ALMA observations of Hα emitters at z~2

from MAHALO to SWIMS-18

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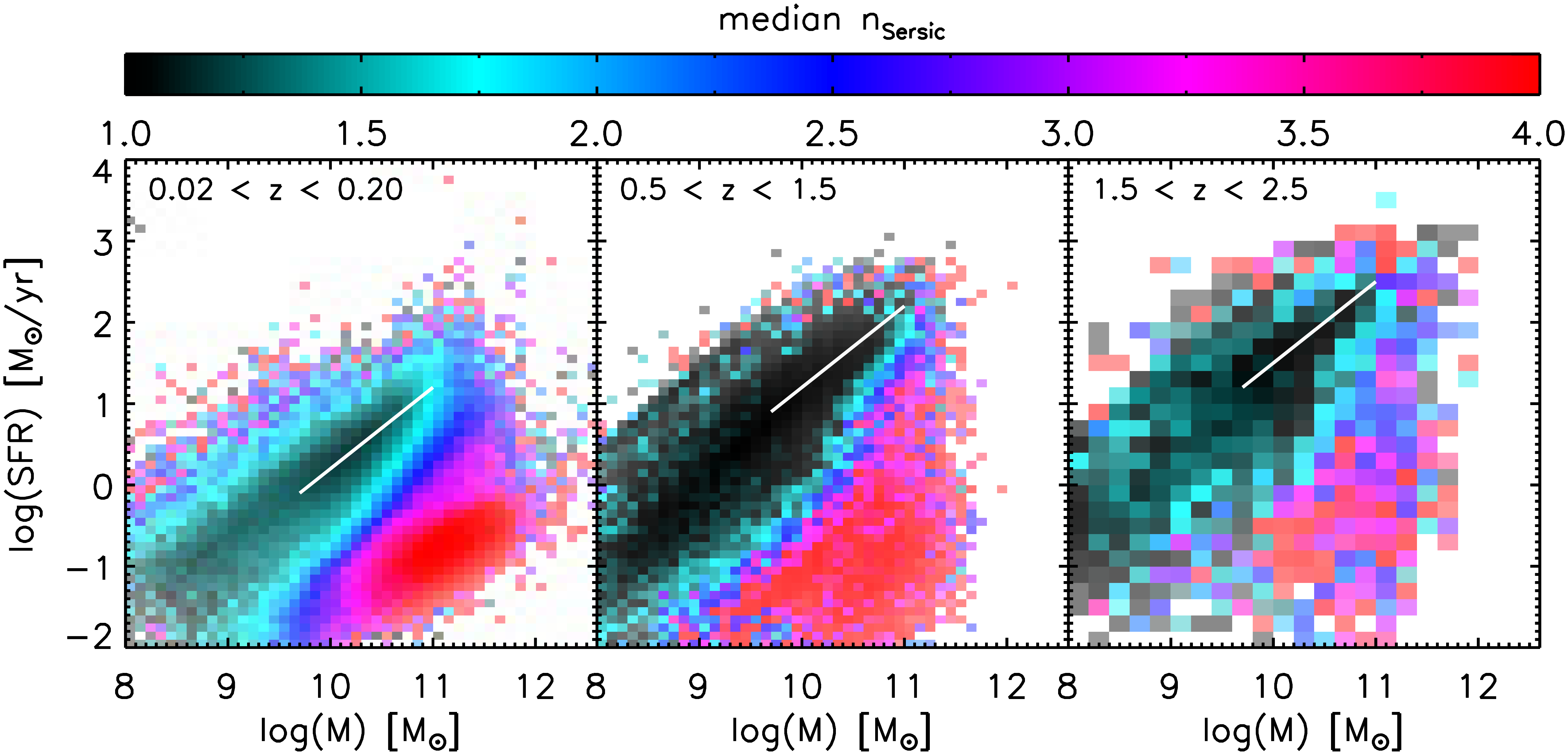
Tadaki et al. 2013, ApJ, 778, 114
Tadaki et al. 2014, ApJ, 780, 77
Tadaki et al. 2015, ApJL, 811, L3
Tadaki et al. in prep

Contents

1. Review of recent z~2 galaxy studies

2. ALMA observations of Hα emitters at z~2

Hubble sequence is already in place at z~2.5



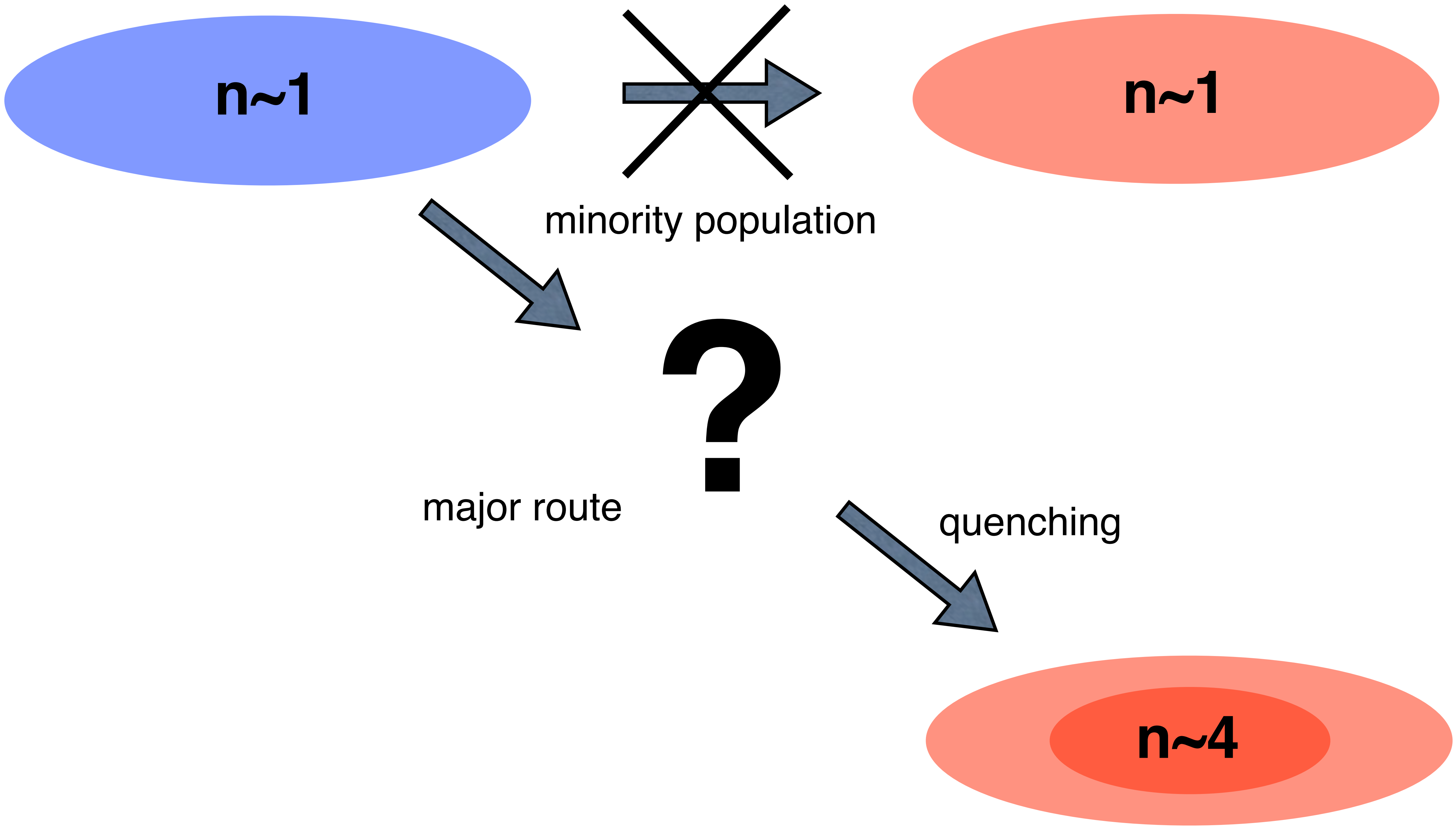
star-forming galaxies · · · n~1, disk-dominated

quiescent galaxies · · · n~4, bulge-dominated

Wuyts+11

Hubble sequence is already in place at z~2.5

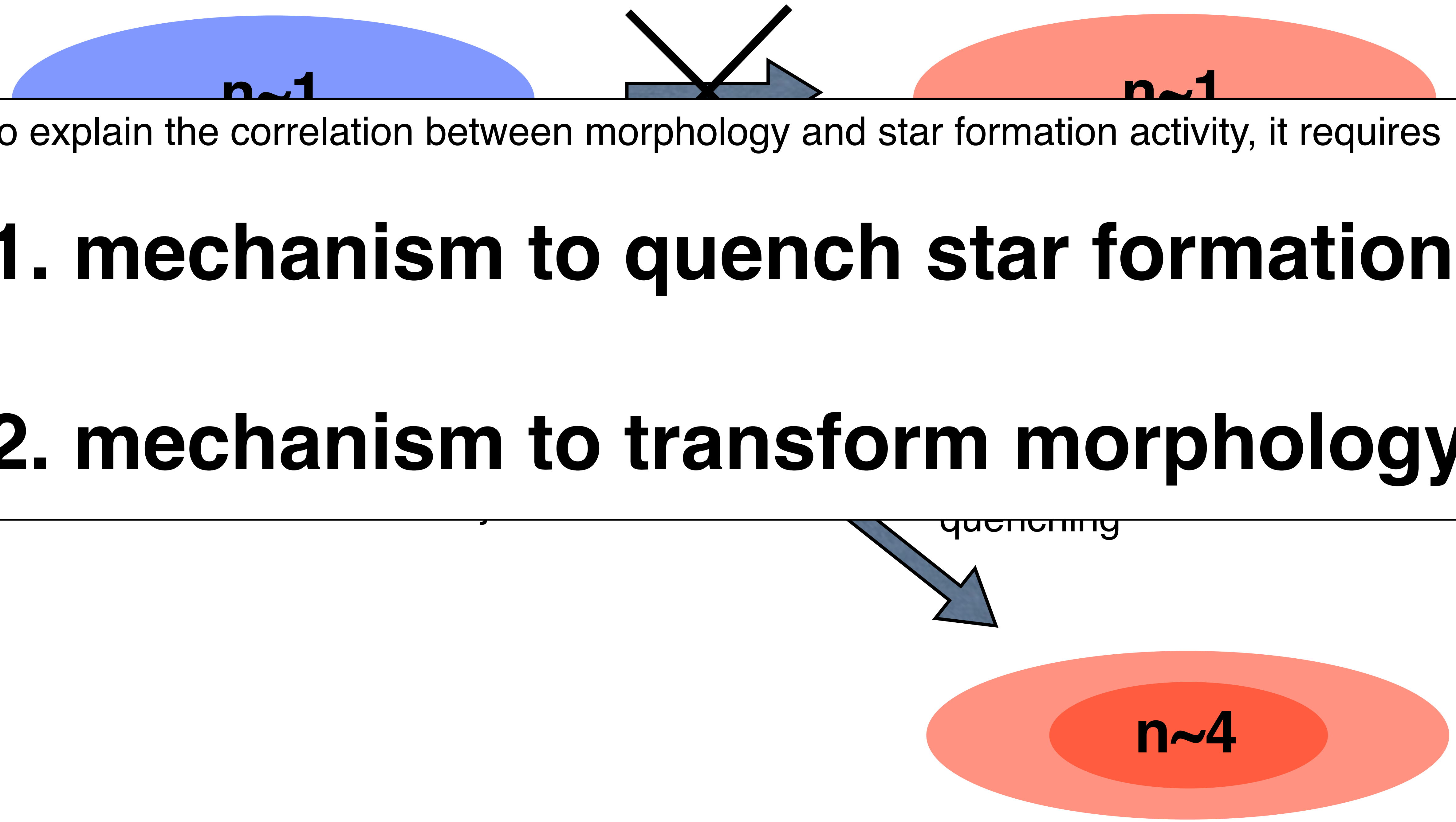
star-forming galaxies are disk-dominated



quiescent galaxies are bulge-dominated

Hubble sequence is already in place at z~2.5

star-forming galaxies are disk-dominated



to explain the correlation between morphology and star formation activity, it requires

