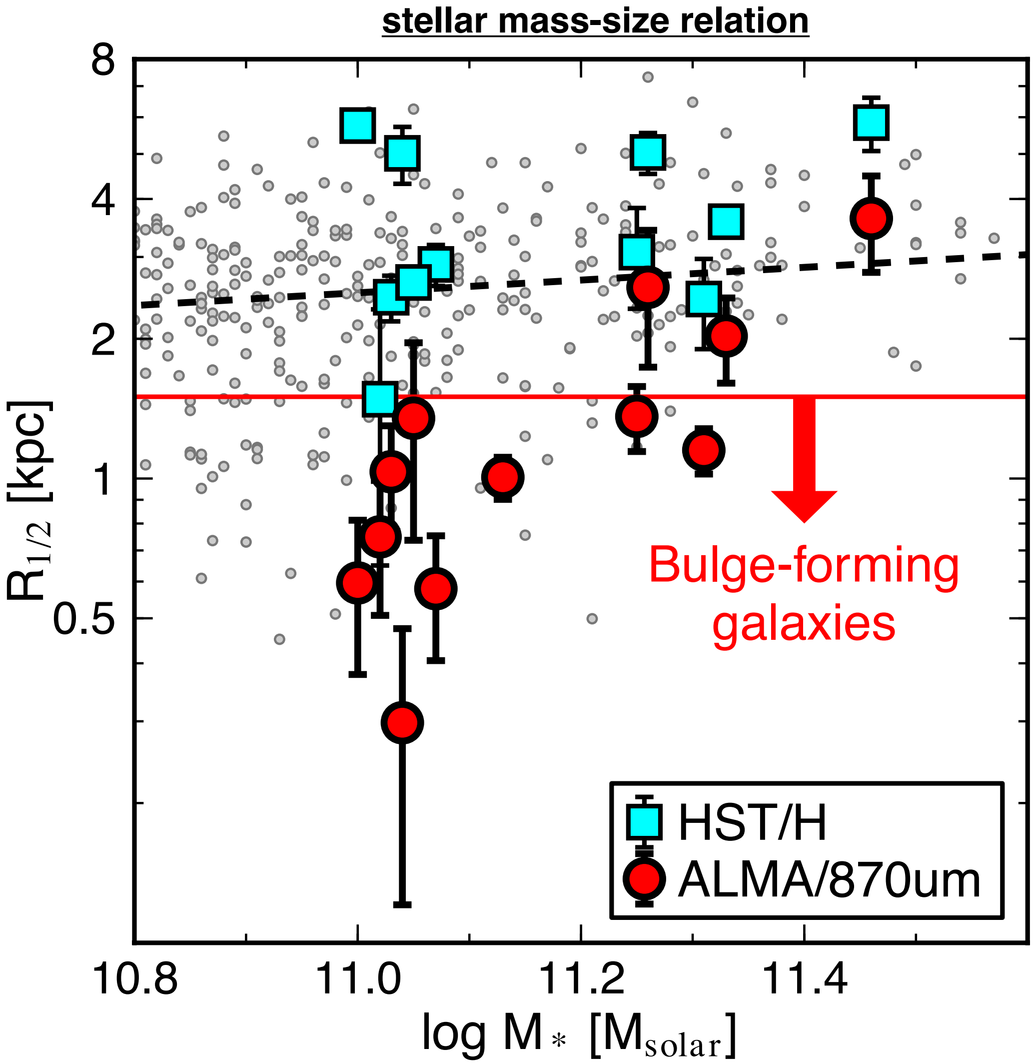
$$f(R) = \exp(-1.678R/R_{1/2})$$

2D Fourier transform

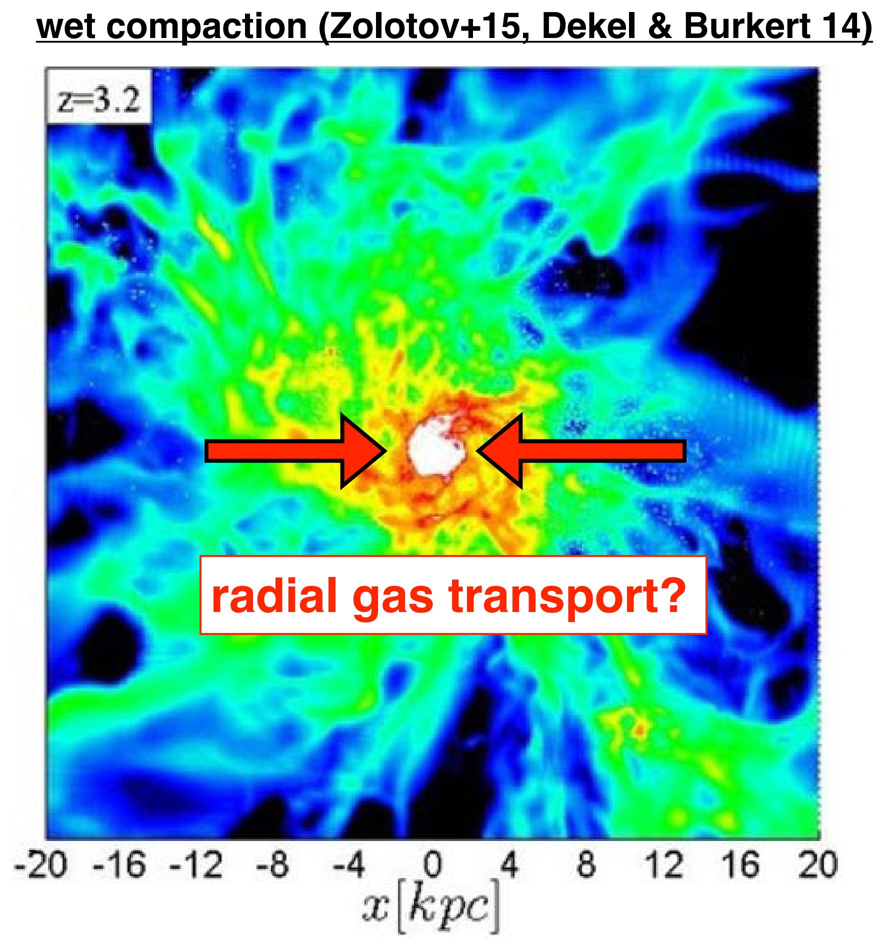
visibility plane:

