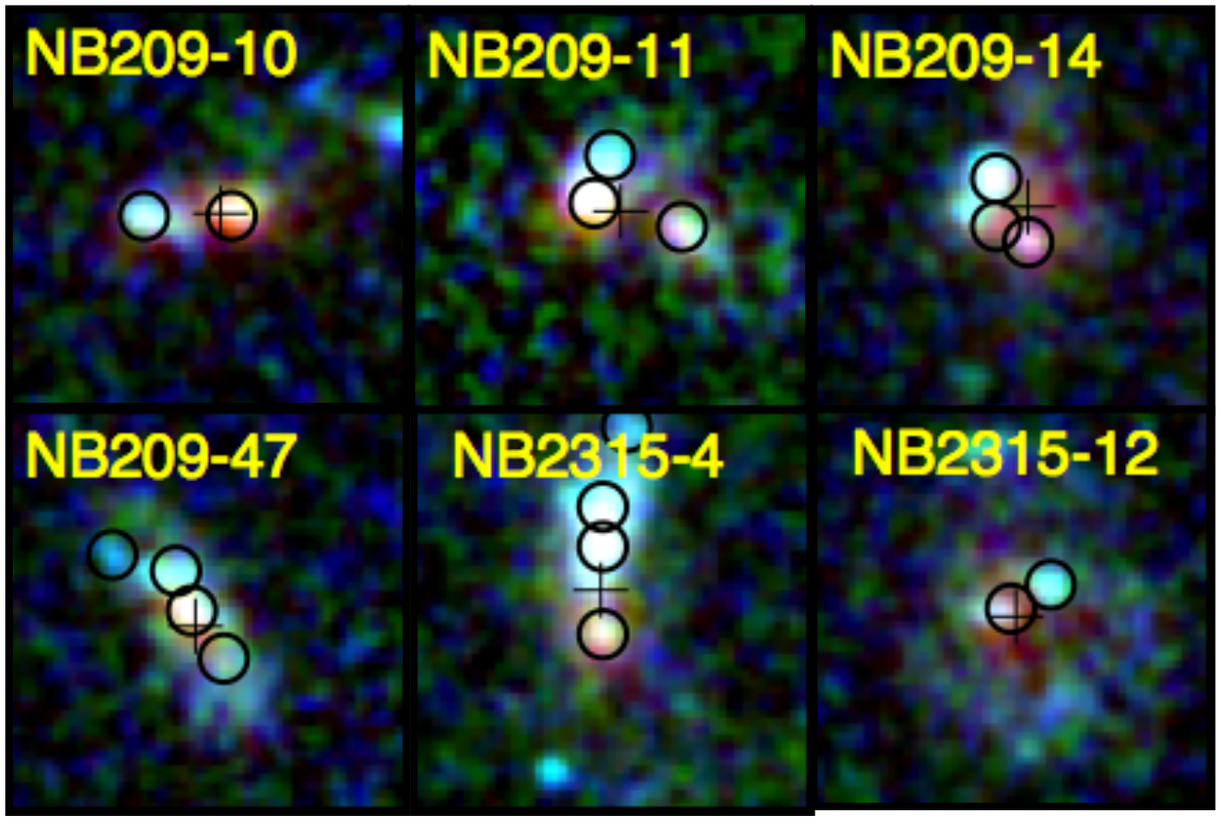
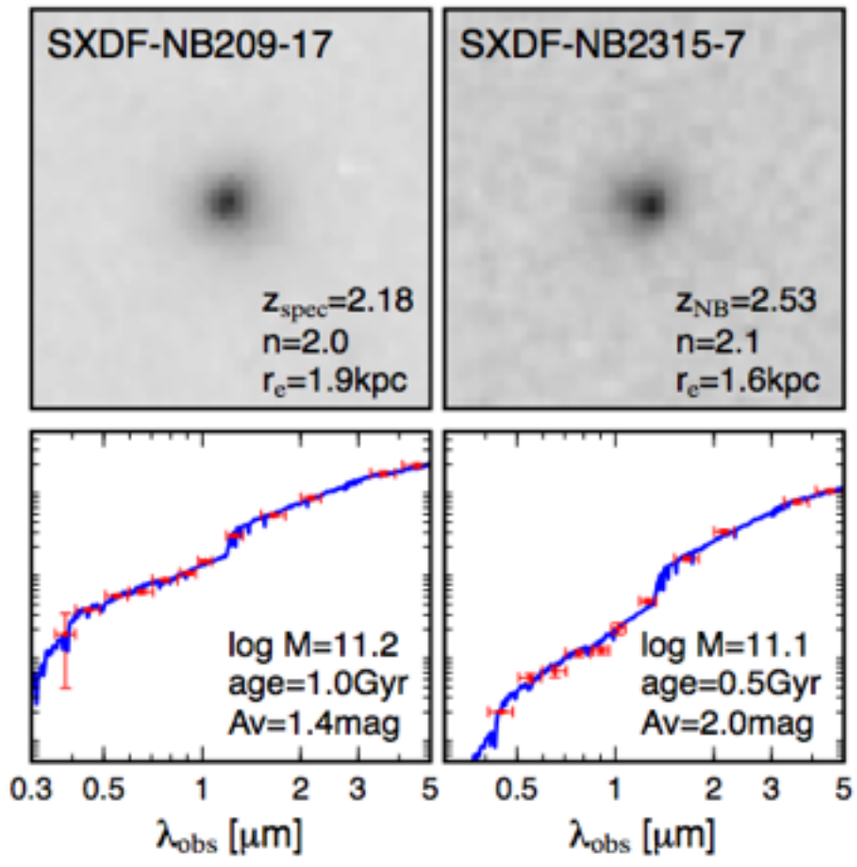
Clumpy galaxies and compact star-forming galaxies

giant clumps, compact SFGs ~ 1kpc





Ken-ichi Tadaki (NAOJ, JSPS research fellow)

Tadayuki Kodama (NAOJ), Ichi Tanaka (NAOJ), Masao Hayashi (ICRR), Yusei Koyama (NAOJ), Rhythm Shimakawa (GUAS)

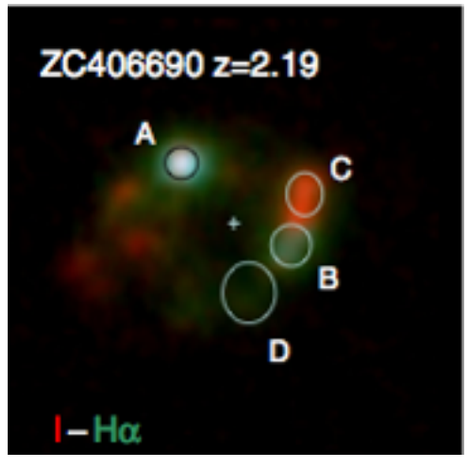
Morphology at peak epoch

Star-forming galaxy

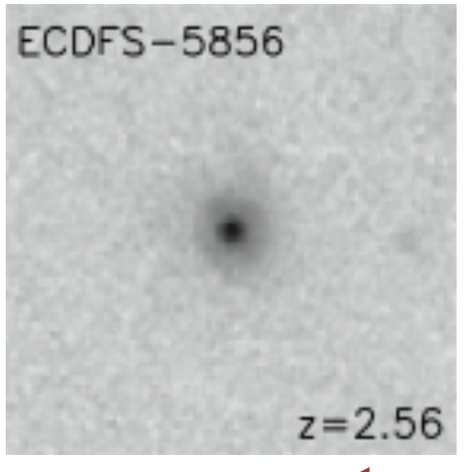
Quiescent galaxy

z=0

Peak epoch



clumpy



compact

Genzel+11

van Dokkum+08

Formation of massive quiescent galaxies

EARLY-TRACK

LATE-TRACK

z>2

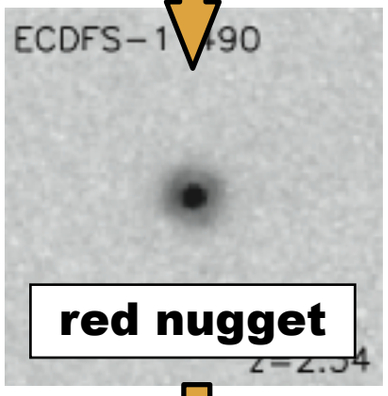
z~2

z=0

wet major merger

blue nugget

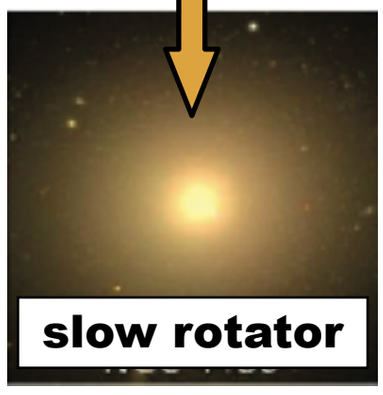
SF quenching by rapid process



van Dokkum+08

red nugget

dry minor merger

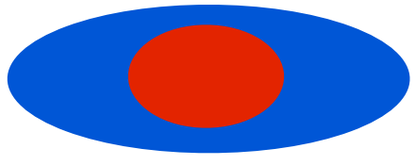


slow rotator

smooth accretion

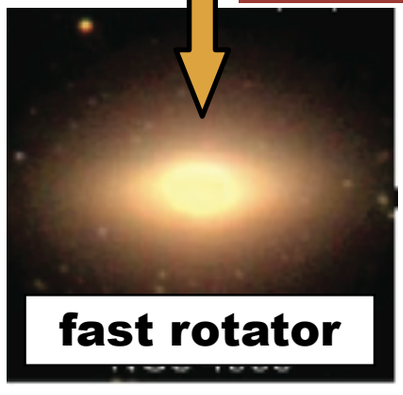
clumpy disk

clump migration or wet minor merger



dusty, old bulge?