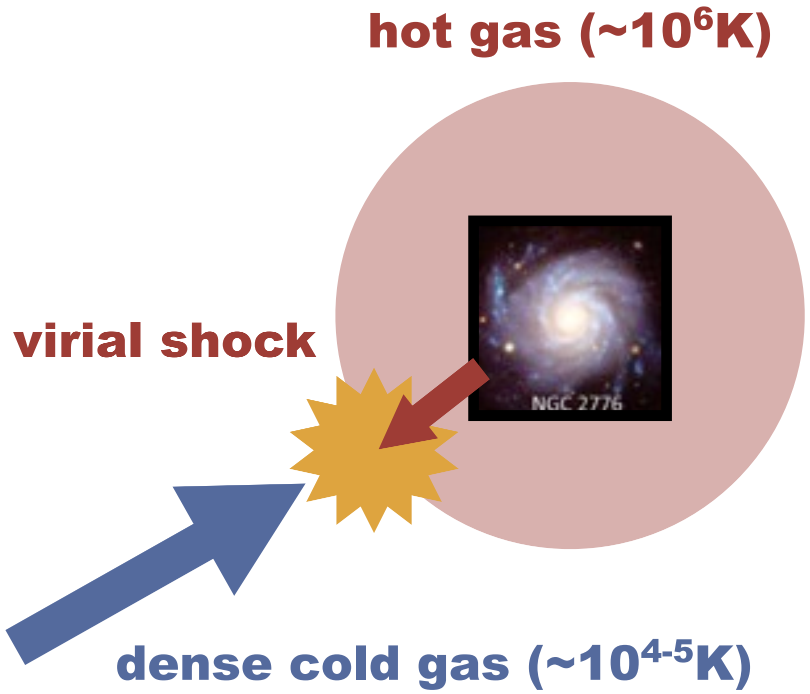
1. mechanism to quench star formation

2. mechanism to transform morphology

quiescent galaxies are bulge-dominated

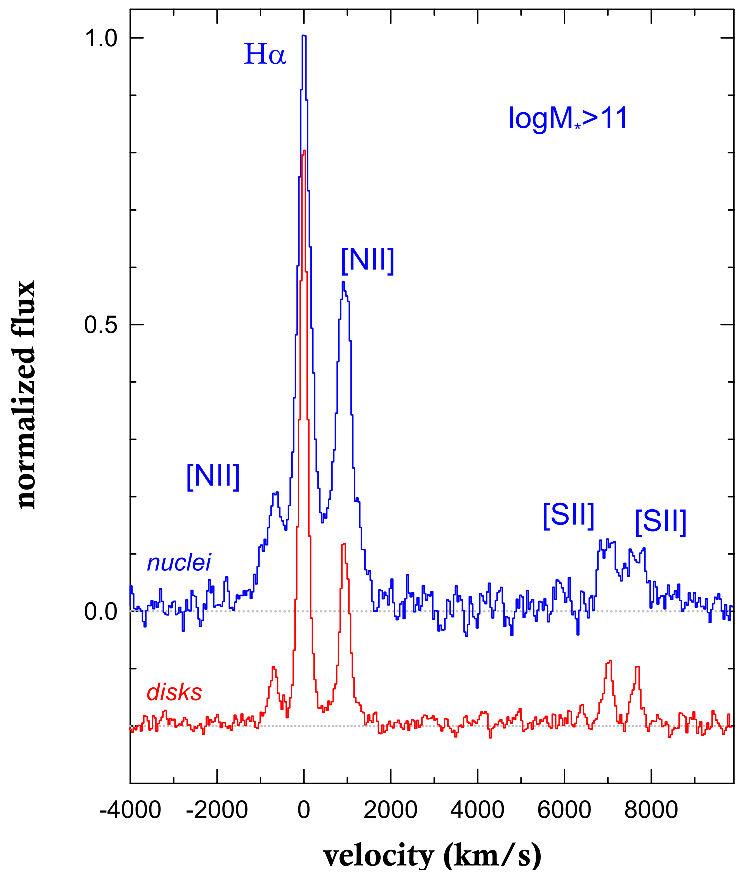
Quenching mechanisms

Halo quenching



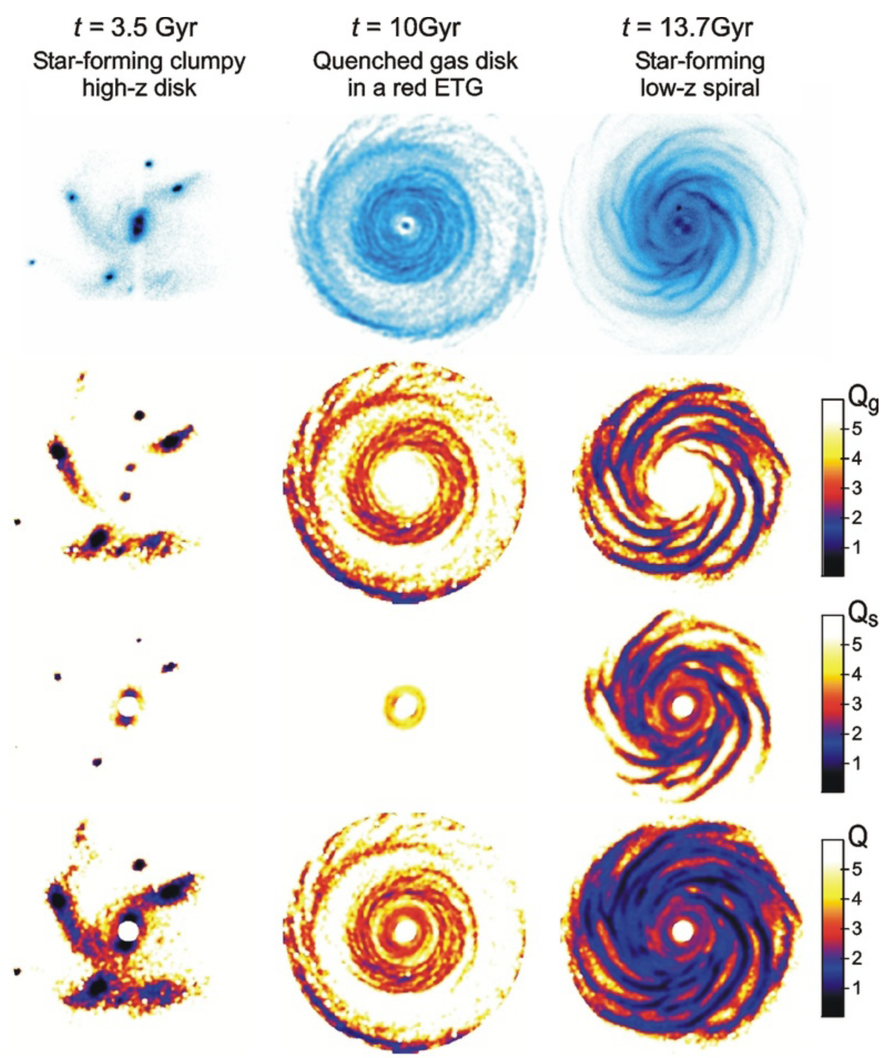
stop gas accretion

AGN/SF feedback



remove gas from inner regions

Morphological quenching

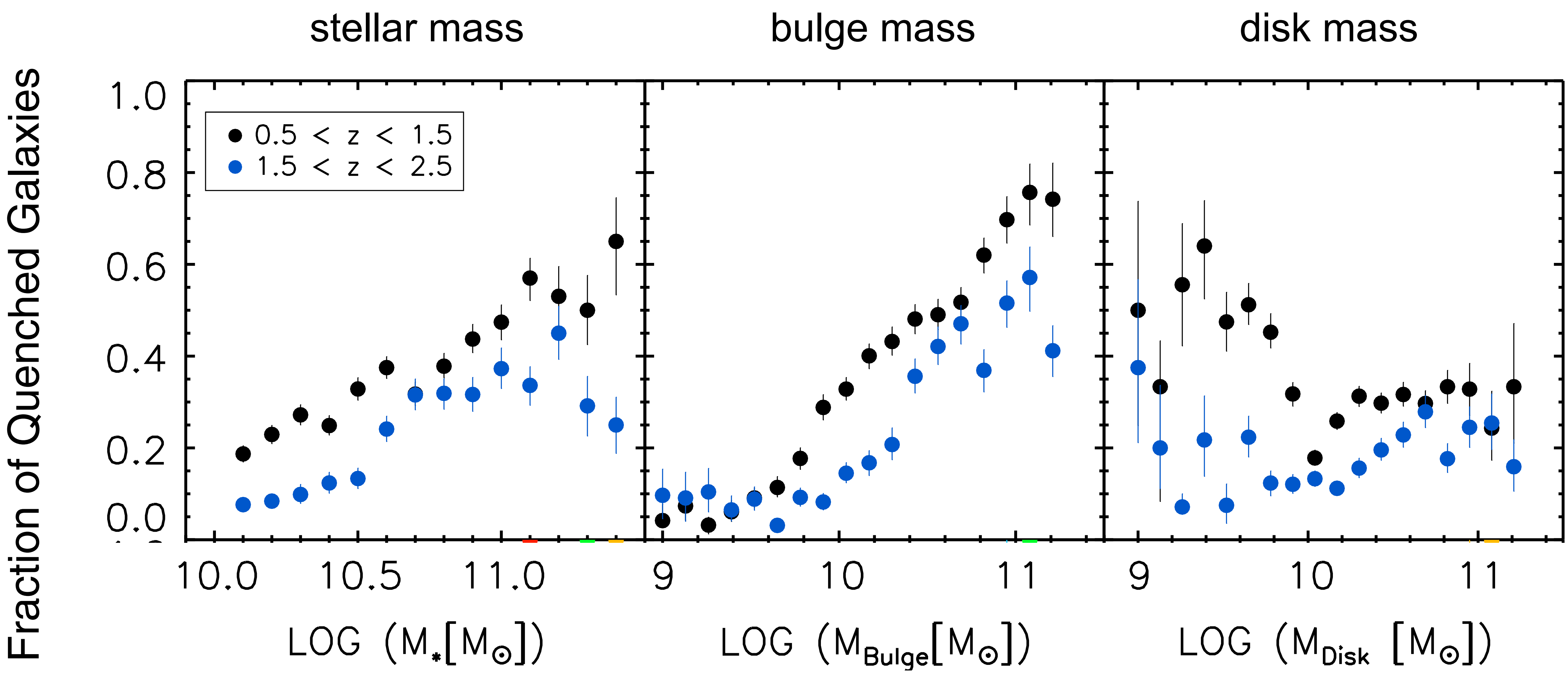


reduce star formation efficiency

bulge formation

Dekel+06, Foerster Schreiber+14, Martig+09

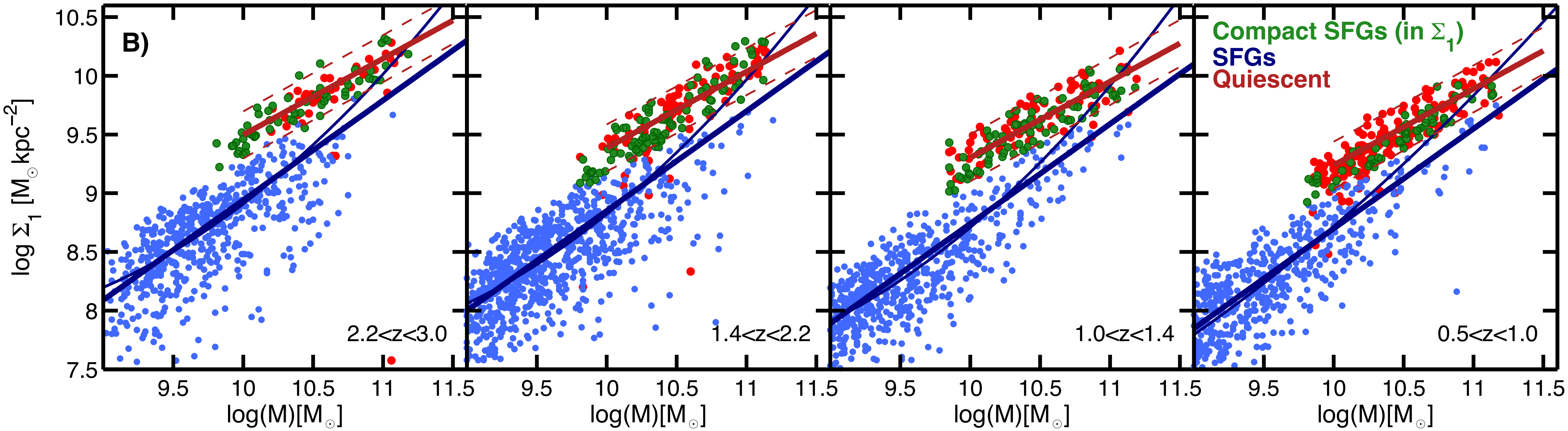
Quenching mechanisms



bulge formation can be key for quenching of star formation, whatever the cause

Lang+14

Quenching by a core with high Σ_{1kpc}



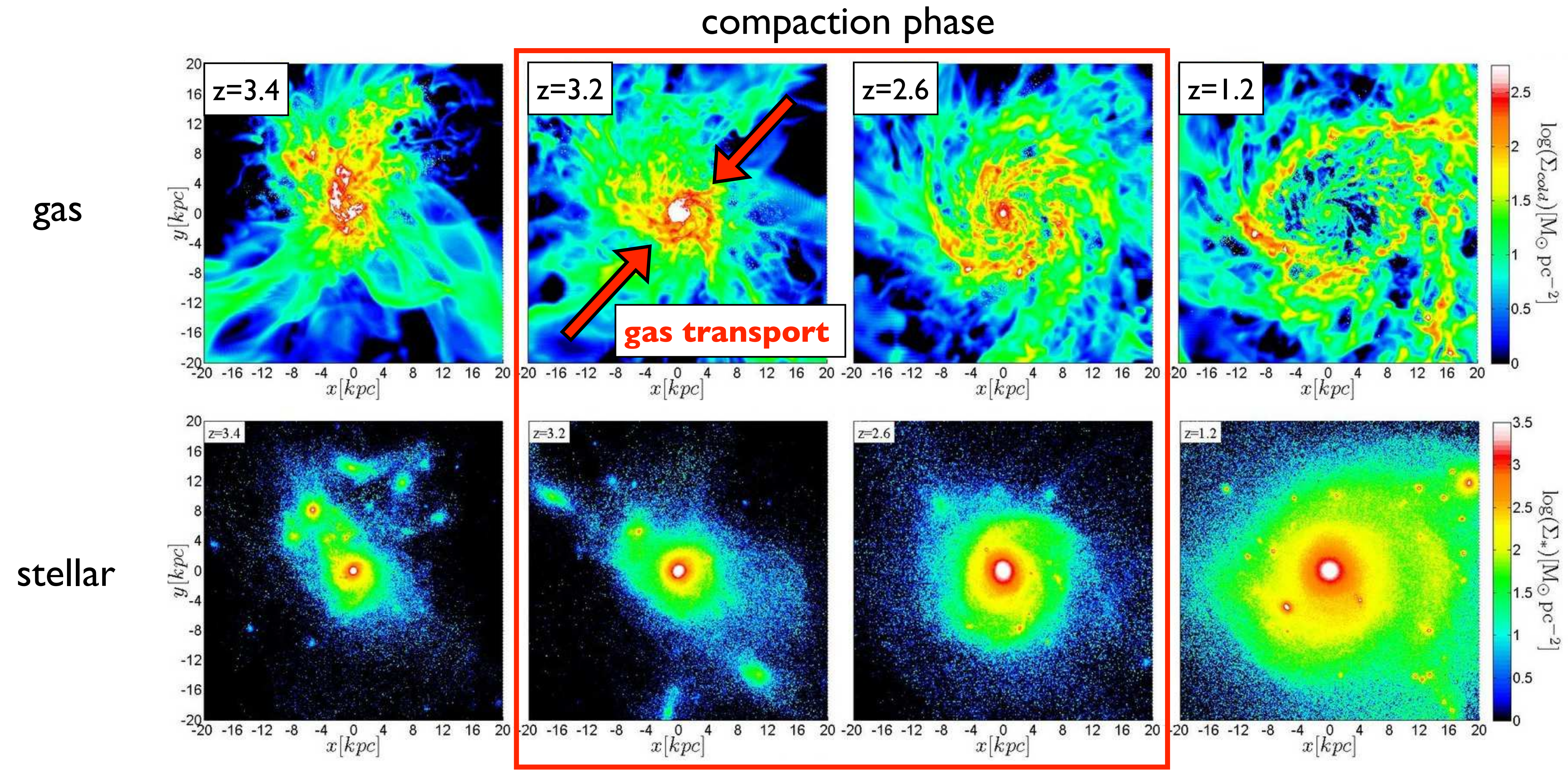
Σ_{1kpc}: stellar mass within a central 1 kpc region

Quiescent galaxies has a dense stellar core (proto-bulge?)