$$g(u) = S_{\rm model} \times \frac{k_0^3}{(u^2 + k_0^2)^{3/2}}$$

Bulge-forming galaxies (BFGs)



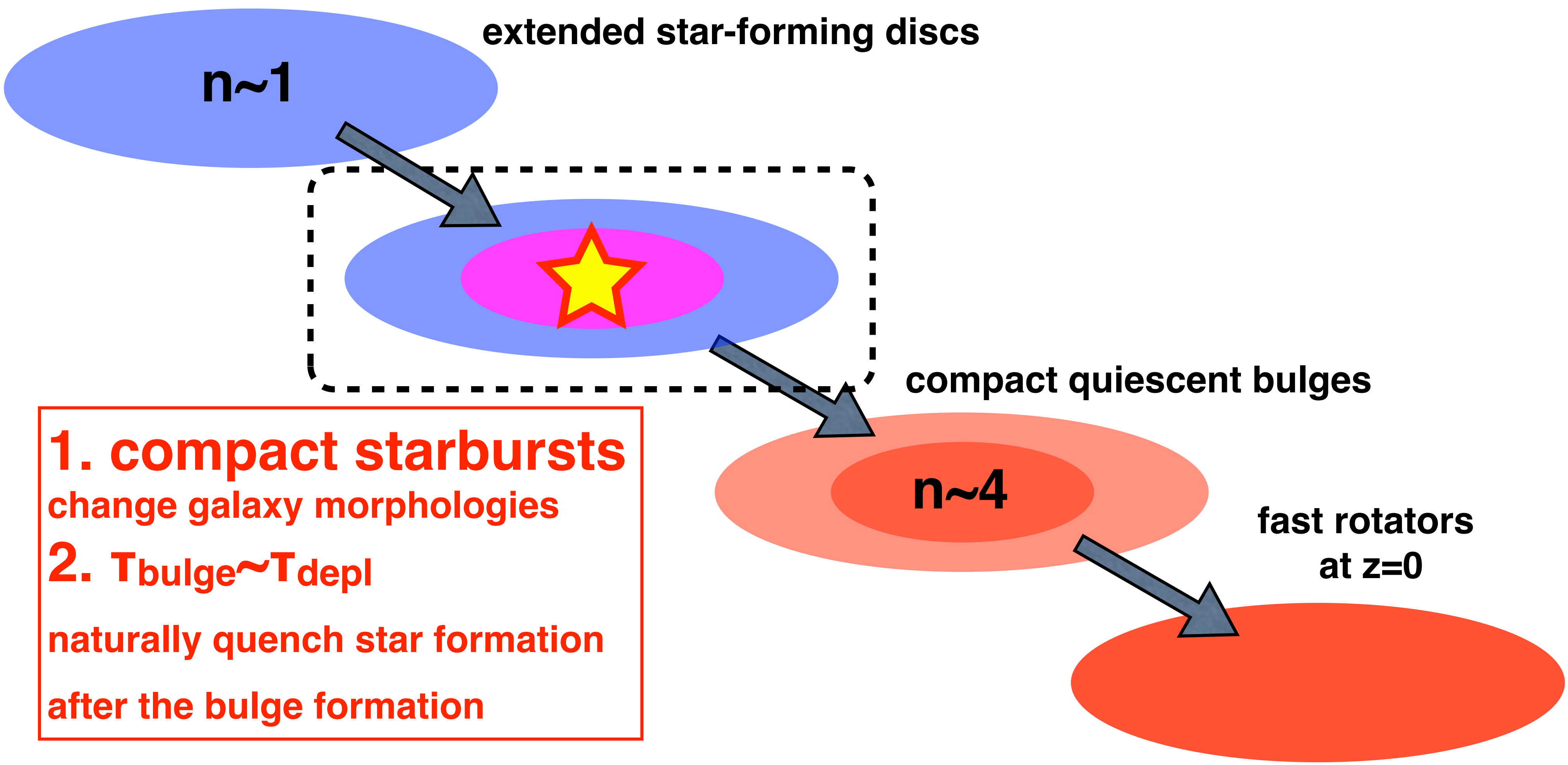
small dots:
3D-HST sample of SFGs at z~2 (*Momcheva+15*)



1. Star-forming regions are extremely compact ($R_{1/2}$<1.5kpc)
2. BFGs have an extended exponential disc ($R_{1/2}$~3 kpc)

Summary

ALMA high-resolution observations reveal compact starbursts in extended rotating discs at z~2.
This process can explain evolution from star-forming discs to quiescent bulges.



1. compact starbursts
change galaxy morphologies
2. $T_{bulge} \sim T_{depl}$
naturally quench star formation
after the bulge formation