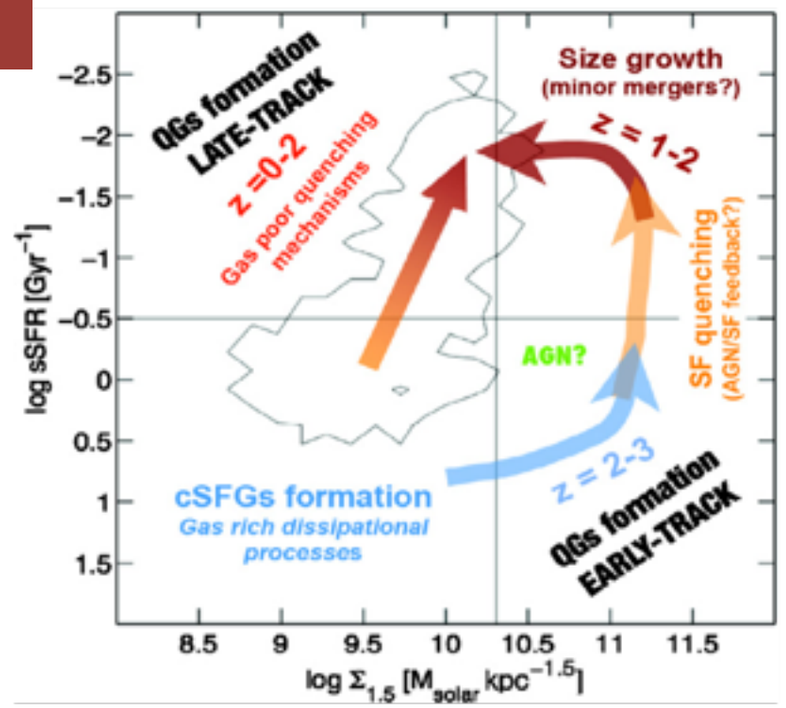
SF quenching by slow process

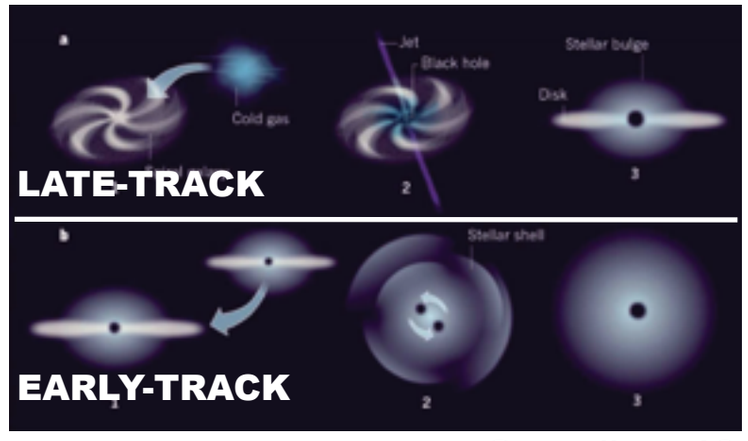


fast rotator

Capperallari+11

Barro+13

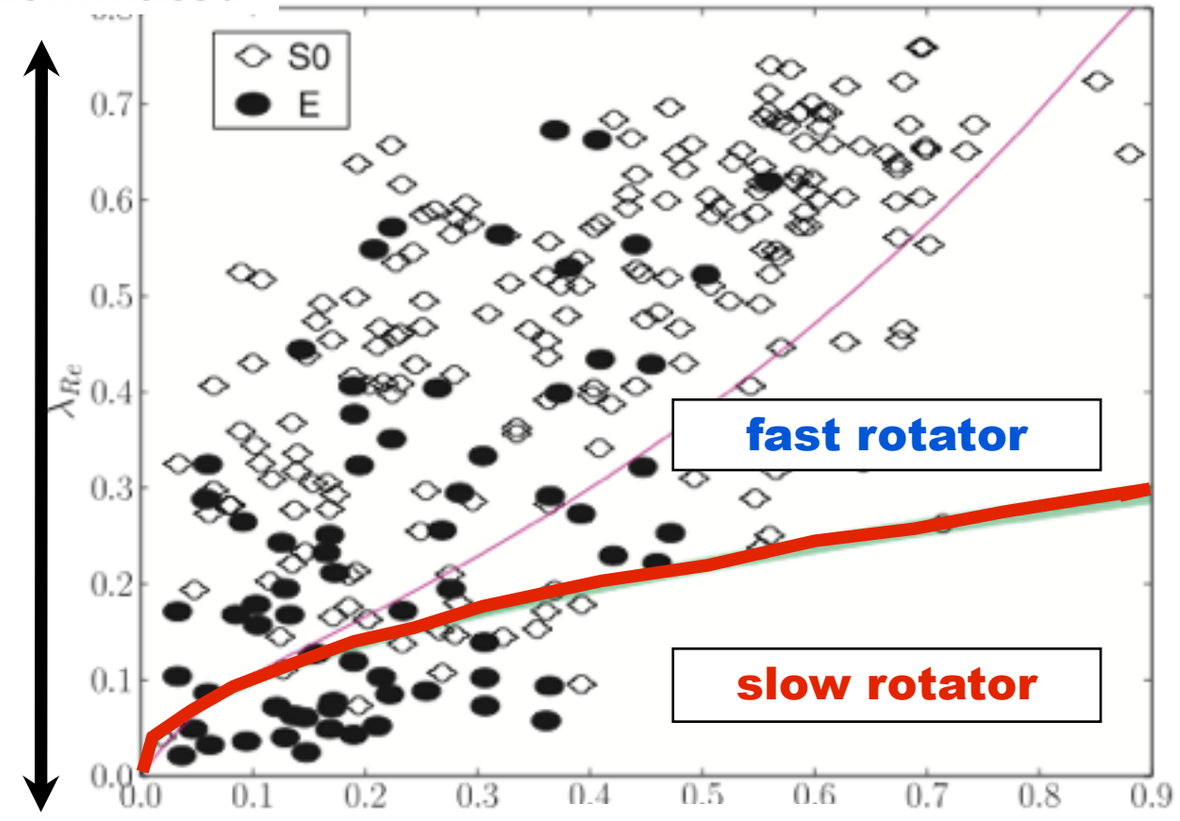




Cappellari+13

Formation of massive quiescent galaxies

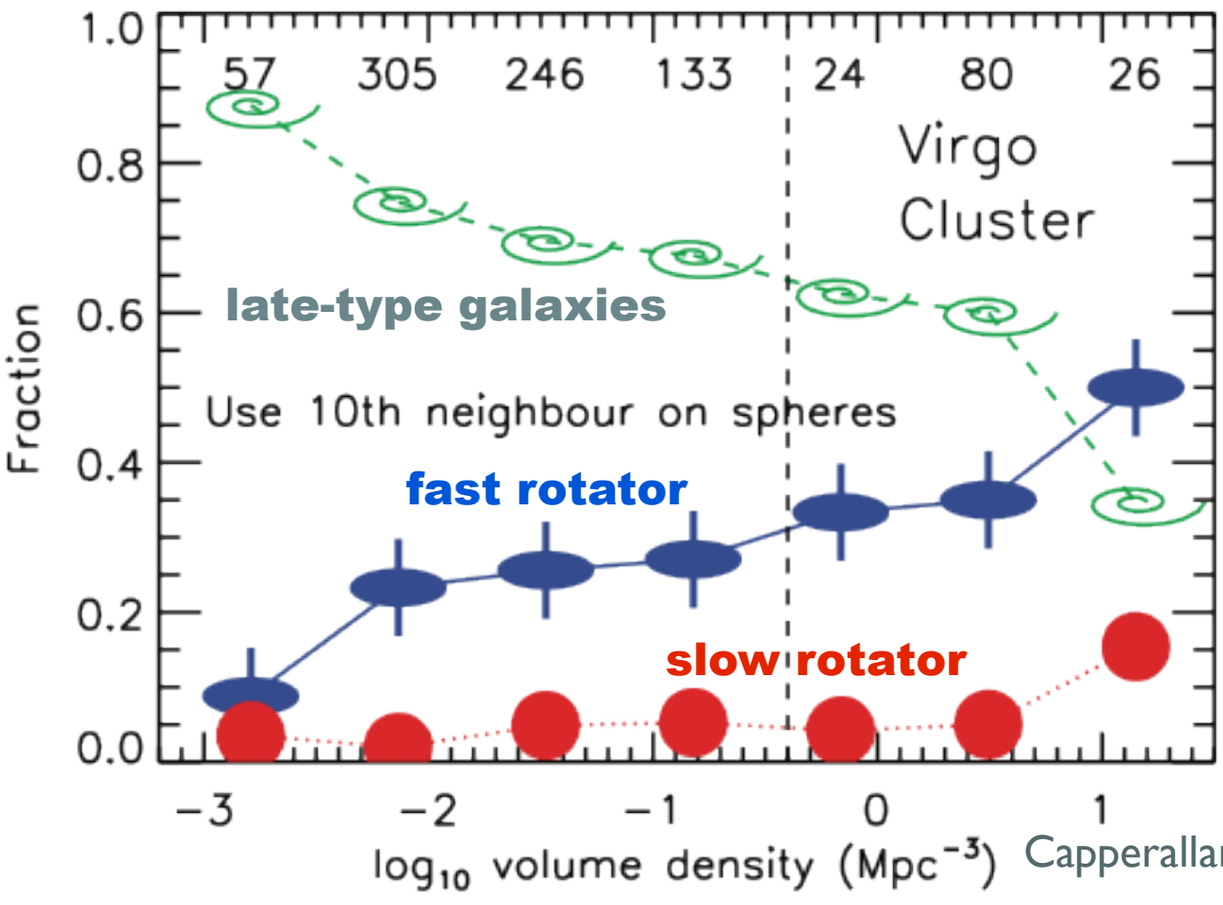
rotation-dominated



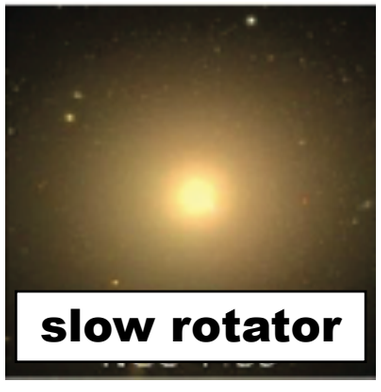
dispersion-dominated

Emsellem+11

morphology-density relation



Capperallari+11



Capperallari+11

Formation of massive quiescent galaxies

EARLY-TRACK

LATE-TRACK

z>2

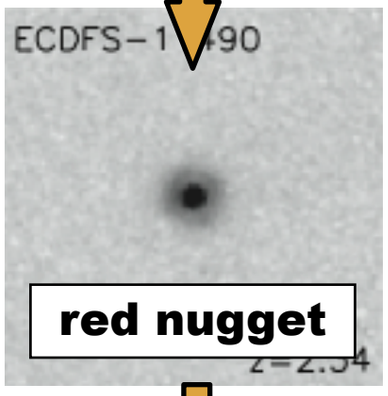
z~2

z=0

wet major merger

blue nugget

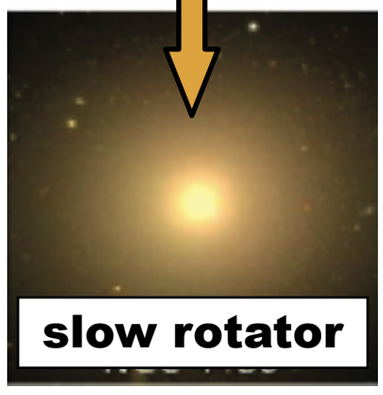
SF quenching by rapid process



van Dokkum+08

red nugget

dry minor merger

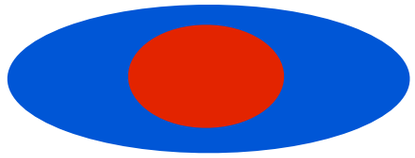


slow rotator

smooth accretion

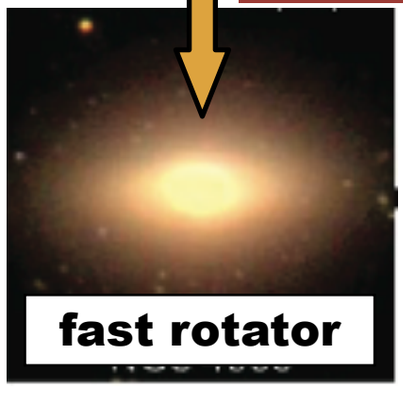
clumpy disk

clump migration or wet minor merger



dusty, old bulge?