Barro et al. 2015, see also Tacchella et al. 2015b

Wet (gas rich) compaction

<u>*hydro-cosmological simulations (Zolotov+15)*</u>

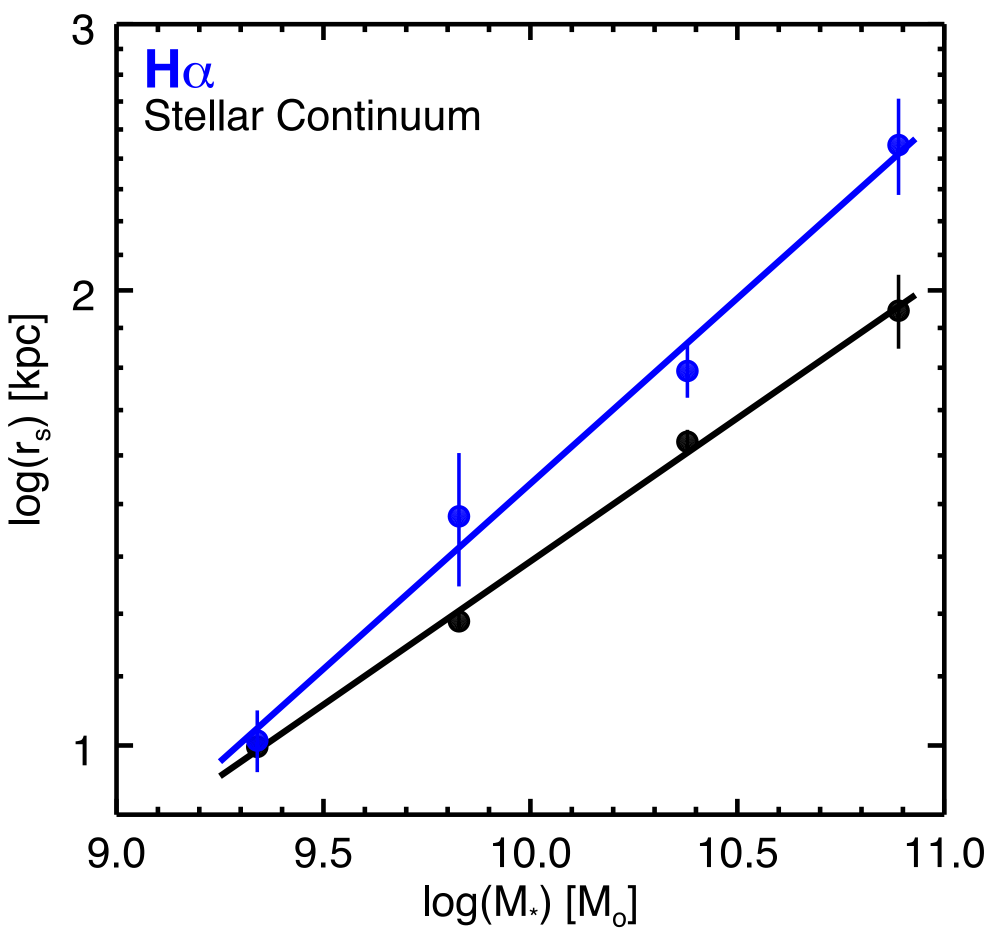


star-forming disks can be smaller than stellar disks

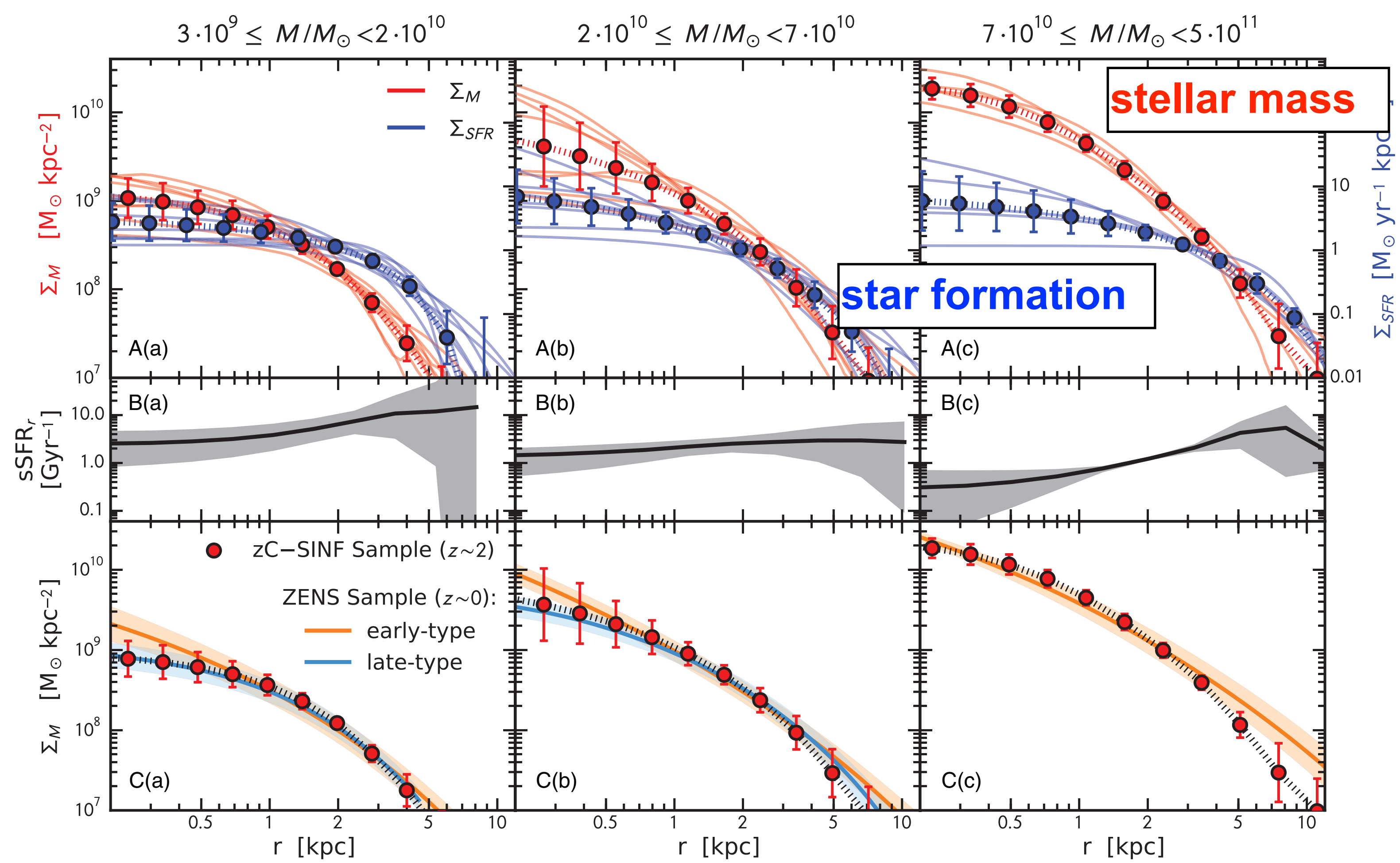
Zolotov+15

Observational studies with Hα emission

Size-mass relation for z~1 galaxies



Radial profiles for z~2 galaxies

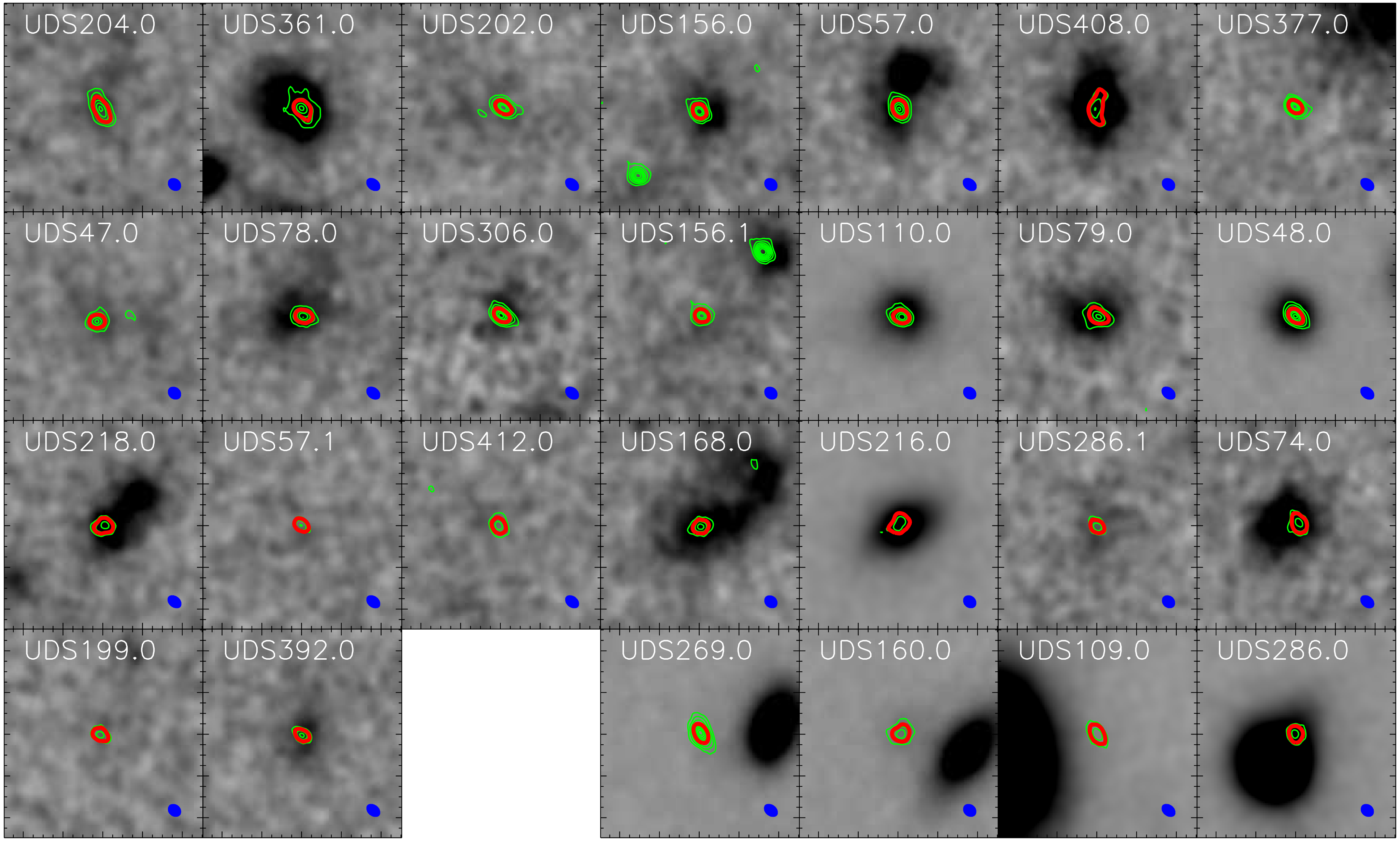


star-forming disks are larger than stellar disks

Nelson et al. 2015, Tacchella et al. 2015a

Observational studies with dust emission

ALMA 870um maps on K-band image for z=2-4 SMGs



star-forming disks are smaller than stellar disks

Simpson et al. 2015

How can we verify the wet compaction?

1. Identification of a compact starburst in extended stellar disks for normal SFGs at z~2
↑ this talk

2. Looking at a correlation between angular momentum and compact starburst

3. Statistical studies with a larger sample
from MAHALO-ALMA to SWIMS-18-ALMA

Contents

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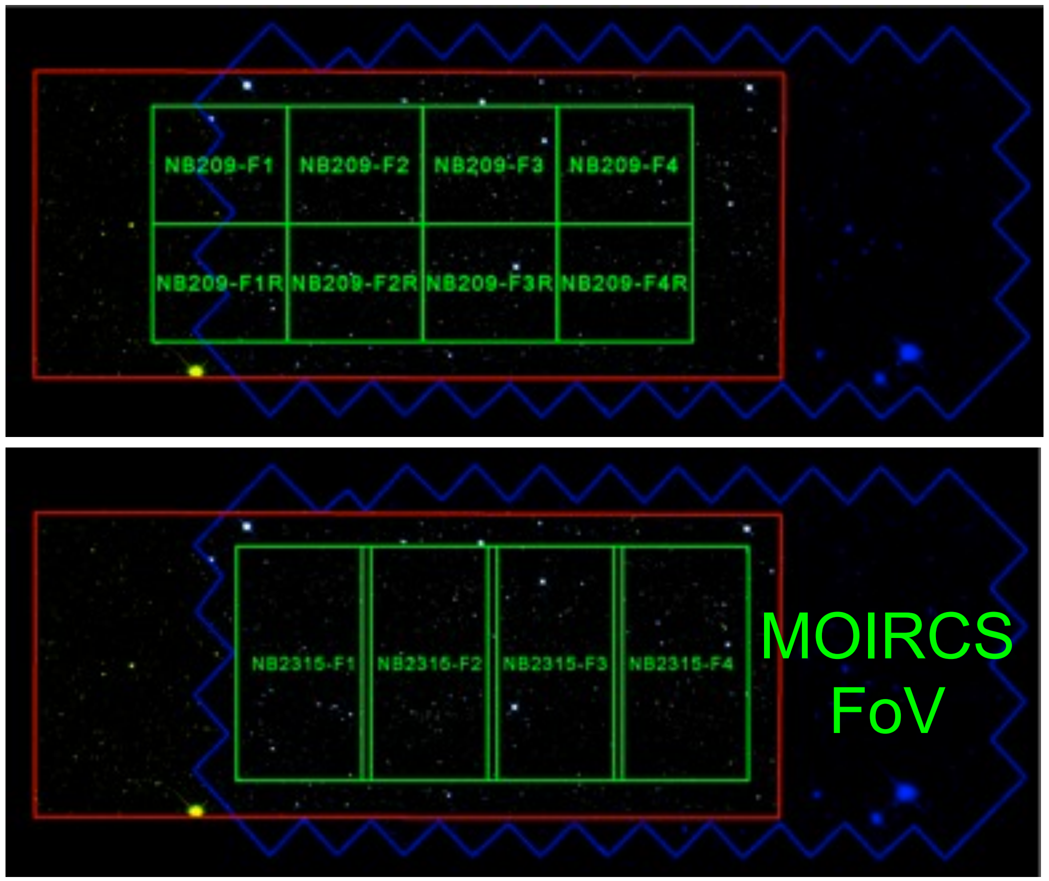
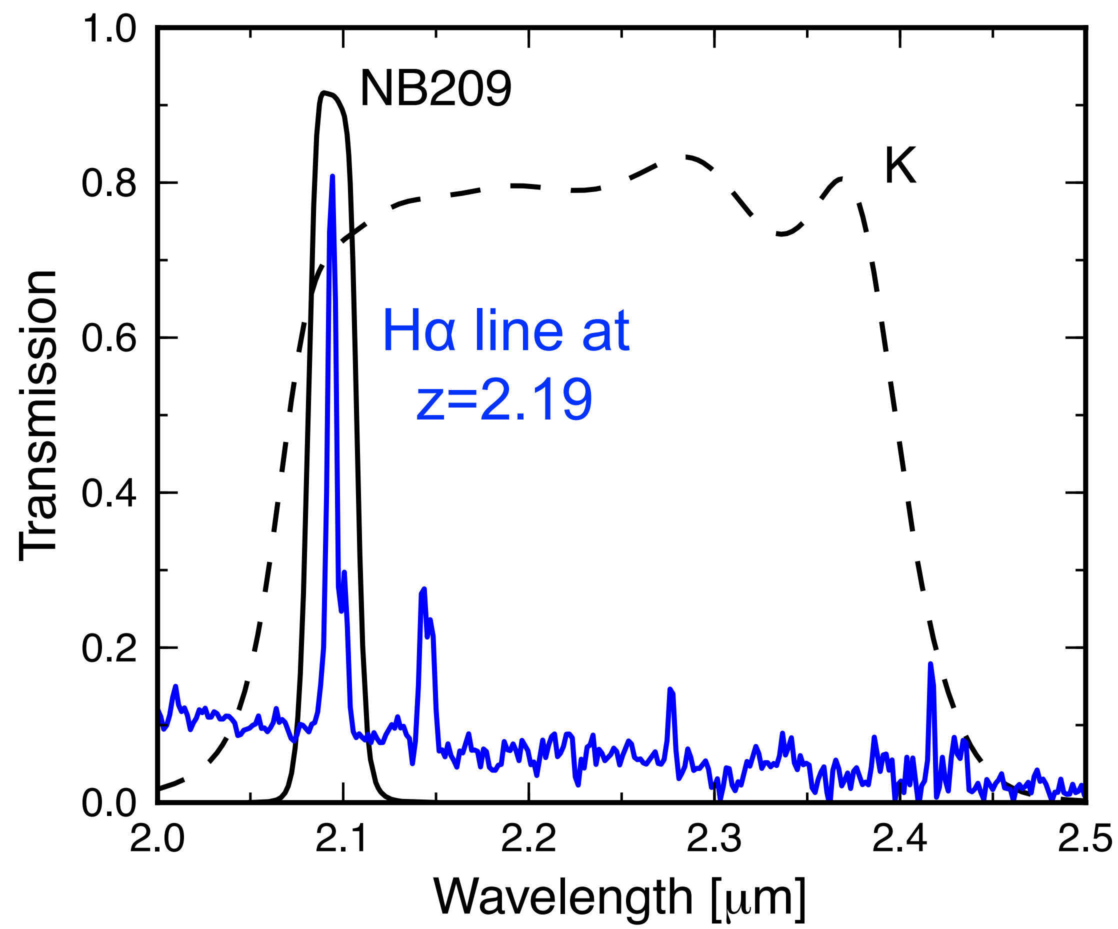
MApping HAlpha and Lines of Oxgen with Subaru (PI: Kodama)