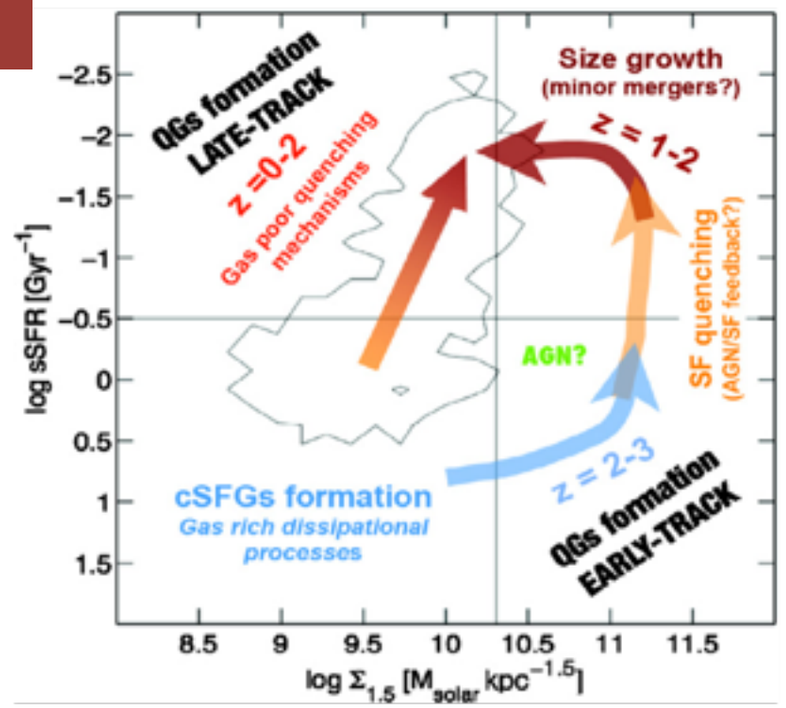
SF quenching by slow process

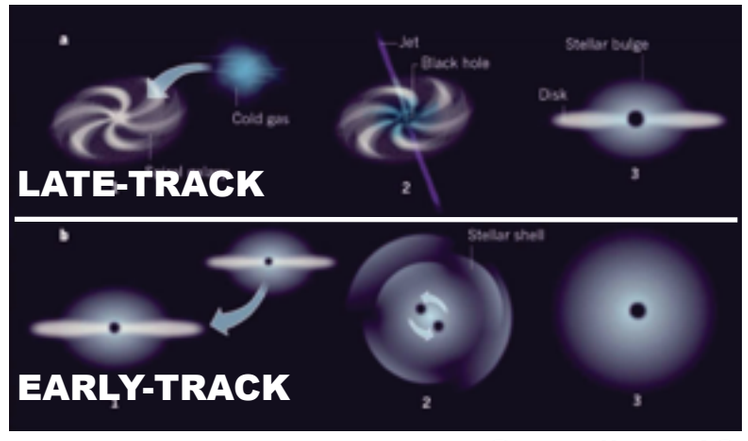


fast rotator

Capperallari+11

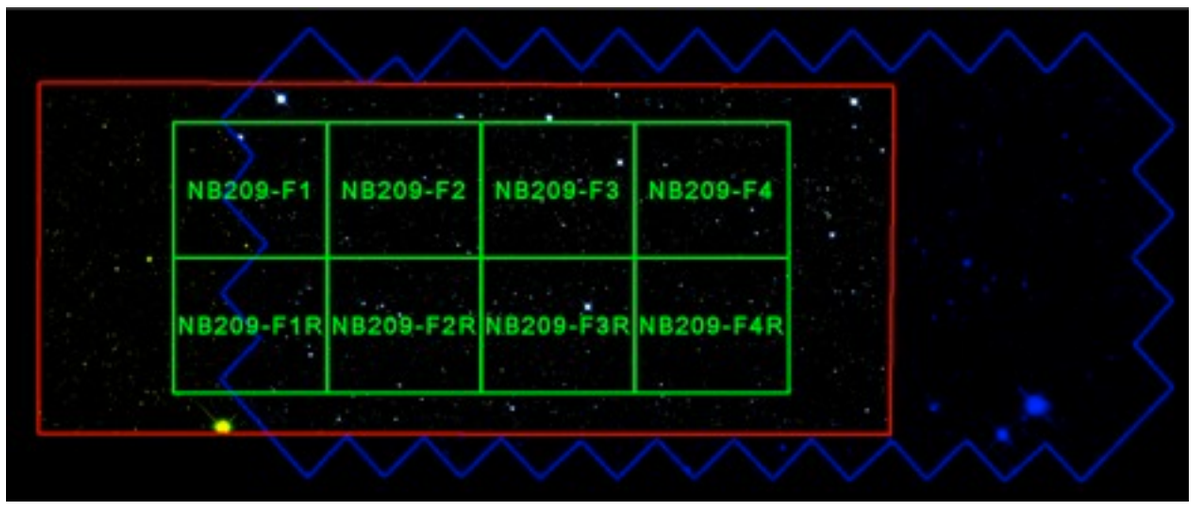
Barro+13

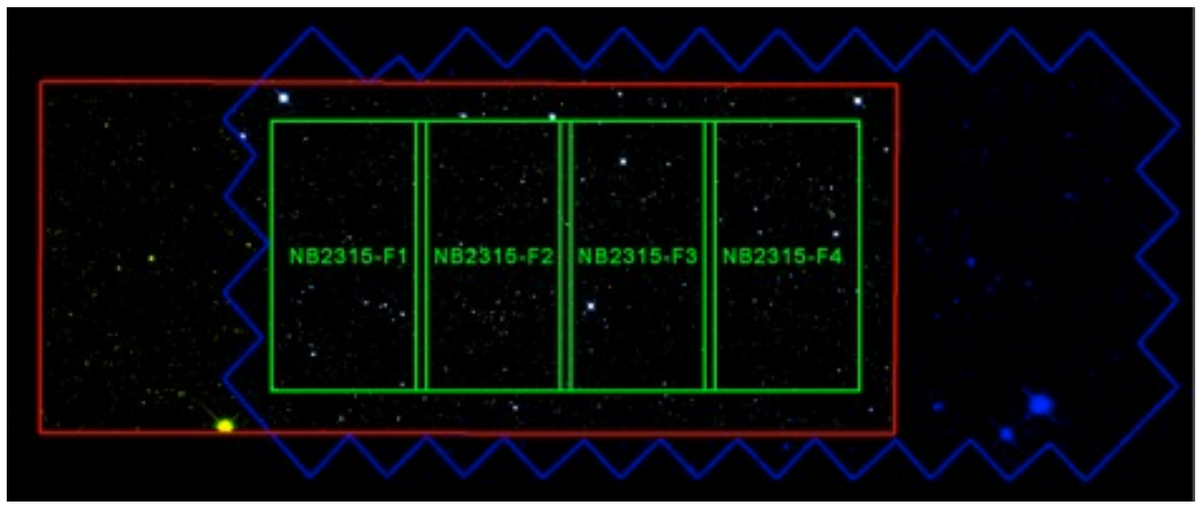




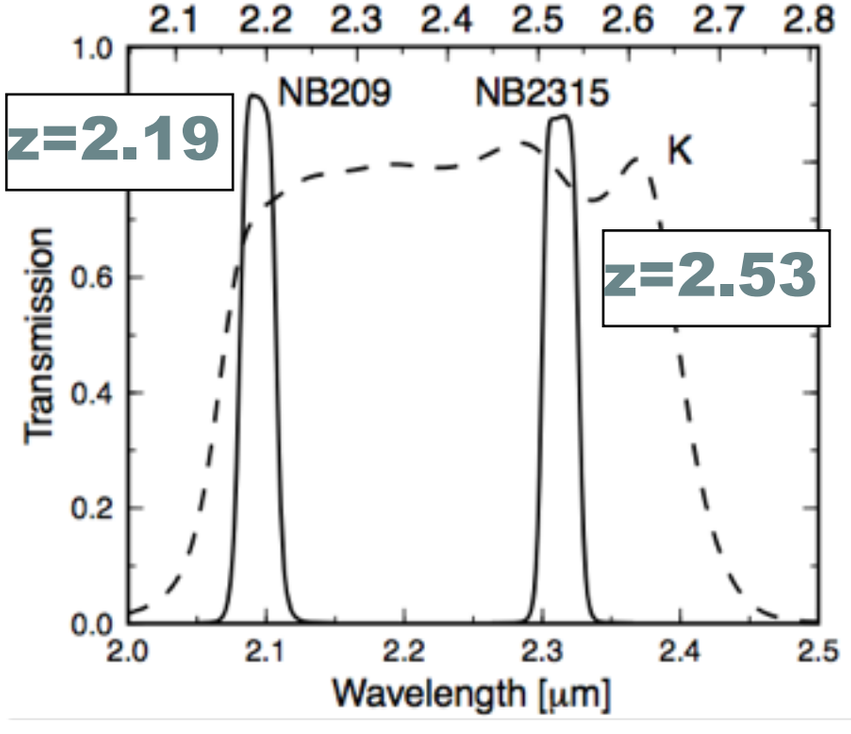
Cappellari+13

MOIRCS NB survey



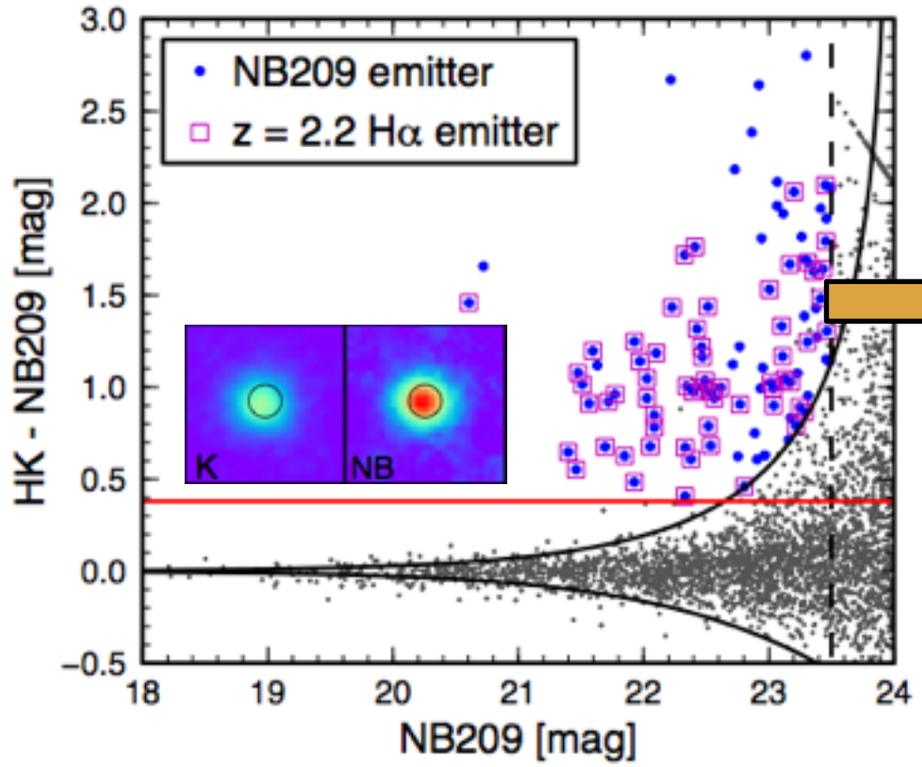


Filter	Instrument	$m_{5\sigma,AB}$
u	CFHT/MegaCam	27.68
B	Subaru/Suprime-Cam	28.38
V	Subaru/Suprime-Cam	28.01
R_c	Subaru/Suprime-Cam	27.78
i'	Subaru/Suprime-Cam	27.69
z'	Subaru/Suprime-Cam	26.67
Y	VLT/HAWK-I	26.69
K_s	VLT/HAWK-I	25.92
J	UKIRT/WFCAM	25.63
H	UKIRT/WFCAM	24.76
K	UKIRT/WFCAM	25.39
3.6μm	*Spitzer*/IRAC	24.72
4.5μm	*Spitzer*/IRAC	24.61



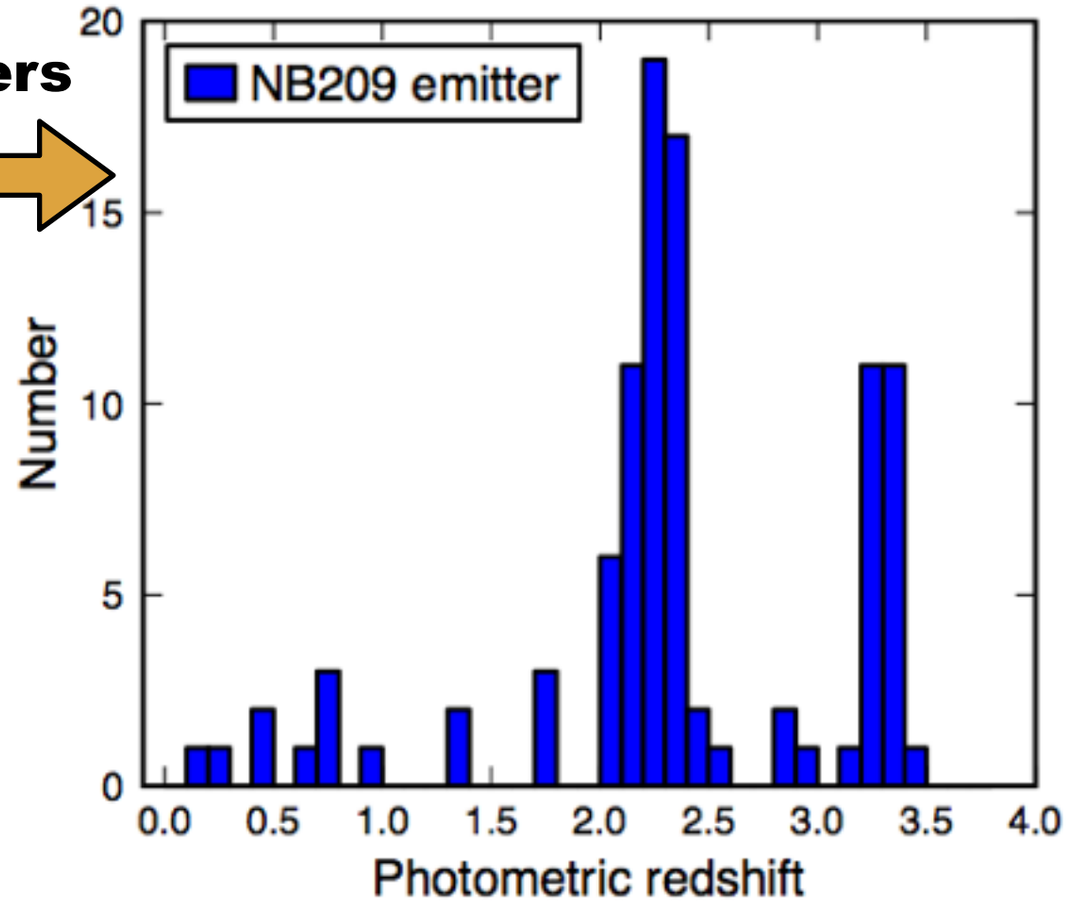
The survey area (~180arcmin^2) corresponds to 1 FoV of ULTIMATE-SUBARU

Sample selection



NB209 emitters

The distribution of z_{phot}

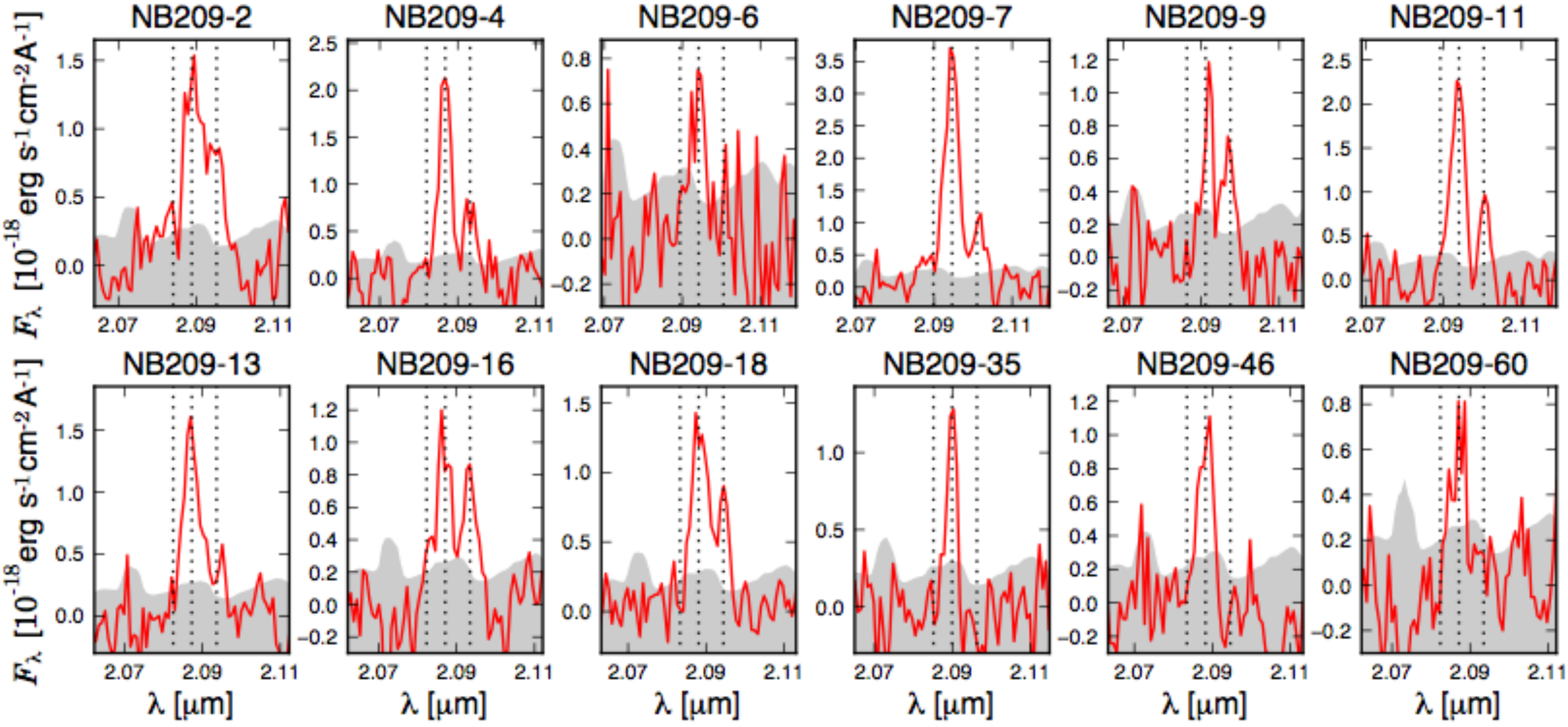


A NB survey provides us a clean sample of star-forming galaxies even at z>2.

105 Hα emitters have been identified by the NB209/NB2315 surveys
t_{int}=2-3h, 8 FoVs with MOIRCS -> t_{int}=40min, 1 FoV with ULTIMATE-SUBARU

MOIRCS spectroscopy

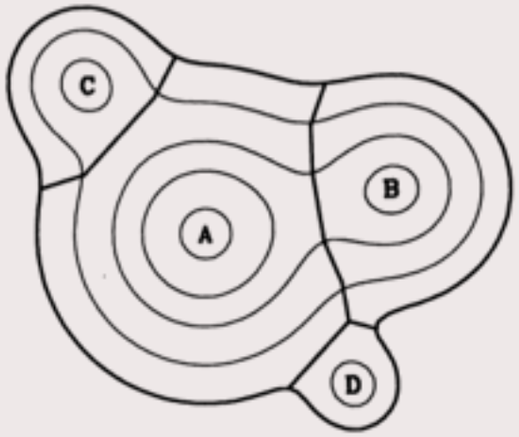
For 12 out of 13 NB209 emitters, a line emission has been detected (>90%).
t_{int}~4h, 1mask with MOIRCS -> t_{int}~1h, 0.1mask with ULTIMATE-SUBARU



To avoid OH lines, R>3000 is required.
R~500 mode is not needed.