SXDF-CANDELS field



Spectra of SFG at z=2.19 and NB209 filter

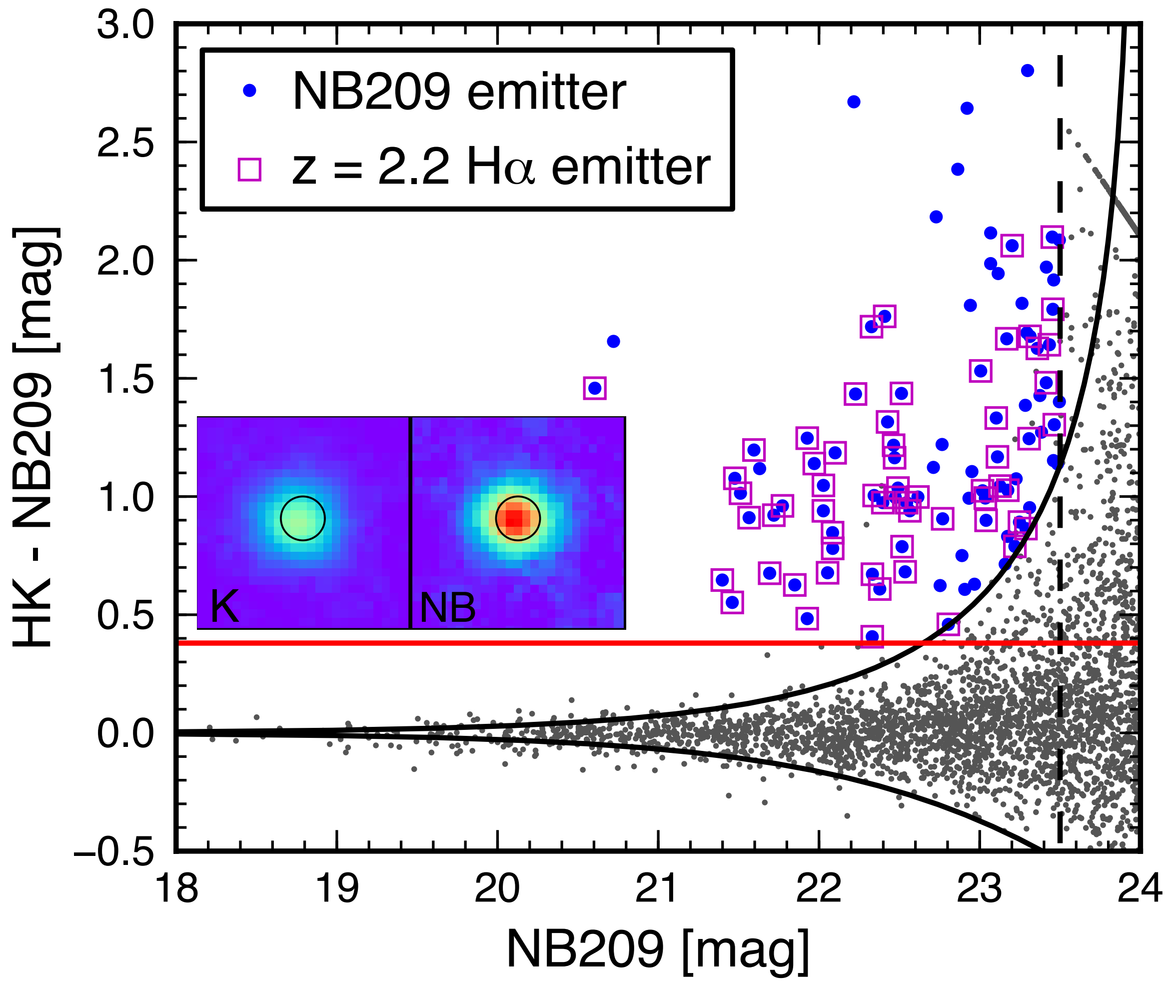


- MOIRCS narrow-band survey in SXDF-CANDELS field
- high-resolution NIR/optical images are available
- NB209/NB2315 can trace Hα emission at z=2.19/2.53

Tadaki et al. 2013

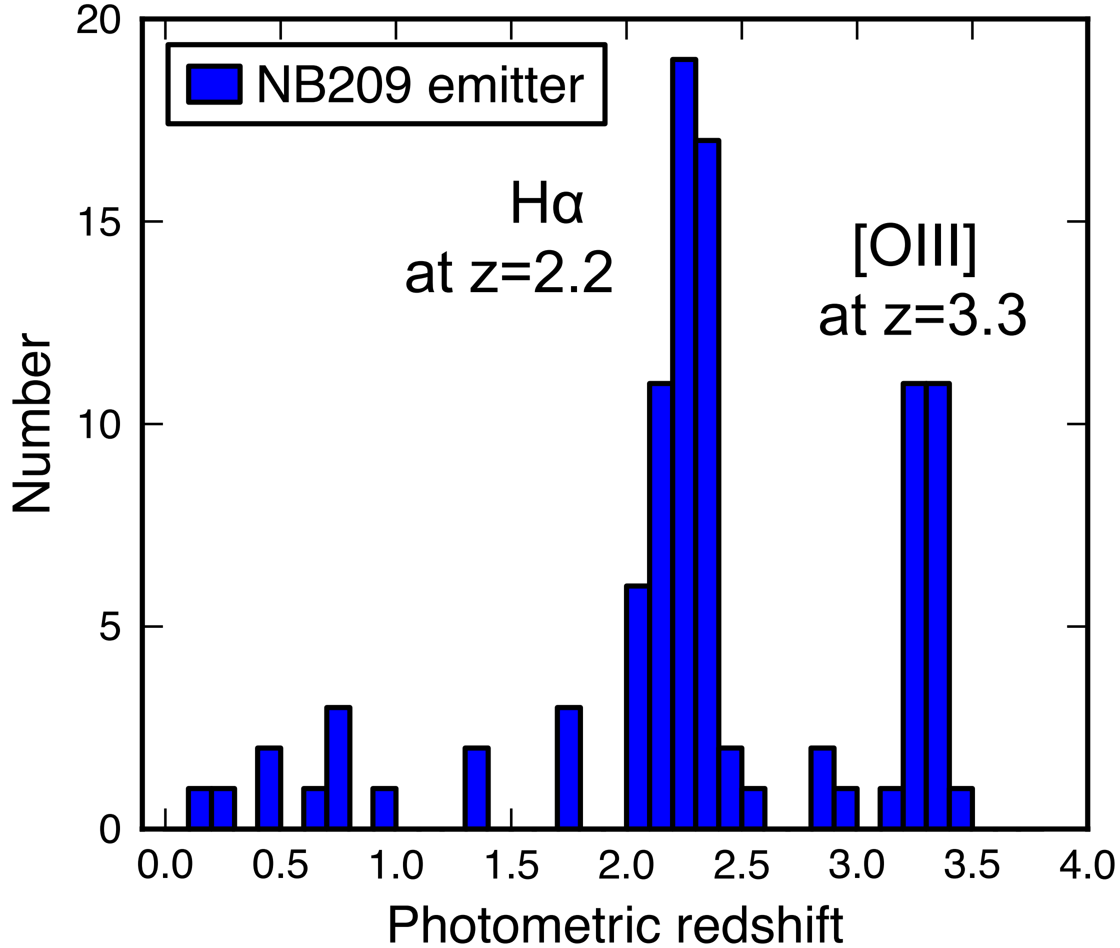
Sample selection

color-magnitude diagram



NB209 emitters

distribution of z_{phot}

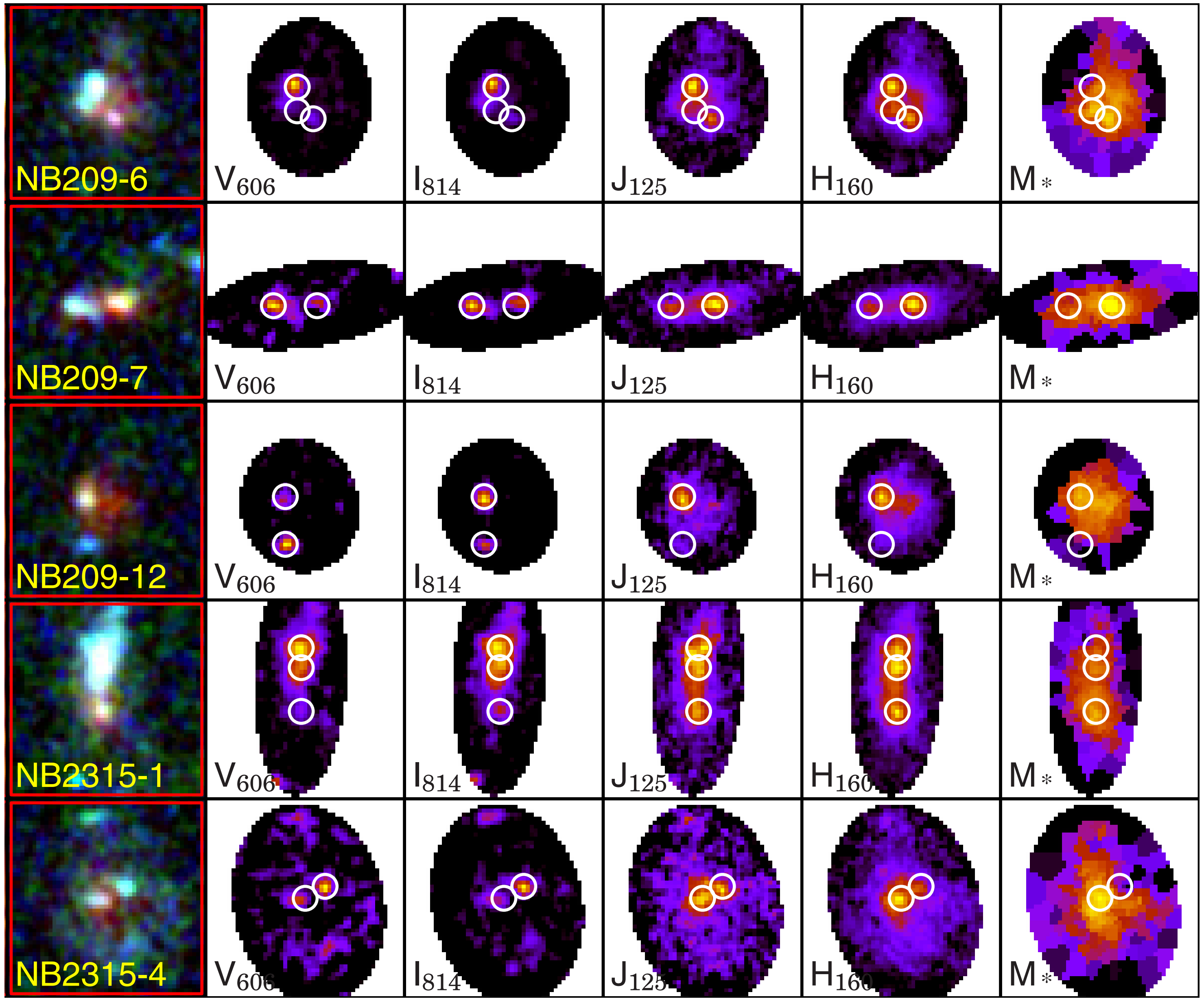


- ~100 Hα emission-line galaxies were identified
- MOIRCS spectroscopy confirms the redshift with success rate of 90%

Tadaki et al. 2013

Star-forming galaxies at z>2 have a clumpy structure

HST images of Hα emitters at z>2 (~24×24 kpc²)

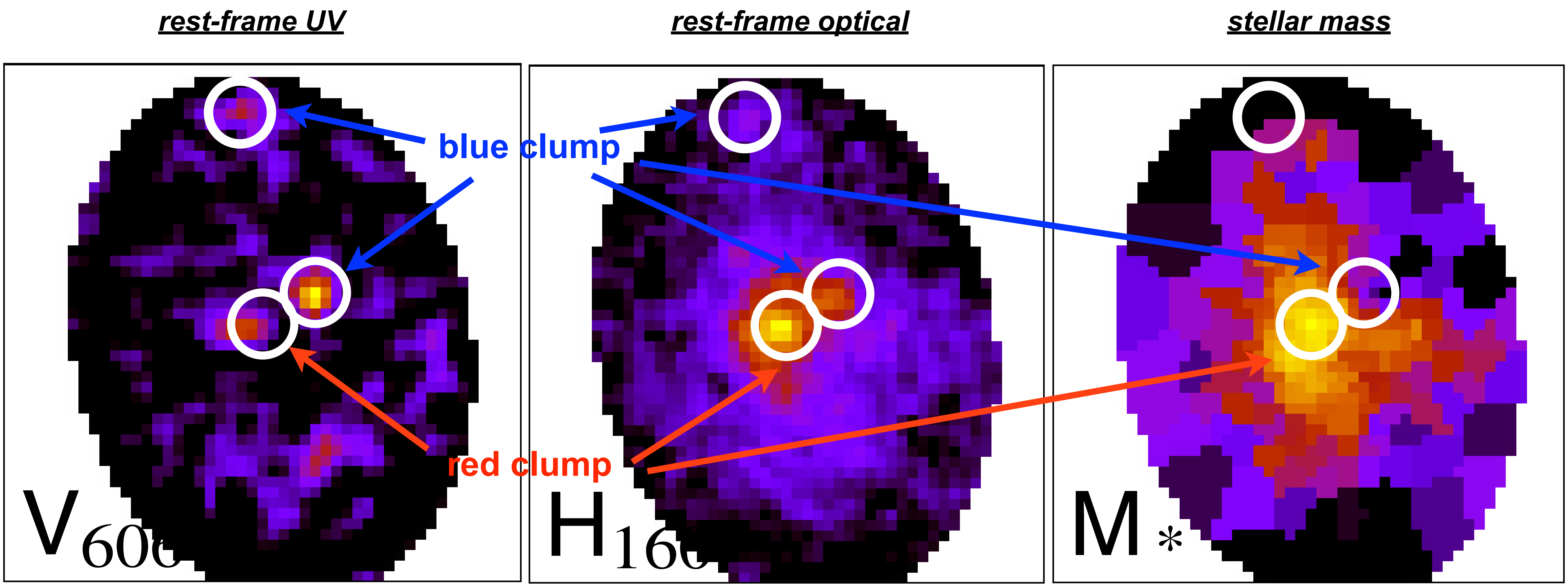


- ~40% show clumpy structure
- stellar mass distribution is smooth

Tadaki et al. 2014, see also Wuyts et al. 2012

Star-forming galaxies at z>2 have a clumpy structure

closeup view (~24×24 kpc^2)



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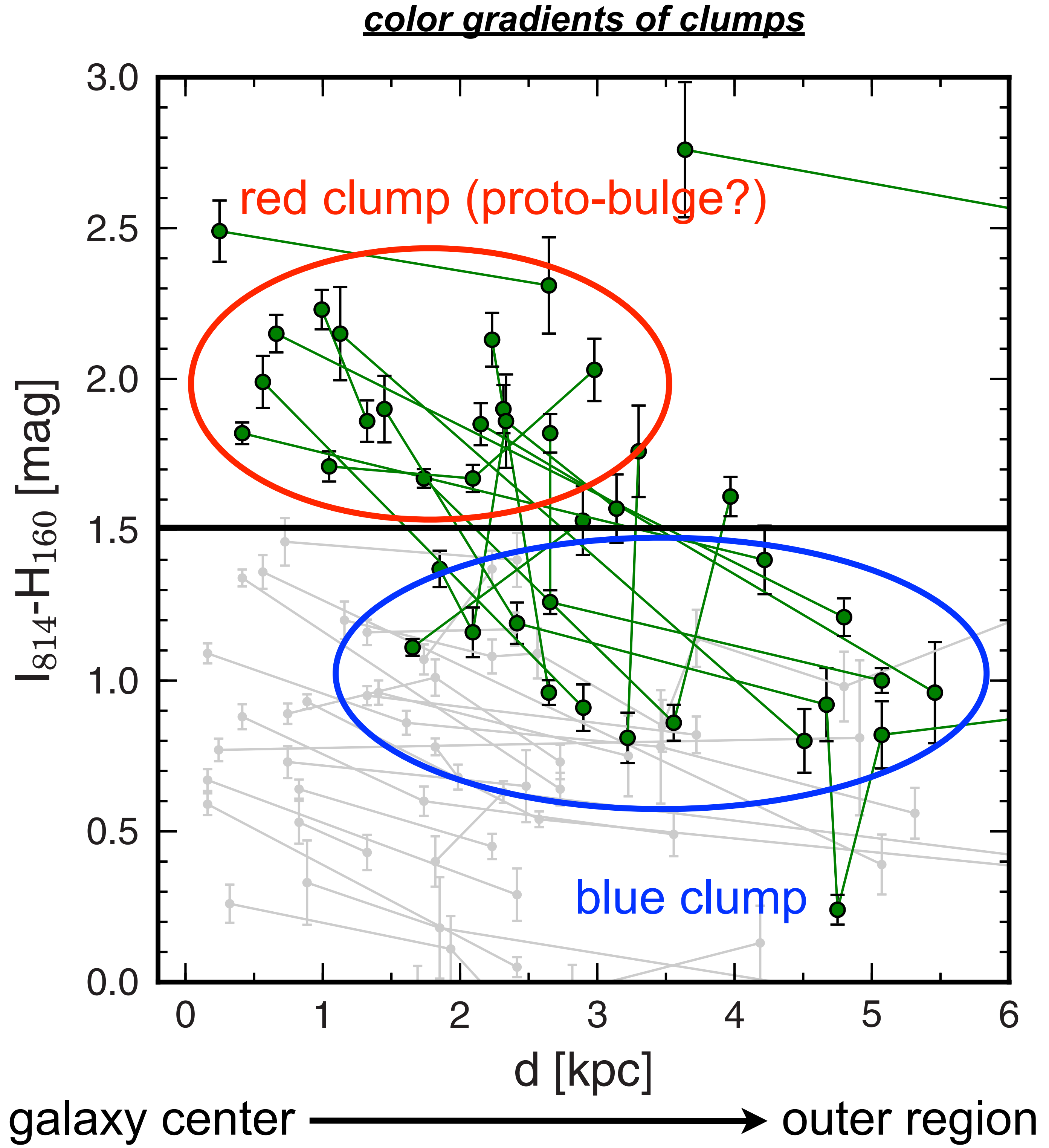
Tadaki et al. 2014

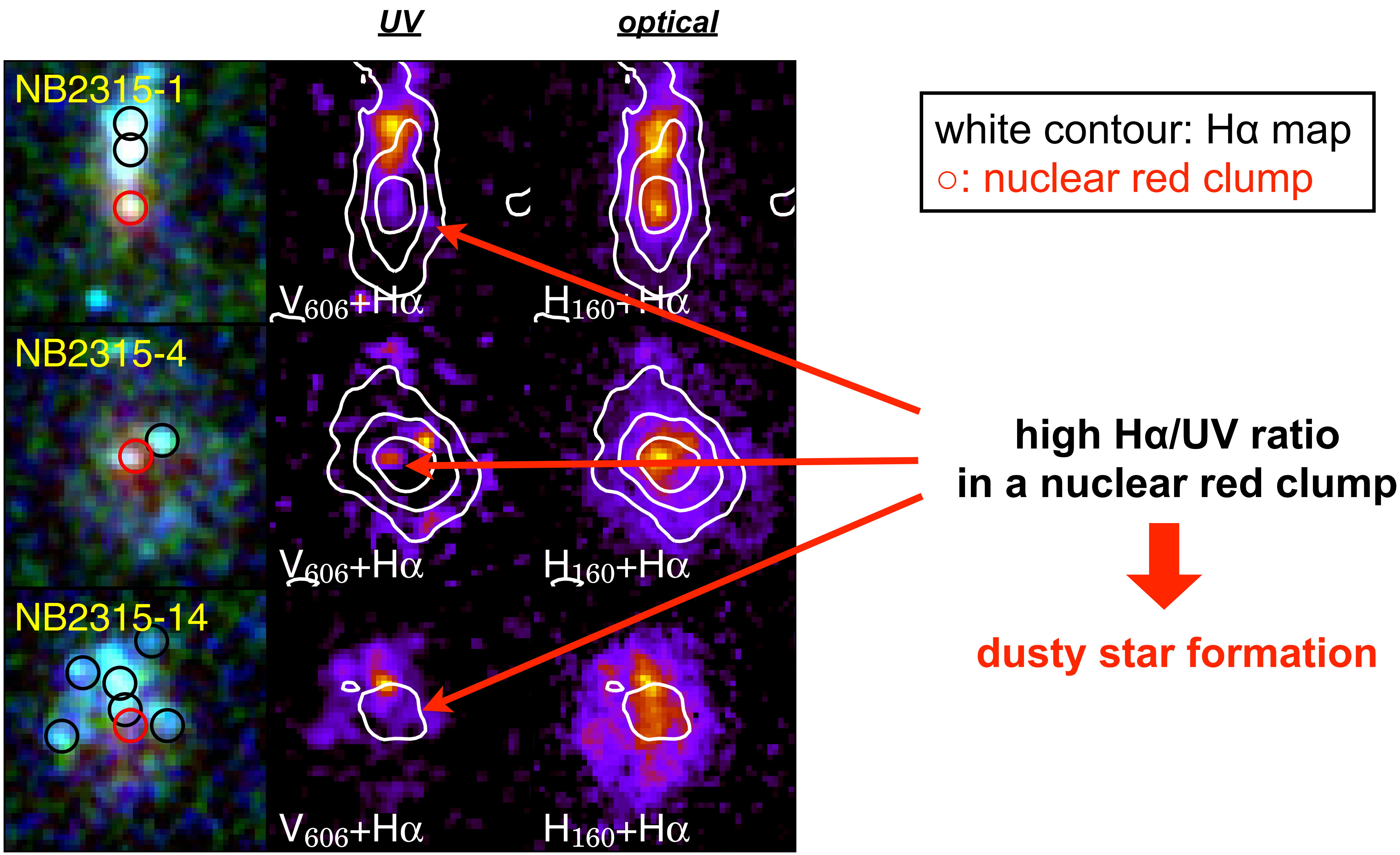
A nuclear clump is redder than off-center clumps



nuclear red clump
is
dusty star-forming?

Tadaki et al. 2014, see also Foerster Shreiber et al. 2011, Guo et al. 2012

A center clump has high Hα/UV ratio

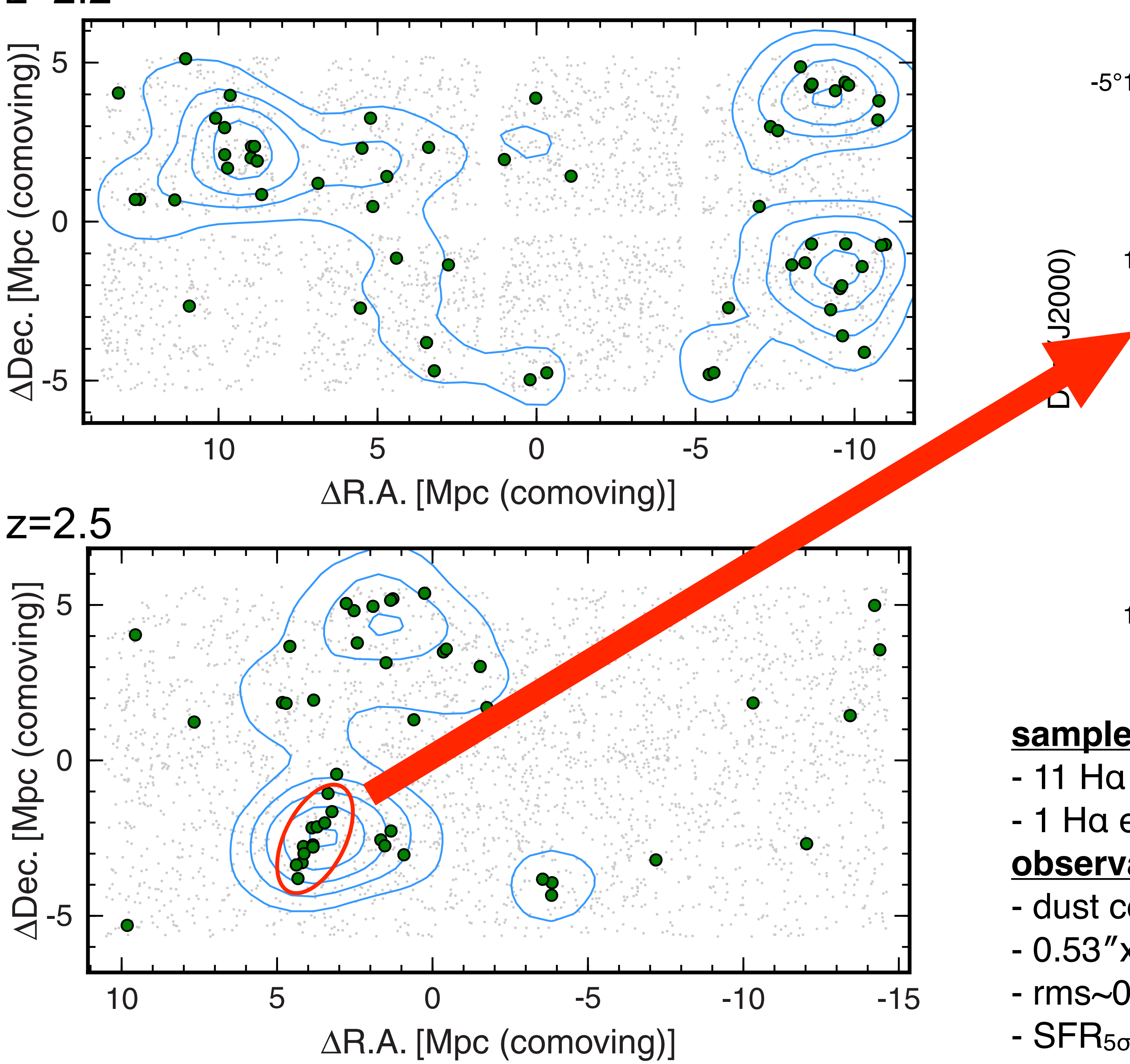


- ALMA enables us to identify such a dusty star-forming component

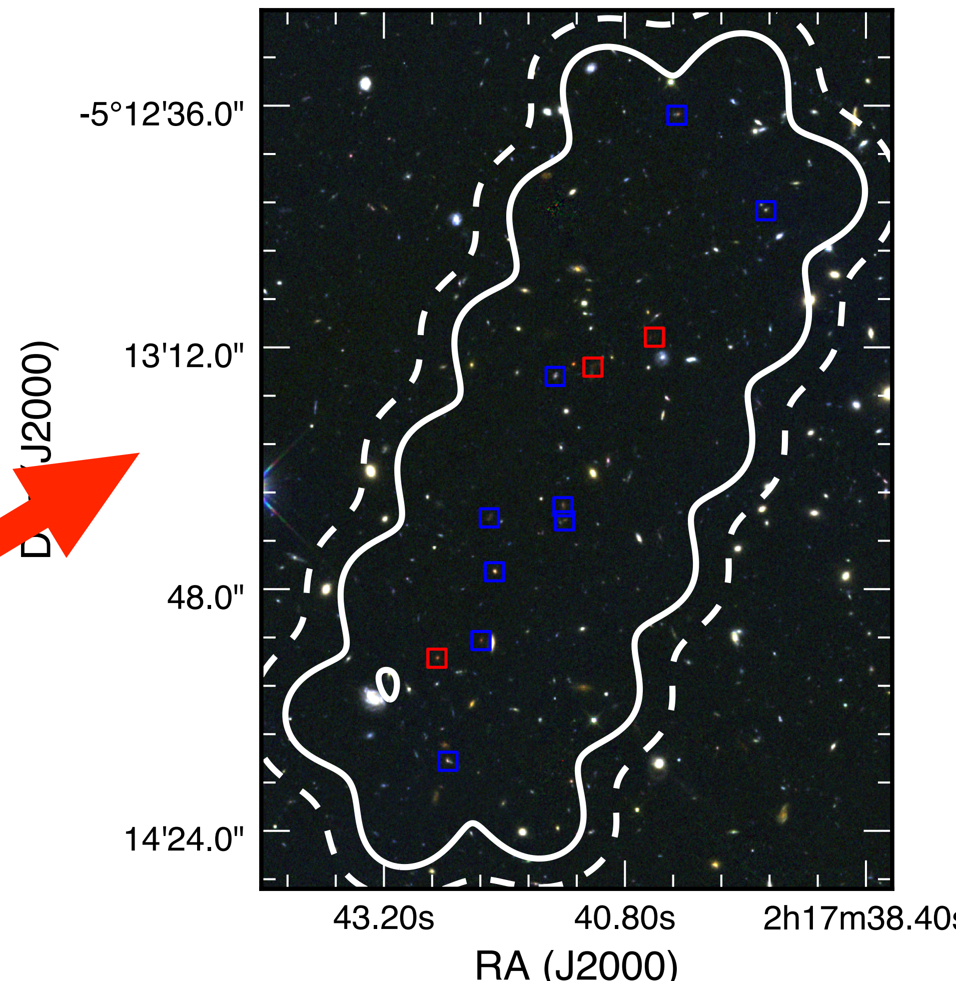
Tadaki et al. 2014

ALMA observation 1

Spatial distribution for Hα emitters



ALMA-SXDF 1.5 arcmin² deep survey (PI: Kohno)