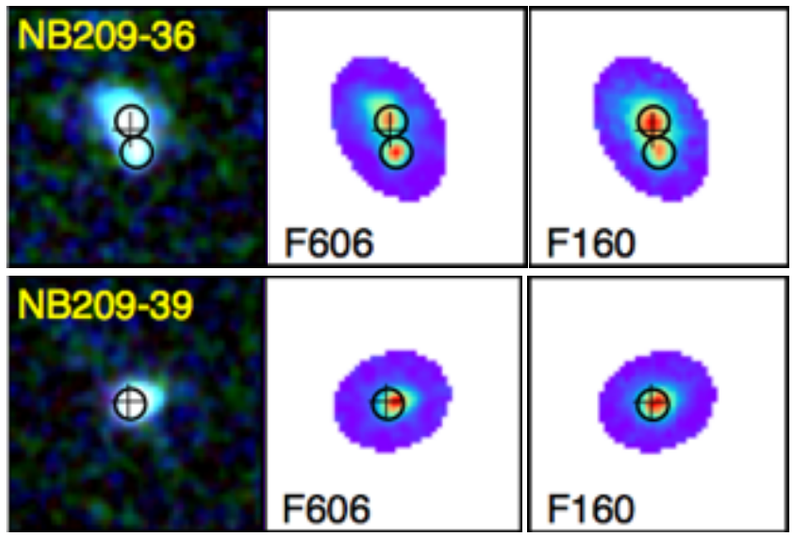
Identification of clumps

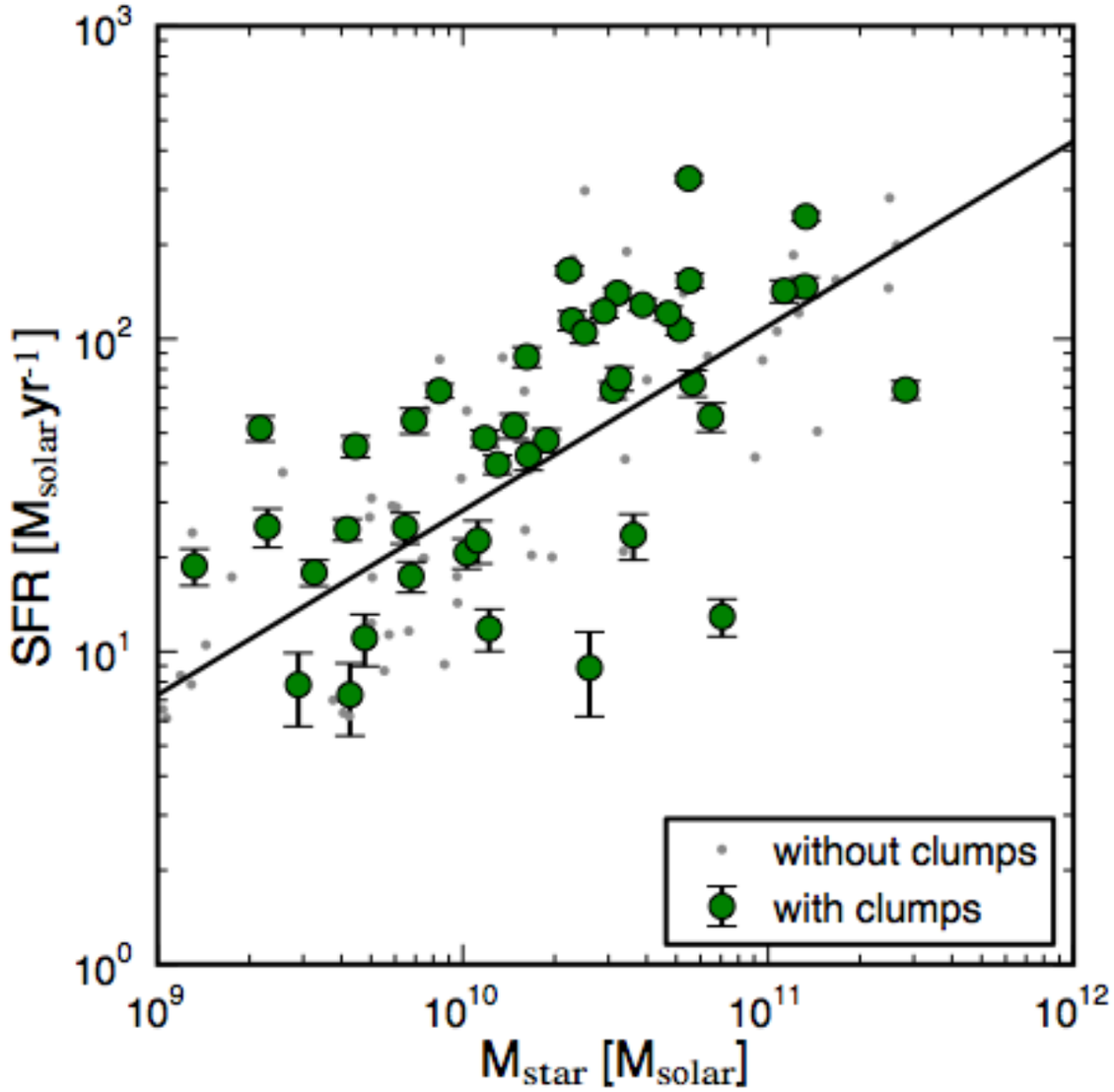
clump-find algorithm (Williams+94)



clumpy

non-clumpy





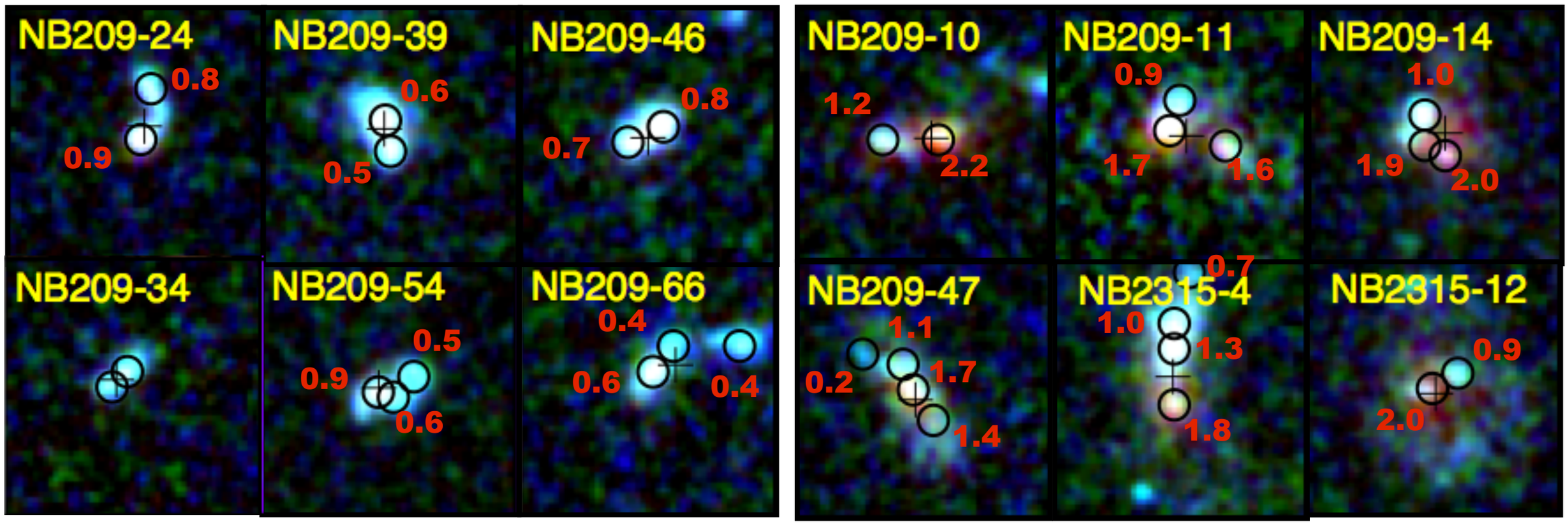
~40% of star-forming galaxies are clumpy

Differences between clumpy and non-clumpy are not seen in M_{star}-SFR.

Clumpy galaxies

less massive clumpy galaxies
(M_{star}<$10^{10}M_\odot$)

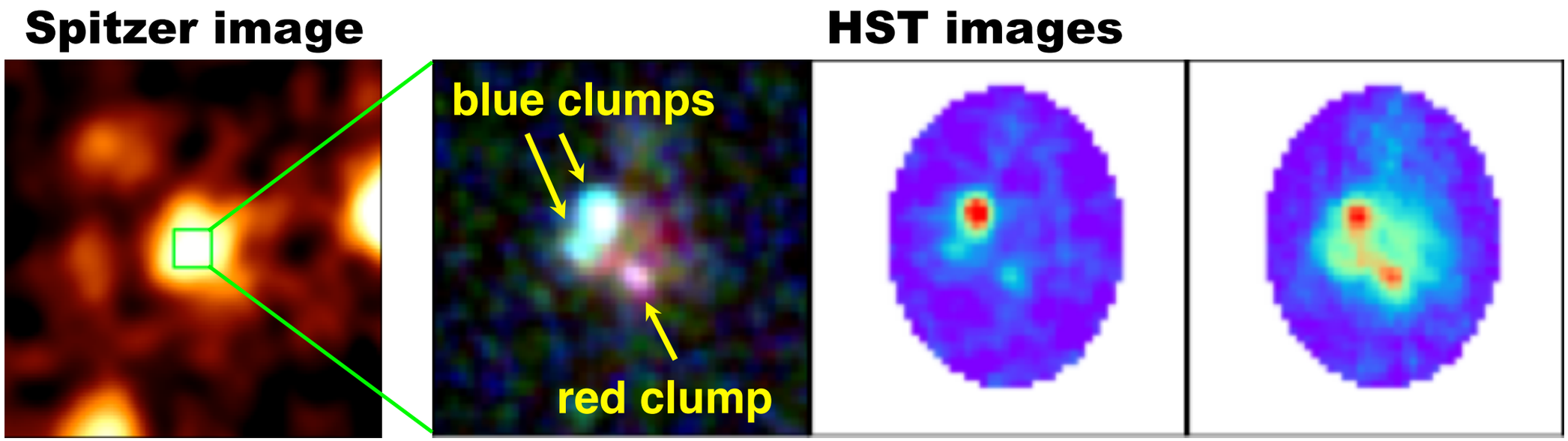
massive clumpy galaxies
(M_{star}=$10^{10\text{-}11}M_\odot$)



color of clumps (I_{814}-H_{160})

Massive clumpy galaxies have a proto-bulge component.

Dusty star-formation in red clump



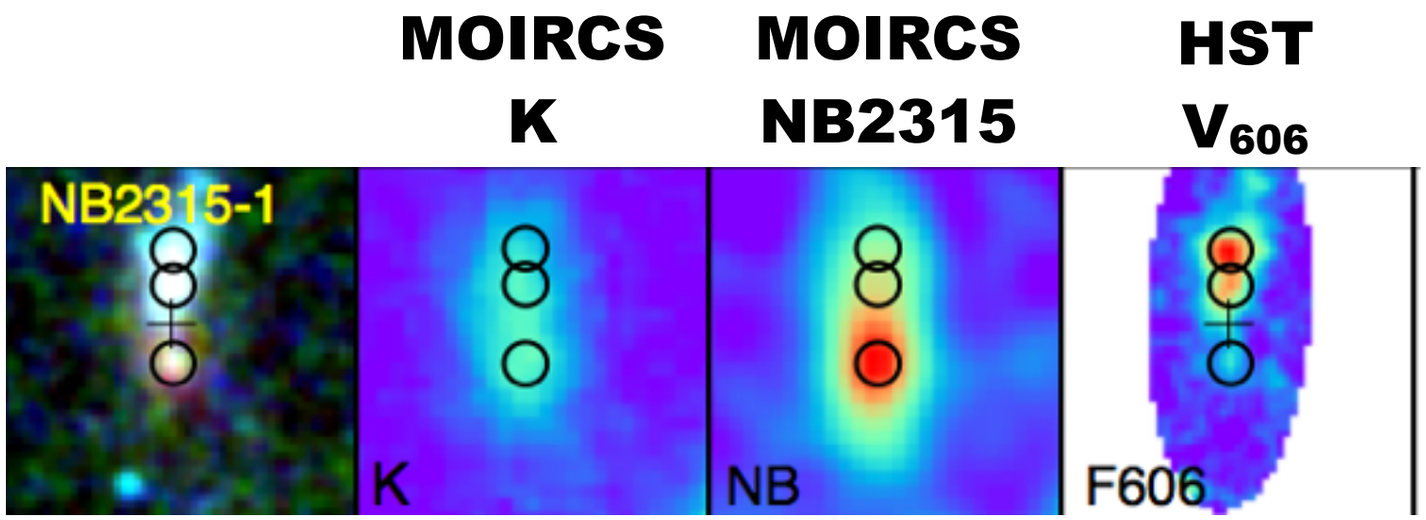
dusty star formation is occurring within this galaxy

blue clump : less dusty
red clump : dusty or old

A red clump is dust obscured star forming proto-bulge?

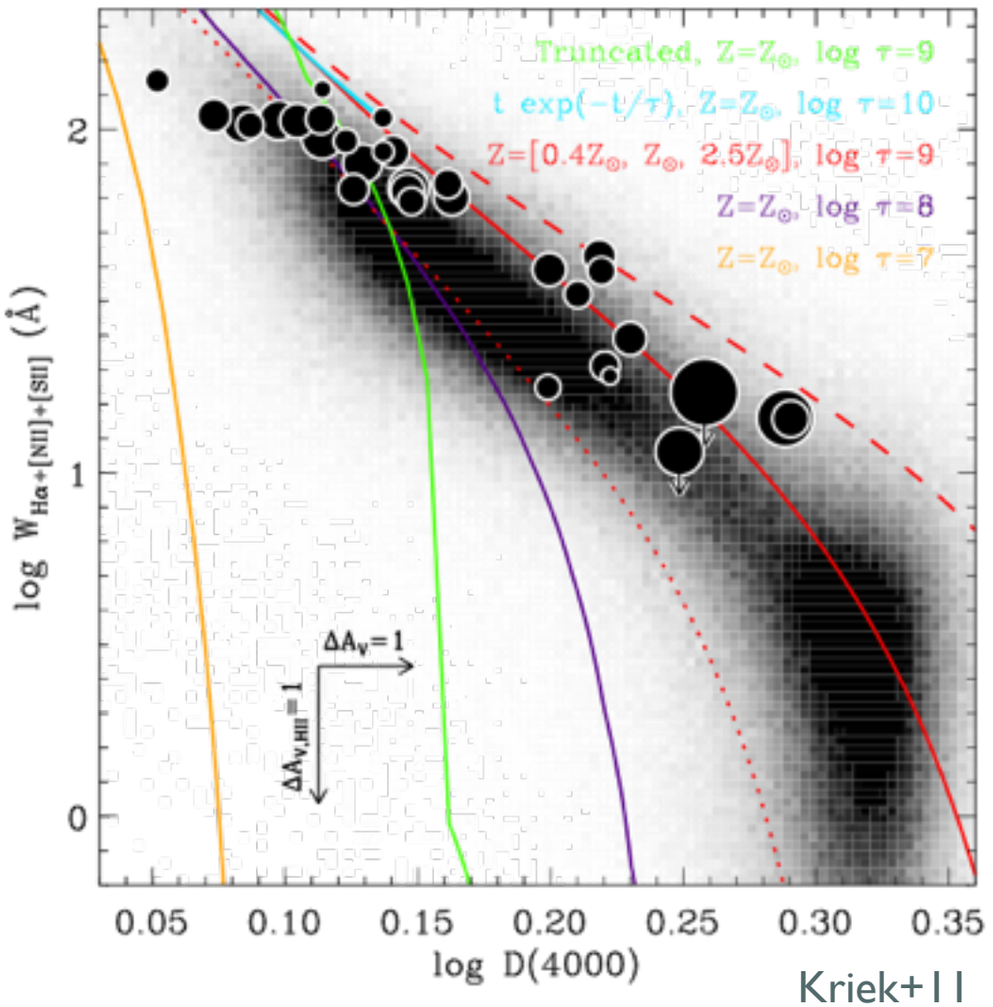
This is not the direct evidence

AO Hα imaging



$EW_{H\alpha+[NII]}$ → age

(Hα/UV → dust extinction)

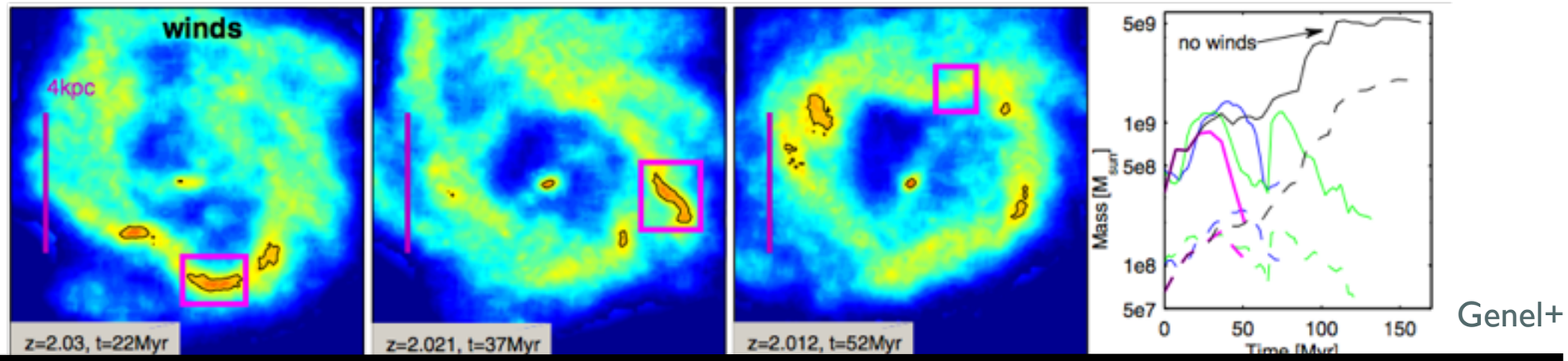


Kriek+11

The relation between radial distance and clump properties provide us important information for clump migration.

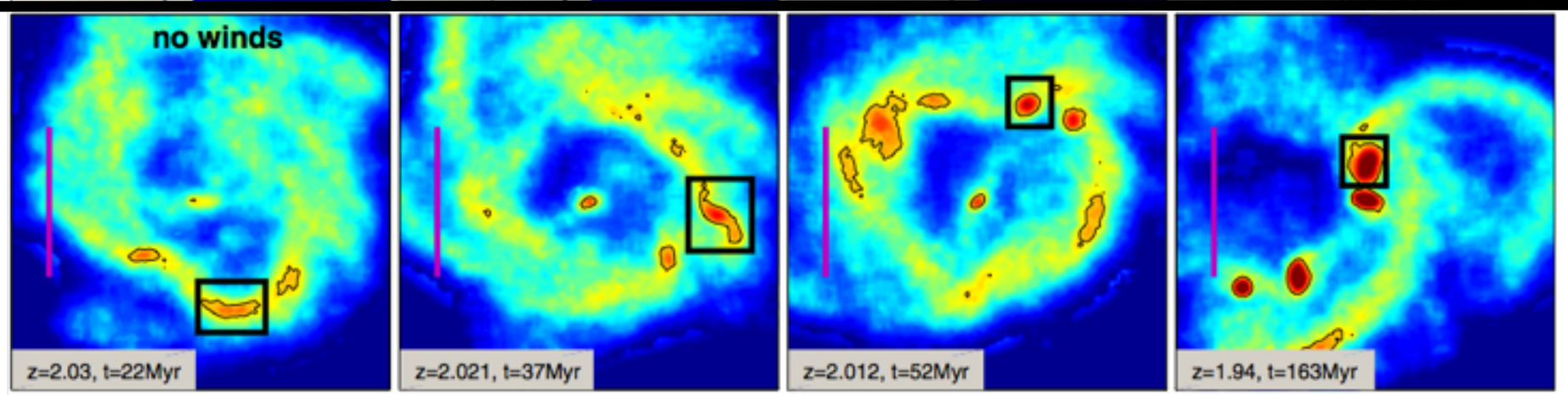
Migration of giant clumps

including strong feedback



Genel+12

no winds



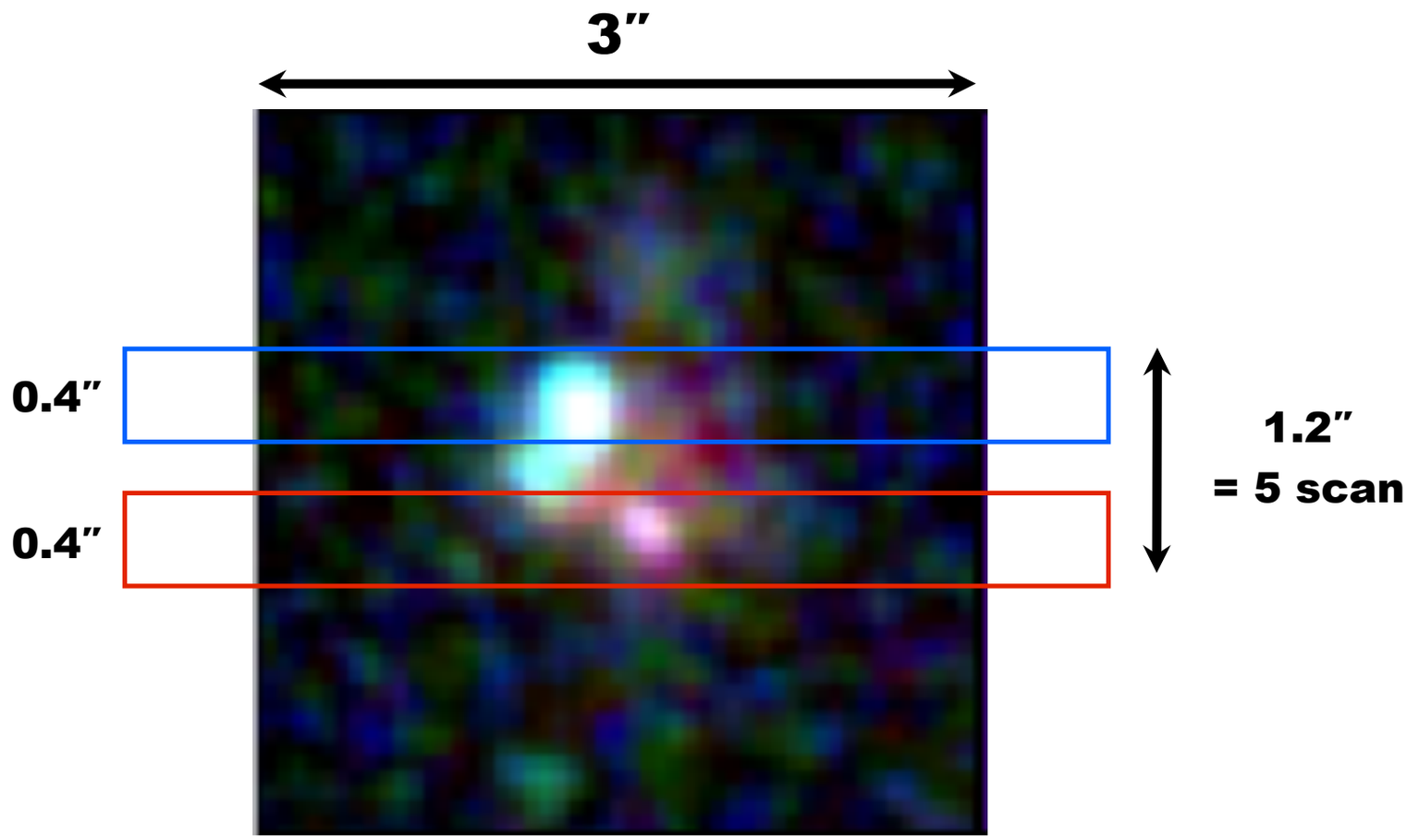
We do not know whether clumps migrate to a bulge or are disrupted by outflows.

But,

the relation between radial distance and clump properties provide us important information for clump migration.