sample

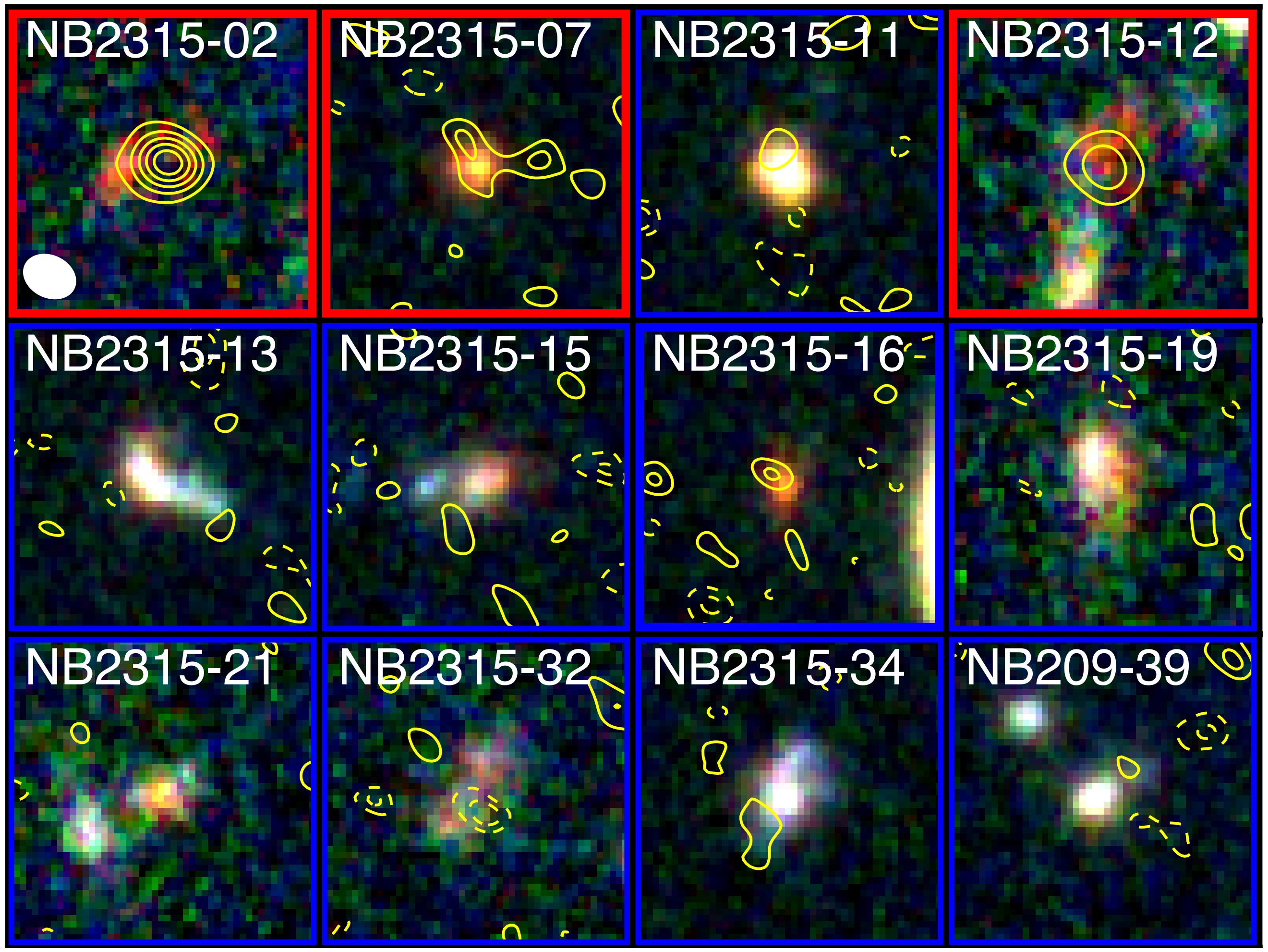
- 11 Hα emitters at z=2.5
- 1 Hα emitter at z=2.2

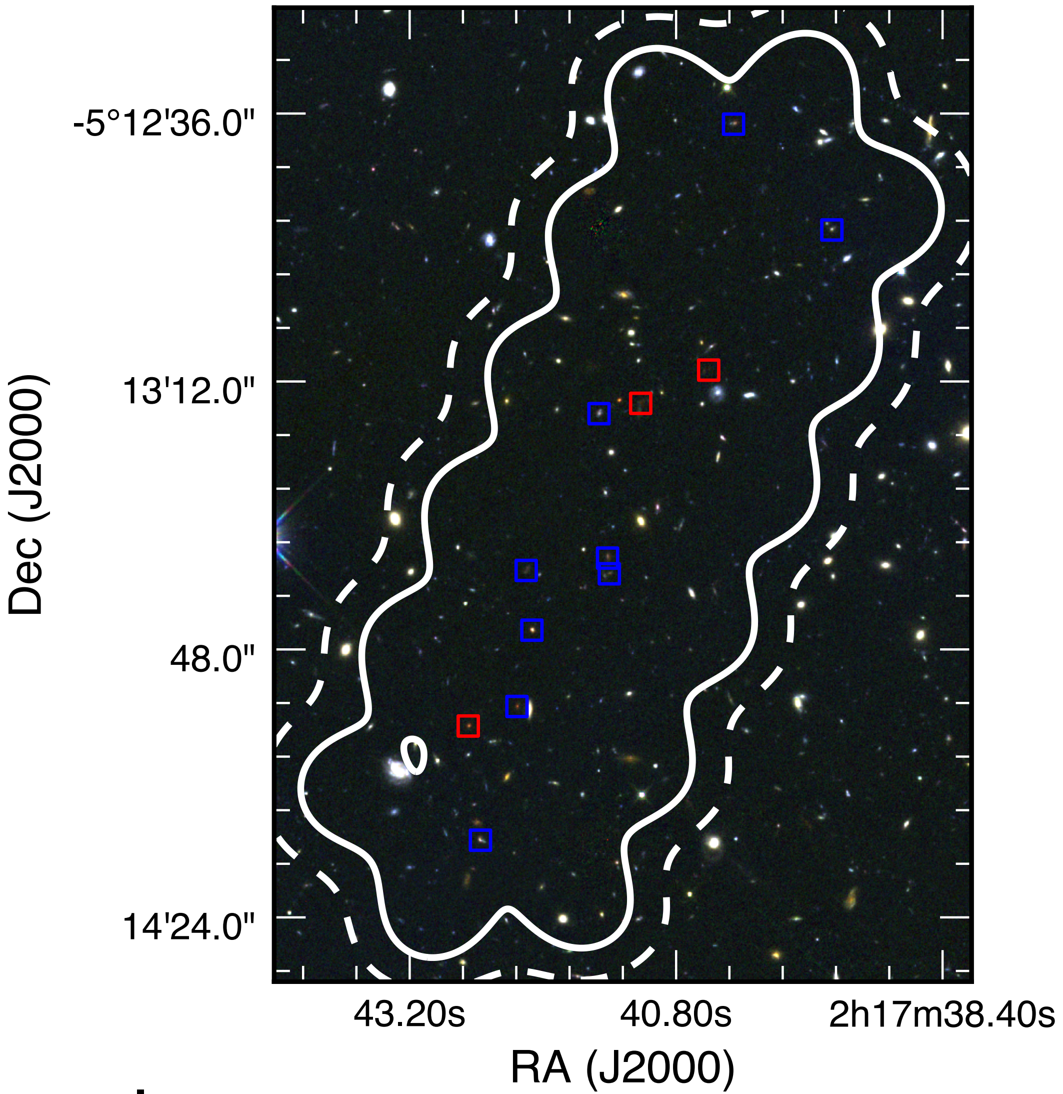
observation

- dust continuum (265GHz, 1.131mm)
- 0.53″x0.41″ resolution (natural weight)
- rms~0.055 mJy/beam
- $SFR_{5\sigma}$~30 M_{sol}/yr (Dale&Helou 02, T_d=30K)