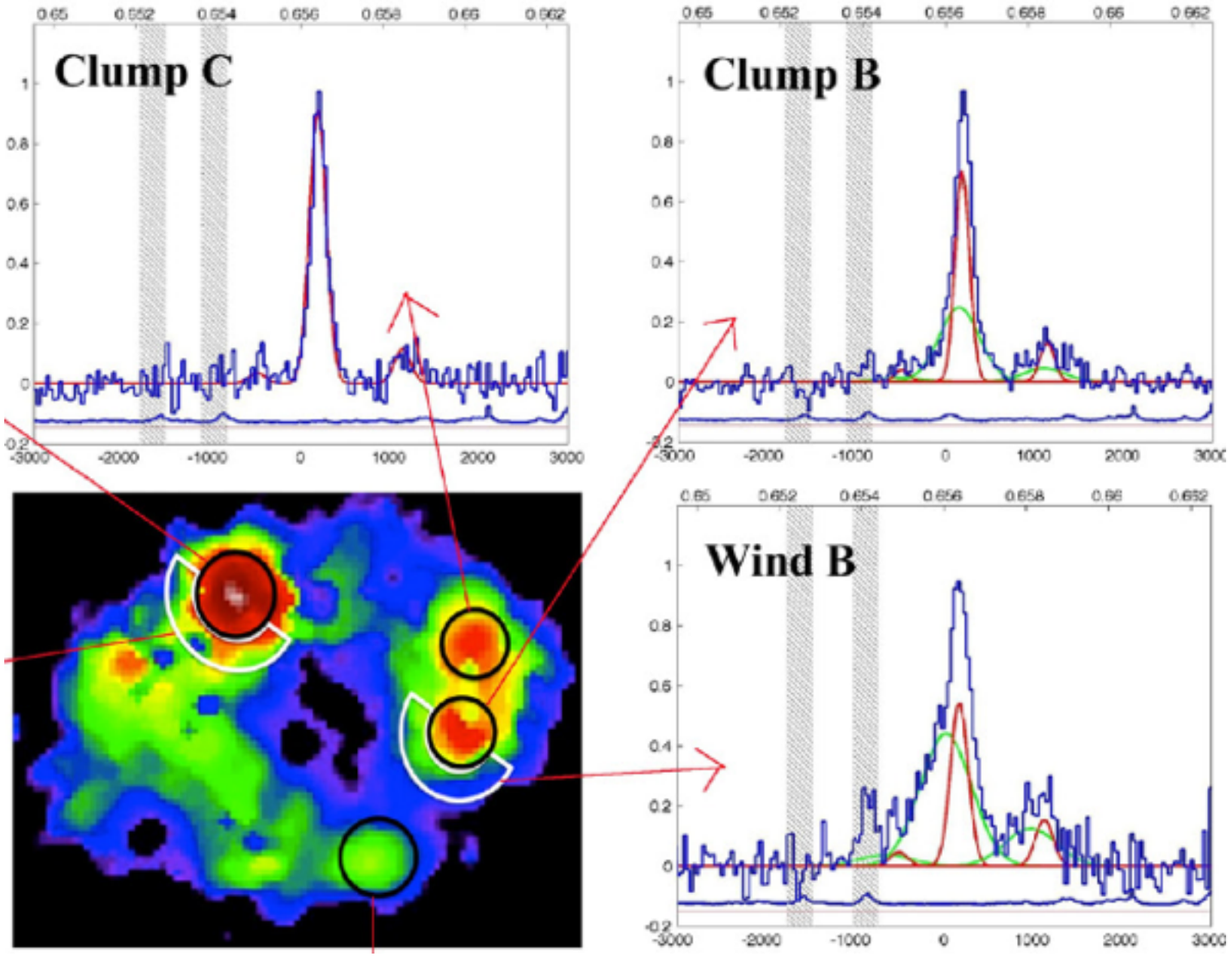
Spectroscopy

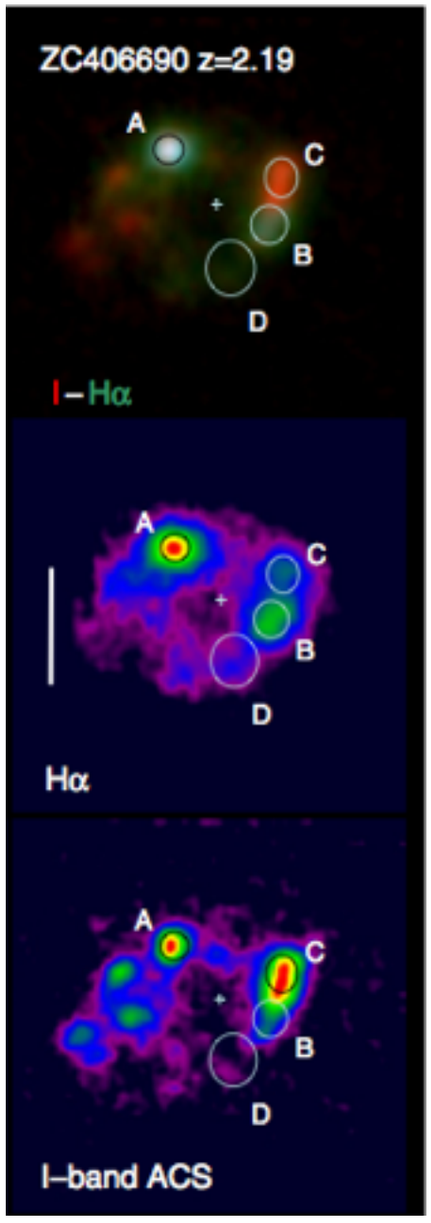
GLAO makes 0.4″slit spectroscopy possible,
spectra depends on the position of slit.
→ IFU is better but …



IFU instrument is not critical ?

Spectroscopy

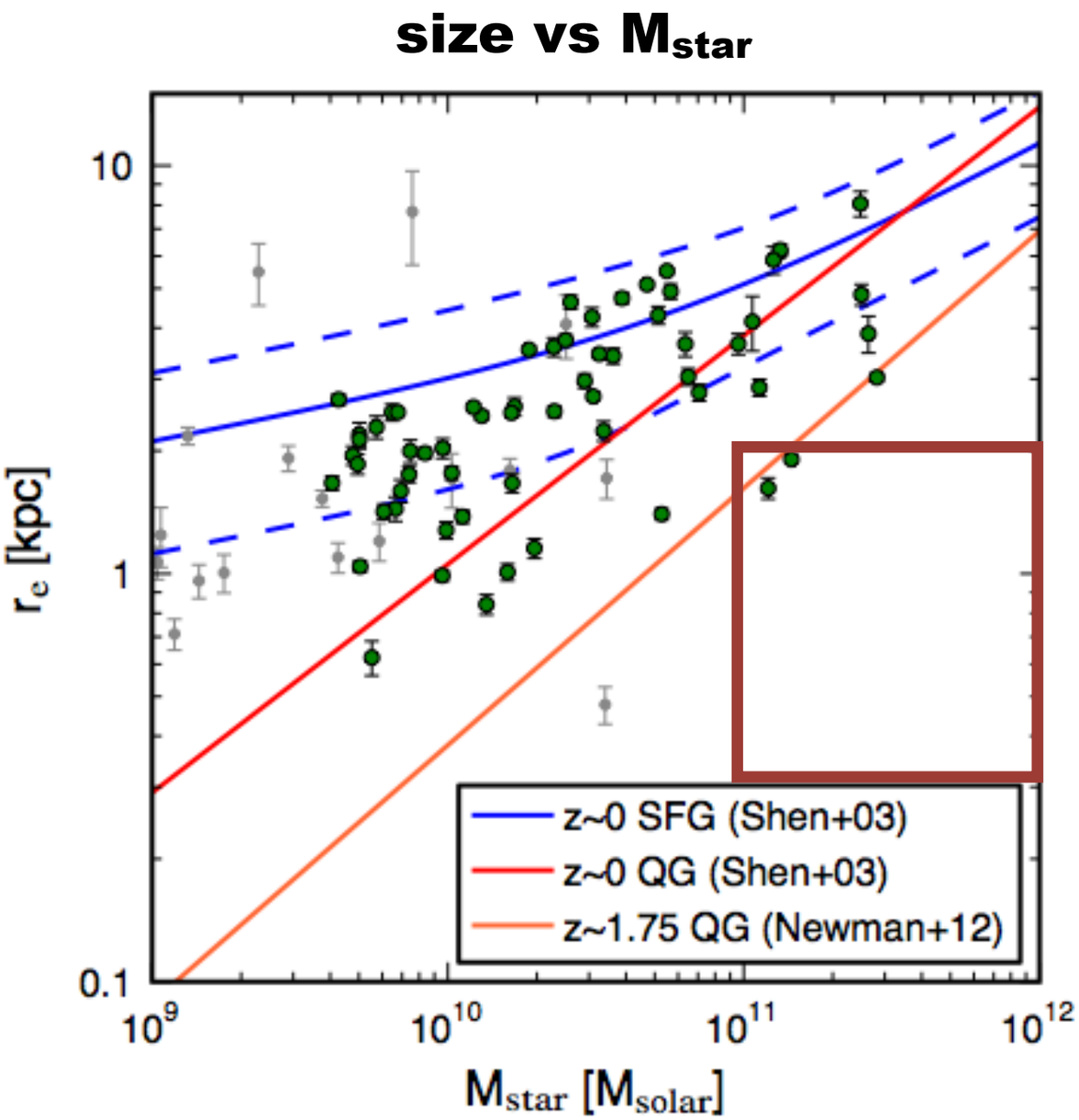


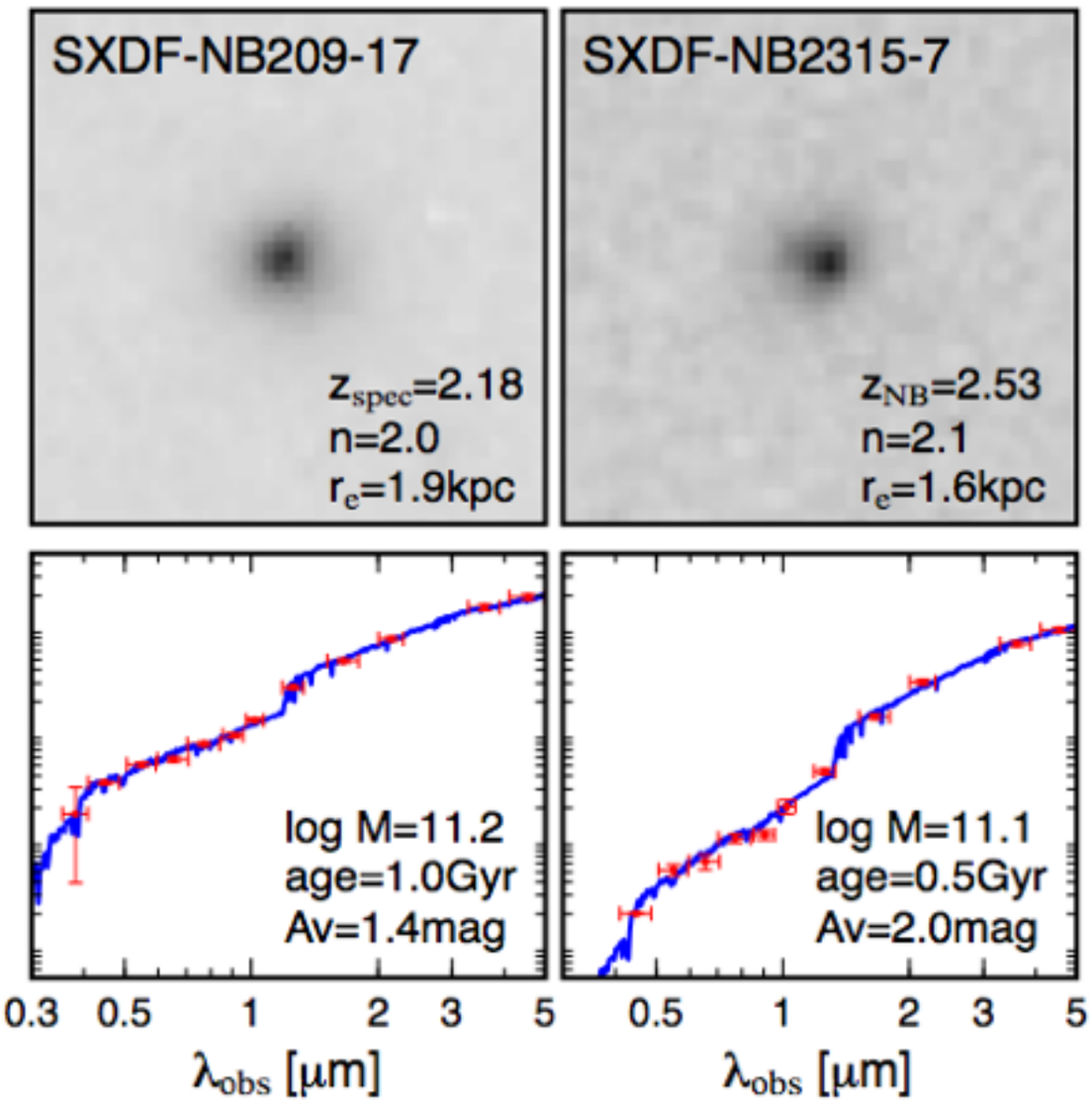


Newman+12, Genzel+11

red clump is AGN or dusty star-forming proto-bulge or old bulge?

Compact Hα emitters

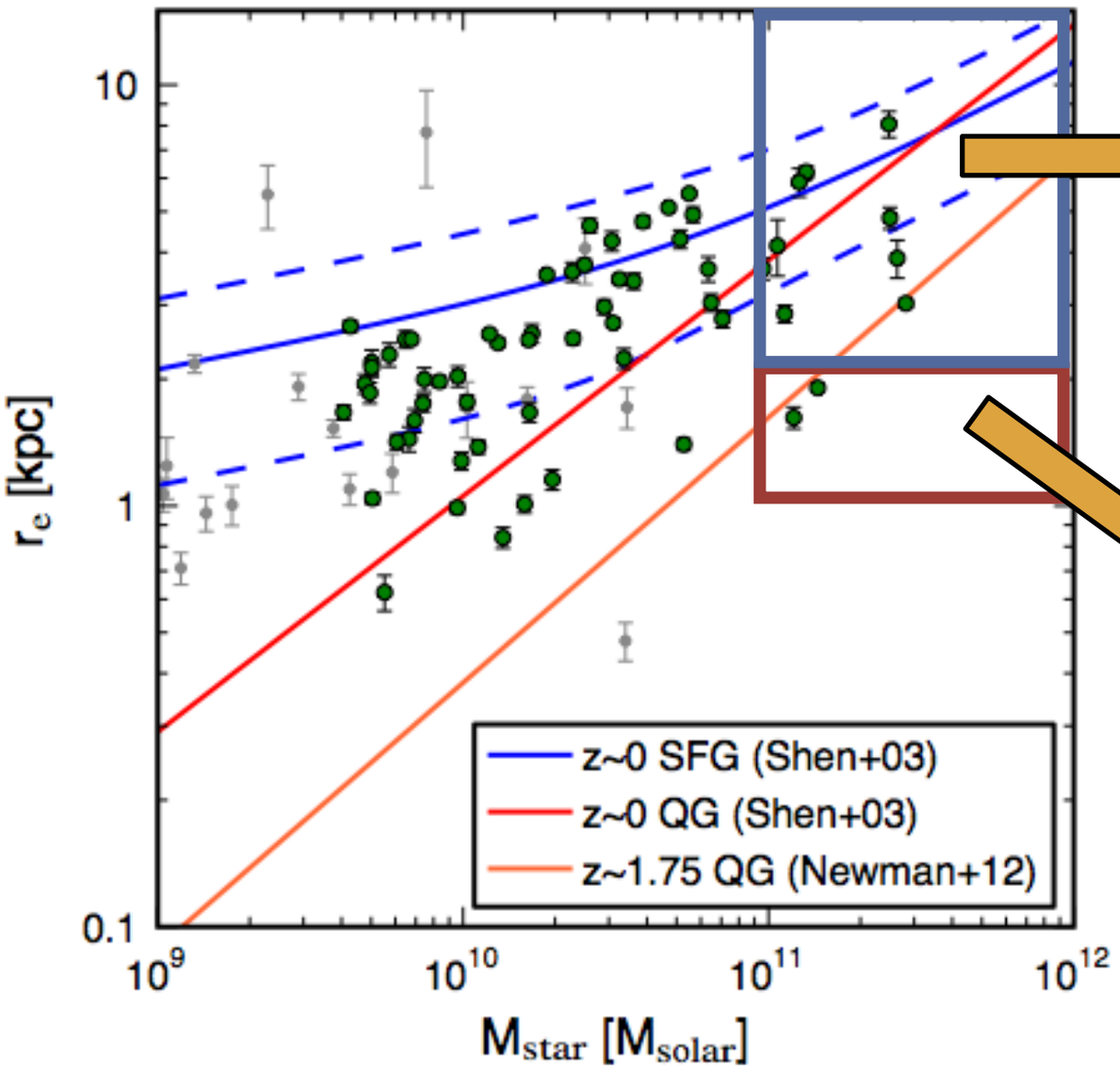




Direct progenitors of compact QGs ?

Compact Hα emitters

What is the difference between compact and extended SFG?



extended disk

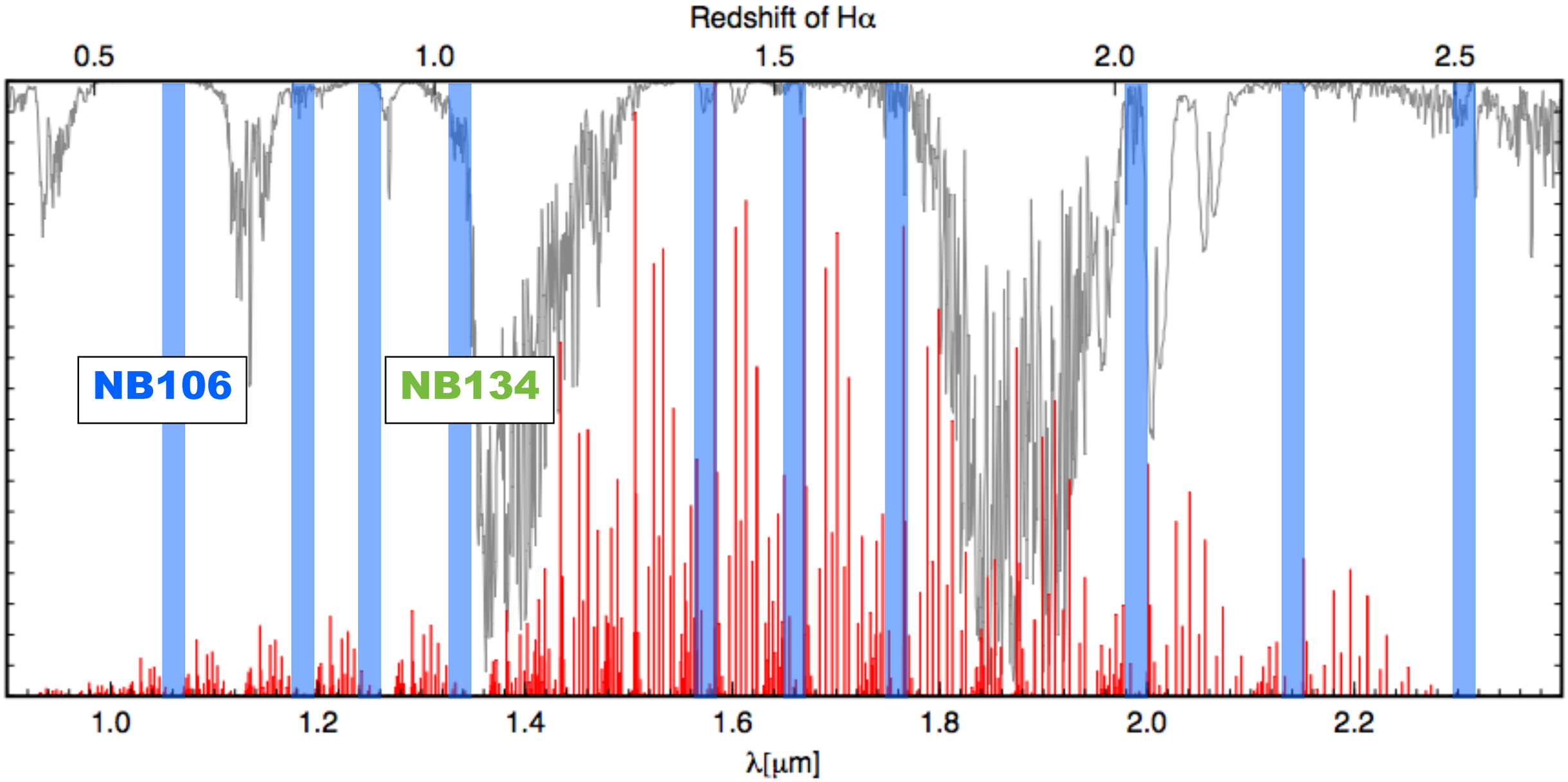
star formation by secular process
rotation-dominated system?

compact SFGs

star formation by gas rich major mergers
dispersion-dominated system?

TMT can spatially resolve compact SFGs.

Proposal : Ultimate NB&spec survey



J-band : z~1 HAE, z>7 LAE, z>2 QG

H-band : z~1.5 HAE

K-band : z~2 HAE

Proposal : Ultimate NB&spec survey

Field : SXDF or COSMOS

1. NB survey in 0.5 degree^2
(1hour) × (10 NB filters/FoV) × (10 FoVs) = 100 hours

2. Slit scan spectroscopy
(2.5 hours×5 scan, R>3000) × (2-band) × (8 masks)= 200 hours

A NB sample of ~10,000 SFGs is constructed.
A spectroscopic sample of ~1,000 SFGs is constructed.

To avoid OH lines, R>3000 is required.

Wider field instrument is better even if FoV splits.

My answers to questions from Iwata-san

Q1. Which instrument is essentially important?

A1. Wide-Field NIR Imager and MOS spectrograph

Q2. What is the optimal plate scale

A2. A scale to identify clumps and compact SFGs (~1kpc) are required. 0.1”/pix seems to be good.

Q3. Can you highlight synergies between this instrument and the TMT

A3. Compact SFGs are good targets for IFU spectroscopy by TMT.

Q4. Does this have competitive capabilities with space mission?

A4. The combination of NB imaging with spectroscopy is unique.