Tadaki et al. 2014, Tadaki et al. 2015, ApJL, 811, 3L

ALMA observation 1





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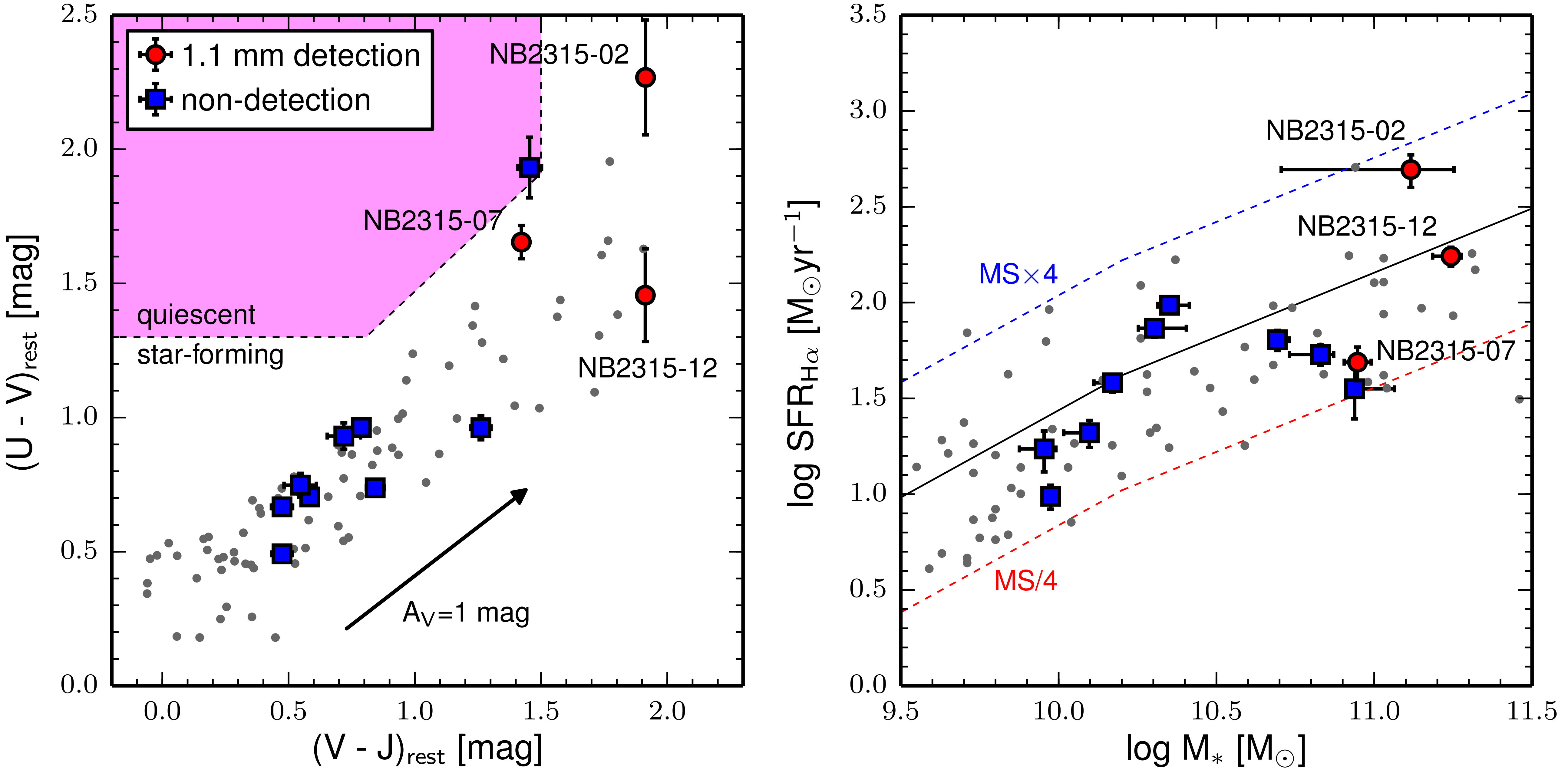
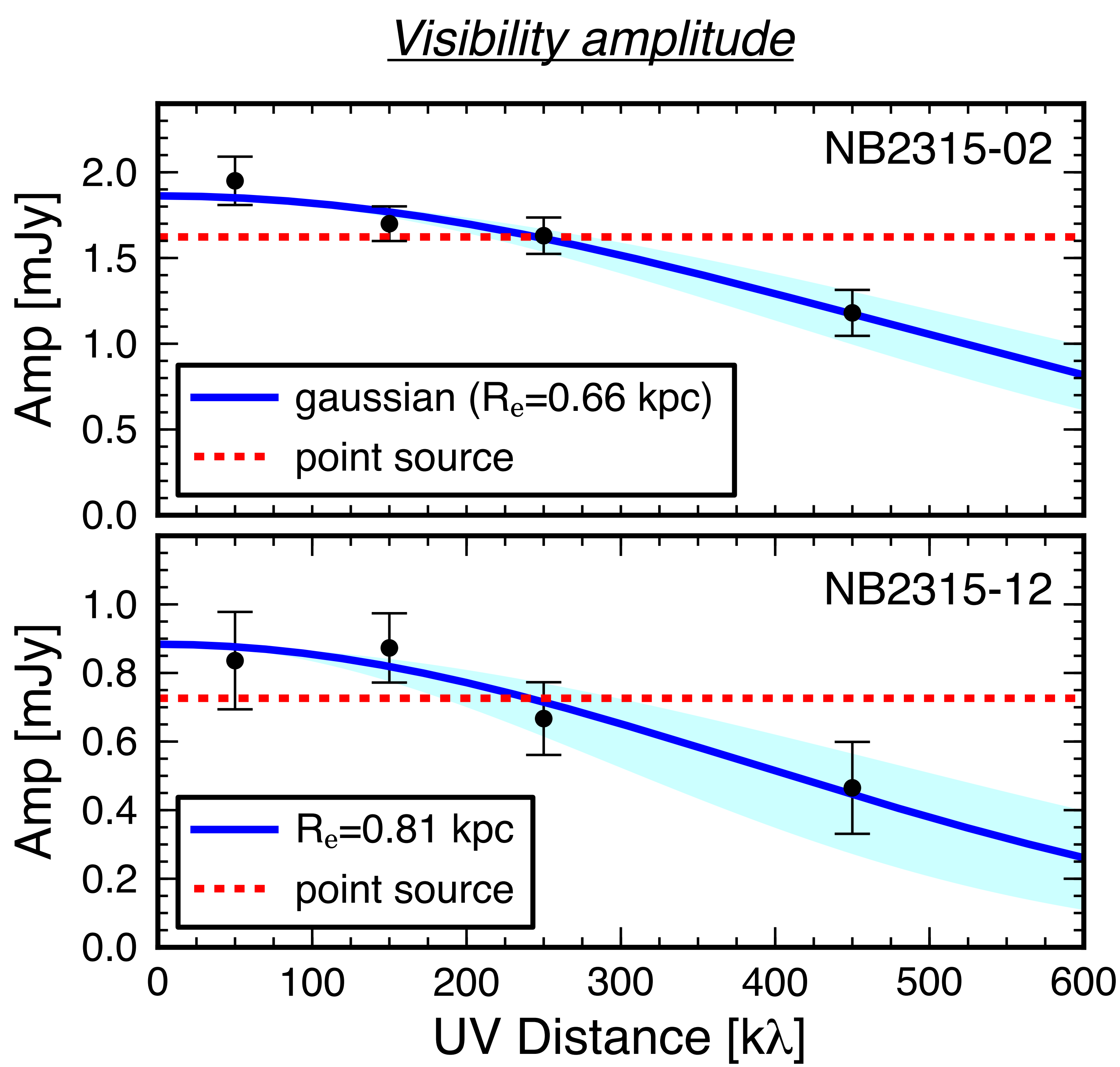
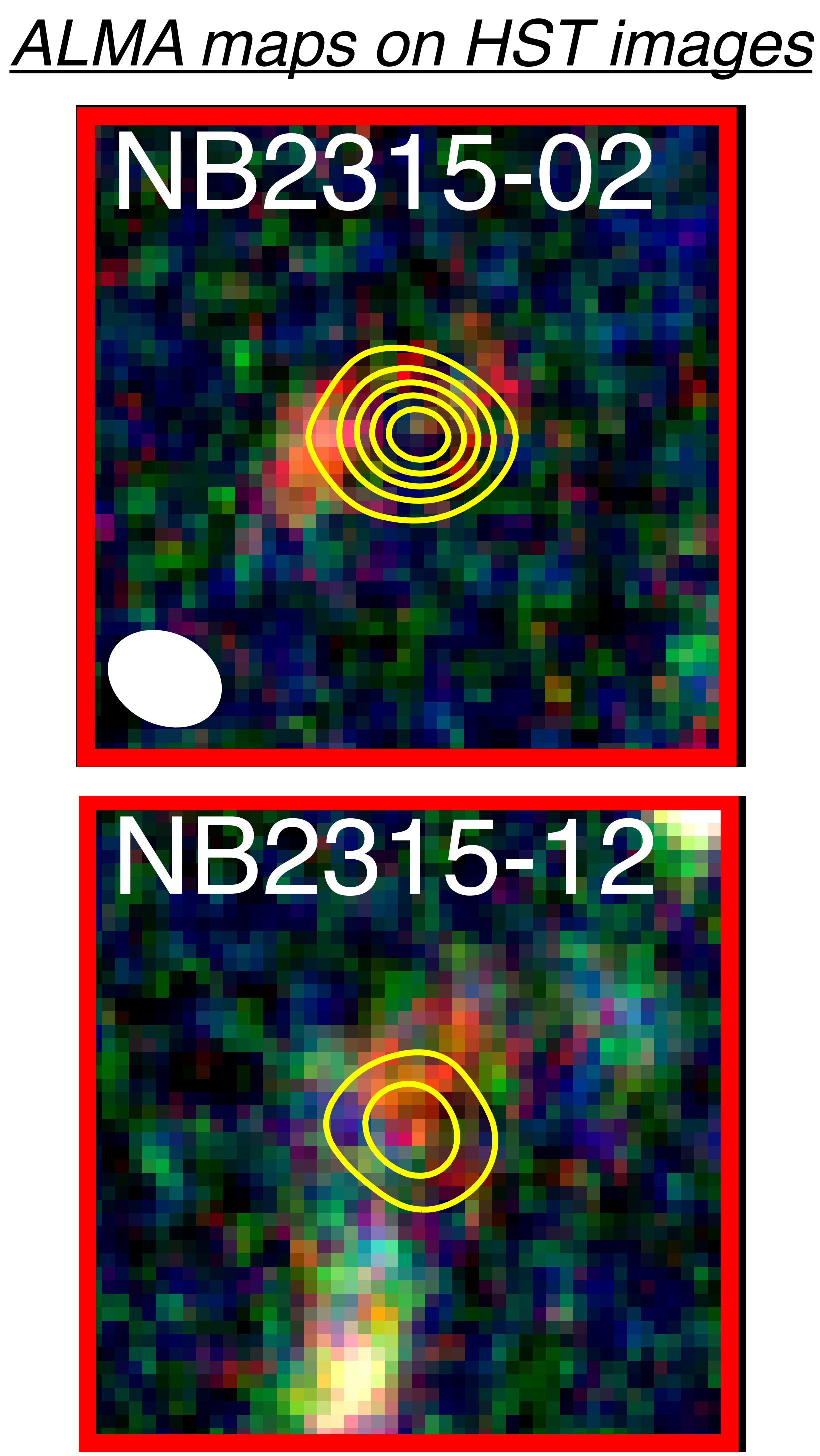


Tadaki et al. 2015, ApJL, 811, 3L

ALMA observation 1





intense star formation is occurring in a compact region （$\Sigma_{1kpc,SFR}$>300 $M_{sol}yr^{-1}$)

Tadaki et al. 2015, ApJL, 811, 3L

ALMA observation 2

Tadaki et al. in prep

ALMA observation 2

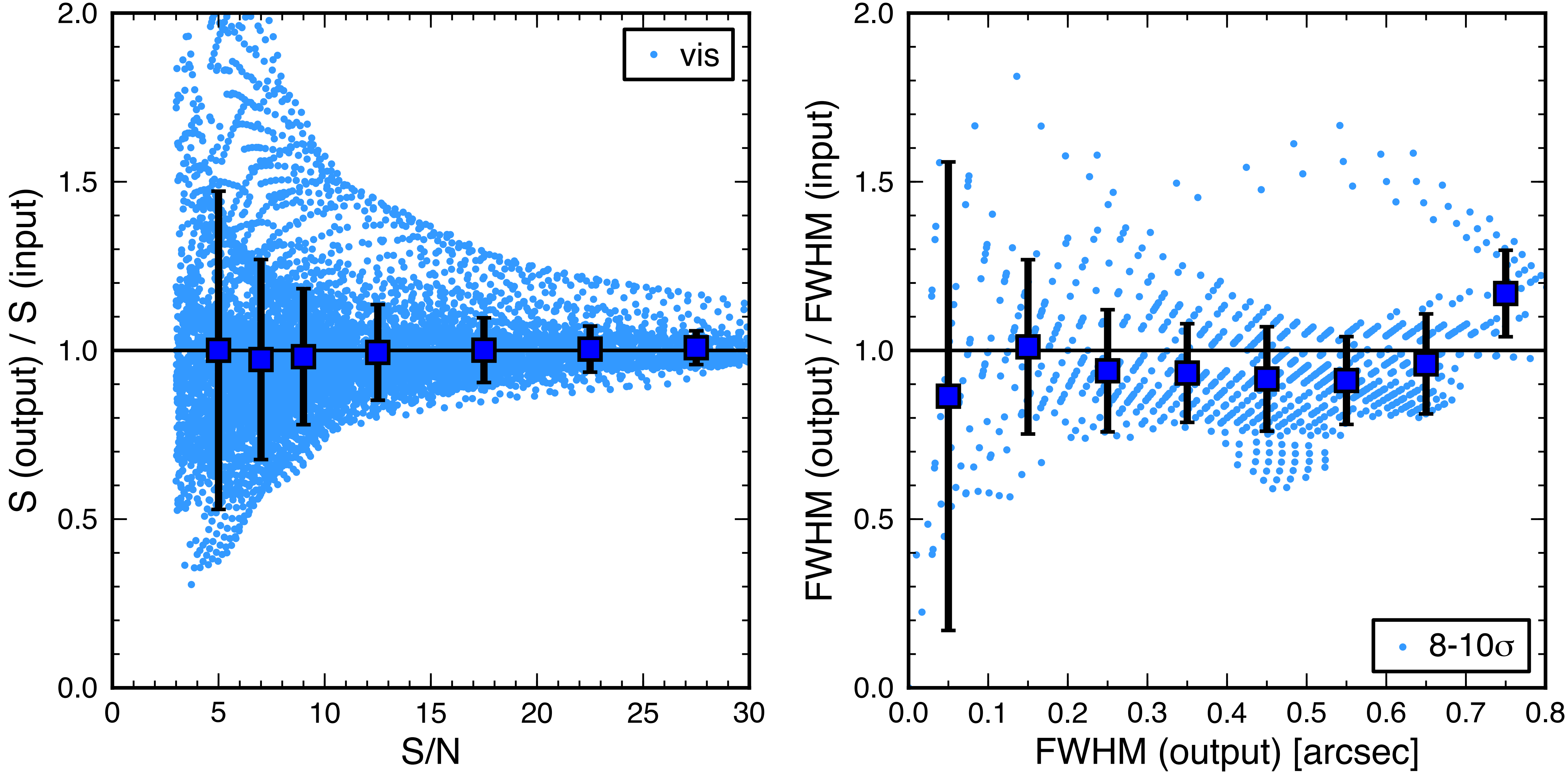
Tadaki et al. in prep

ALMA observation 2

Tadaki et al. in prep

Uncertainties for size measurements at 870um

simulations with mimic circular gaussian sources

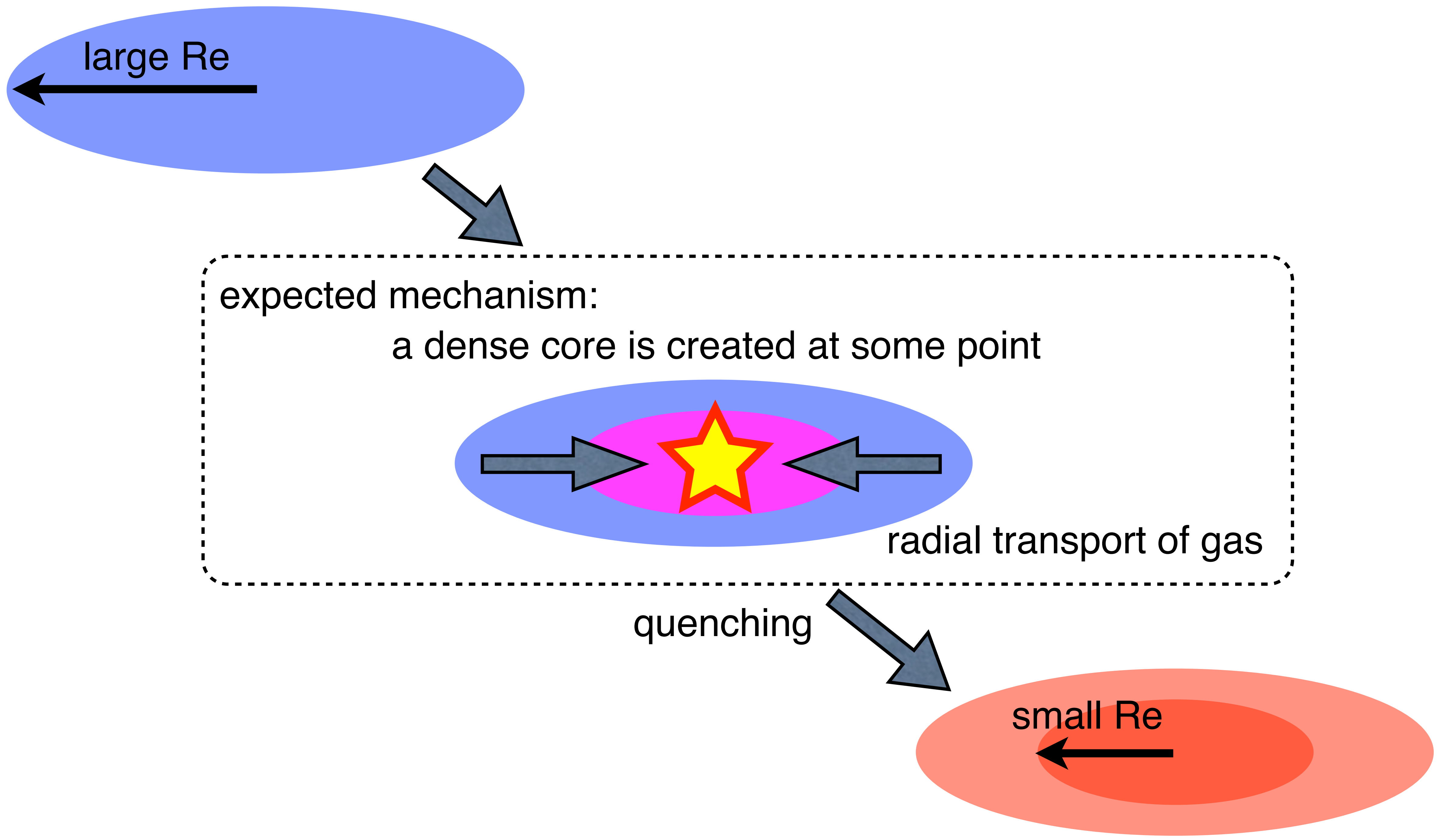


For objects with S/N>8, uncertainties for flux/size measurement are 15-20%.

Tadaki et al. in prep

A compact starburst in extended stellar disks?

star-forming galaxies are disk-dominated

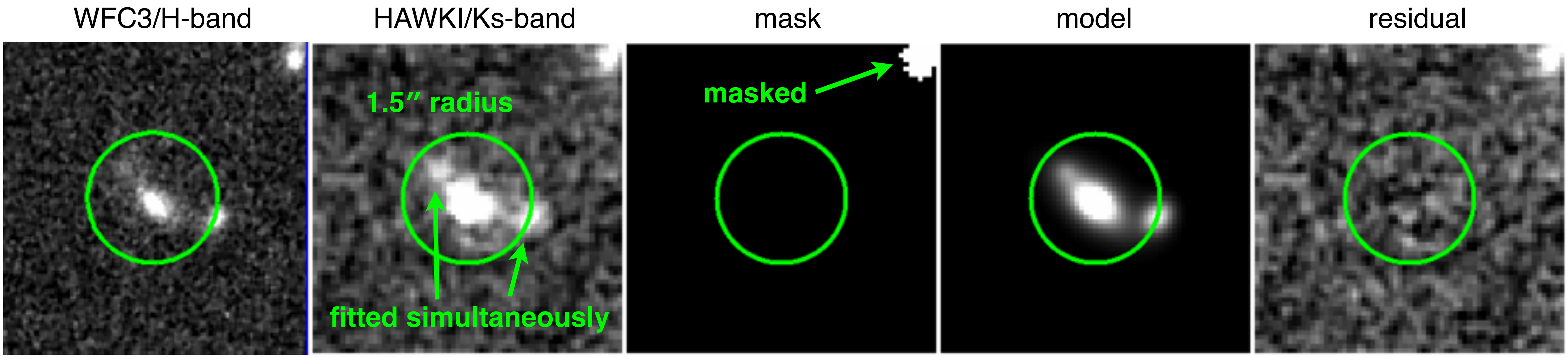


quiescent galaxies are bulge-dominated

GALFIT run on HAWKI/K image (HUGS: Fontana et al. 2014)

Table 1. Layout and summary of observations for the UDS field.

Pointing	Central RA	Central Dec	Area (arcmin^2)	Exp. time (s/h)	Final seeing	Maglim[a]	Maglim[b]
			K-band				
UDS1	02:17:37.470	−05:12:03.810	70	48 360/13.43	0.37	27.4	26.1
UDS2	02:17:07.943	−05:12:03.810	70	46 820/13.00	0.43	27.3	25.9
UDS3	02:18:06.896	−05:12:03.810	70	45 240/12.57	0.41	27.4	25.9

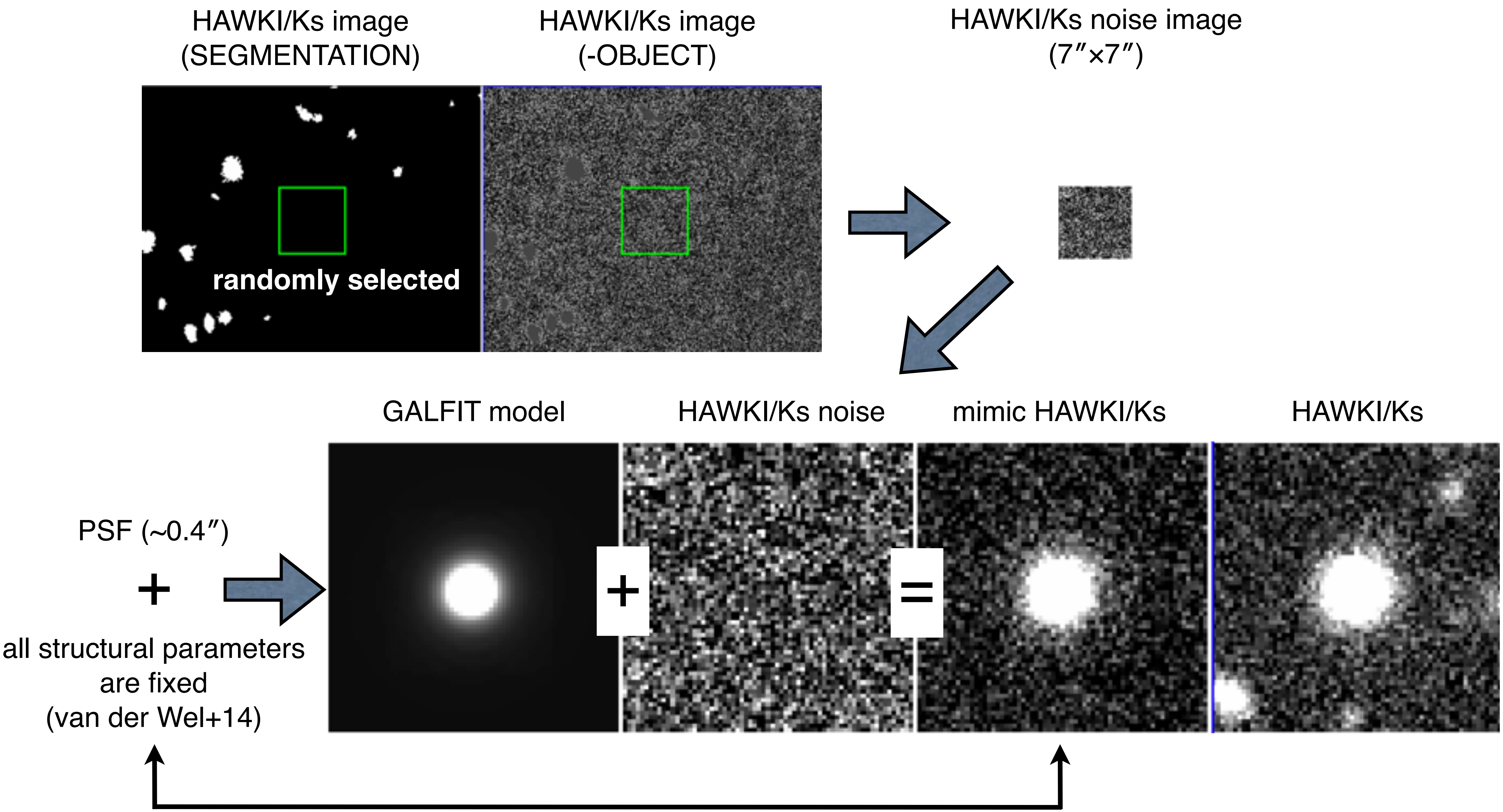


1. 7″× 7″ cutout images are used for fitting
2. sources within 1.5″ radius are fitted simultaneously
3. other neighboring sources are masked
4. input parameters are taken from GALFIT outputs in WFC3/H-band (van der Wel et al. 2014)

- center position: almost fixed (±1.0 pixel ~ 0.01″)
- re,n, mag: free (0.05″<re<3.5″, 0.2<n<8.0)
- q,pa: fixed
- sky: fixed (median sky value is calculated in 7″× 7″ image where all objects are masked)

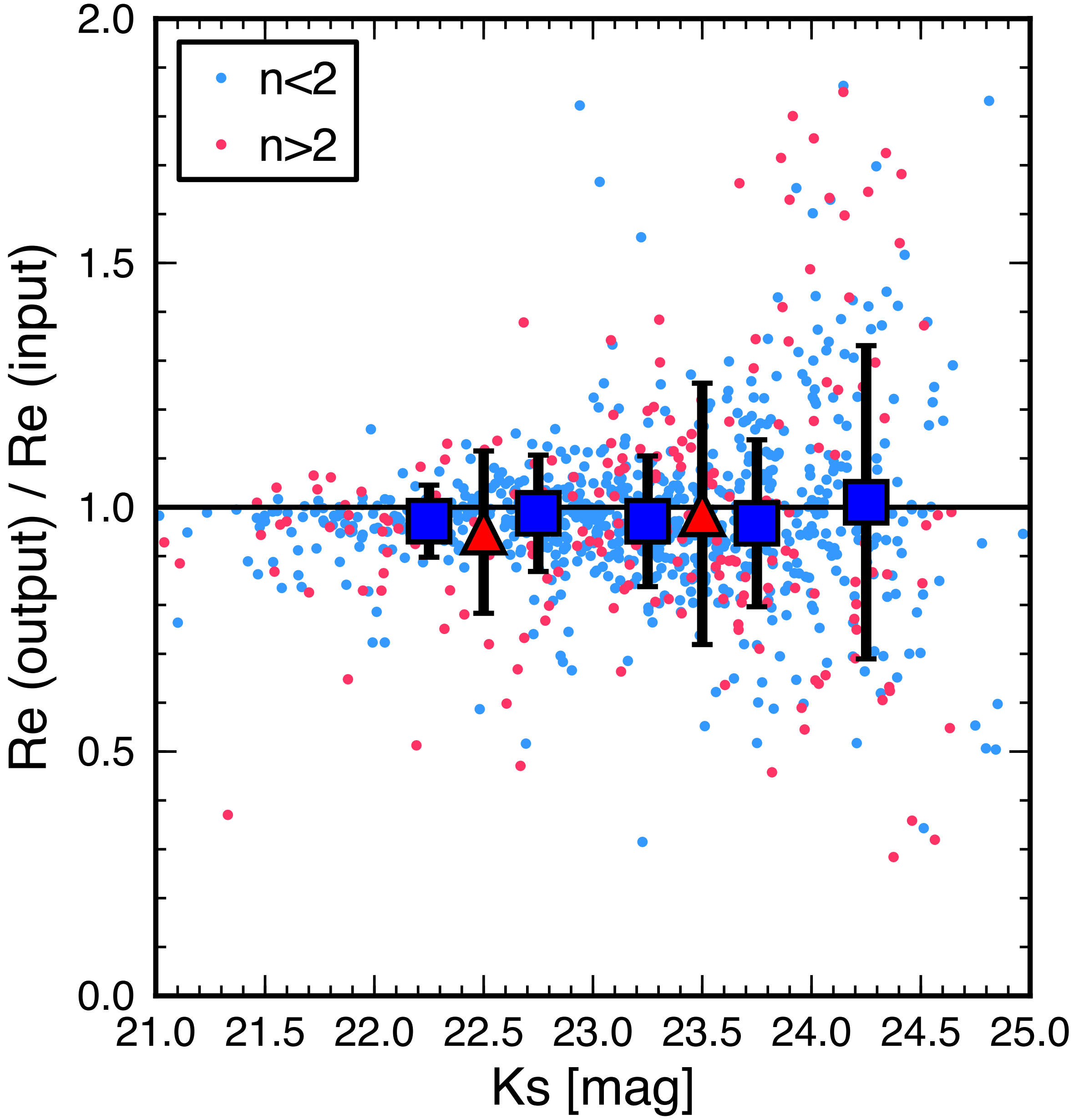
in case where the H-band counterpart does not exist, the SExtractor outputs are used as initial guess.

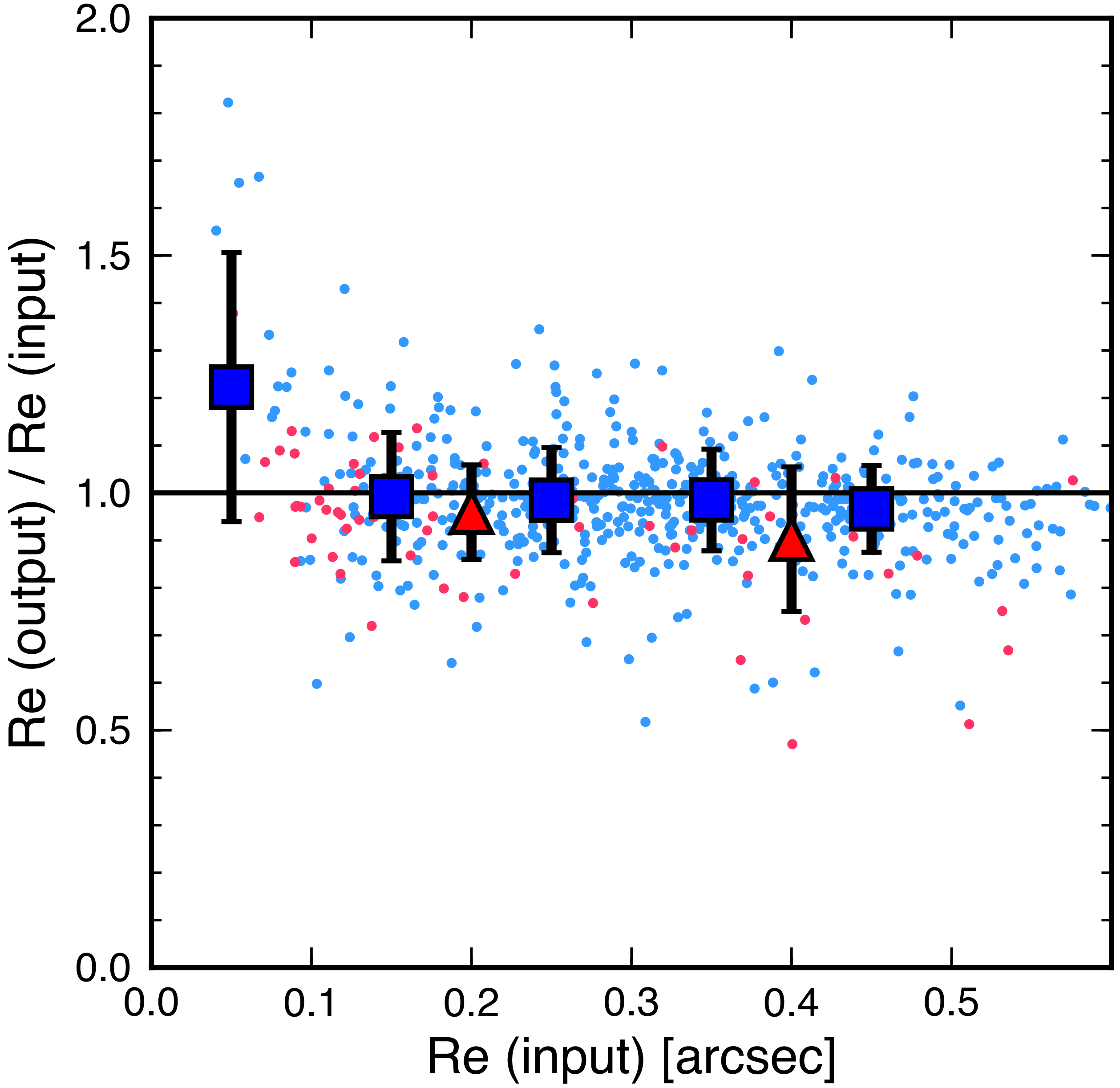
Simulations with GALFIT



compare input with output (GALFIT results with mimic images)

Uncertainties for size measurements





we can measure sizes with <15% accuracy for K<24 galaxies

Mass-size relation for normal star-forming galaxies

Wet compaction?

From MAHALO to SWIMS-18

For massive normal SFGs with $\log M_* > 10.9$, we can detect dust emission with ALMA 6-8 minutes integration

MAHALO: ~20 massive Hα emitters in ~90 $\mathrm{arcmin}^2 \times 2$ NB filters

↓

SWIMS-18: ~720 Hα emitters in 1 $\mathrm{deg}^2 \times 2$ NB filters

NB data is not necessarily deep (5σ~23 mag)

deep K-band images are needed to measure rest-frame optical sizes

seeing < 0.4″ -> K-band observations?
seeing =0.4-0.6″ -> SWIMS-18?

or WFIRST?