Ultimate-Subaru (or TMT-AGE) and Stellar Dynamics of z~1.0 galaxies

- far-field archaeology -

Masayuki Akiyama (Tohoku Univ.)

Connecting star-formation and resulting stellar mass distribution

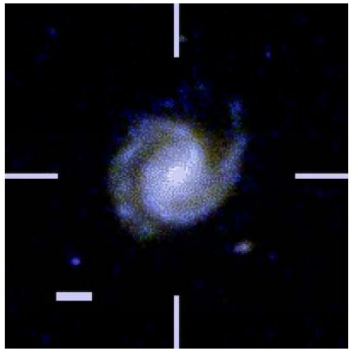
- Understanding the establishment history of "morphological" Hubble sequence in the local universe.

- Connecting star-formation in the high-redshift universe and stellar mass distribution seen in the local universe.

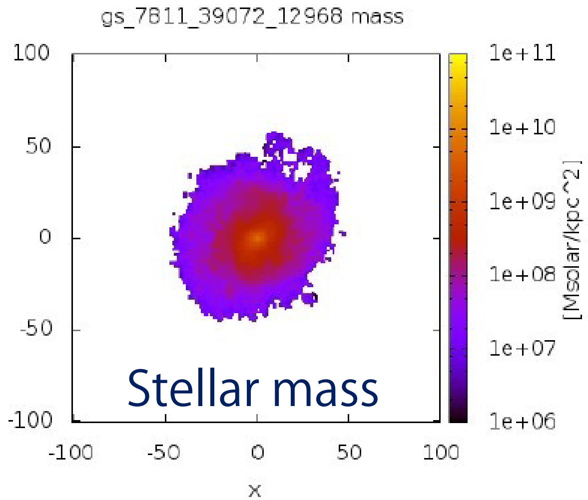
- Step-by-step approach: example : z=0.8-1.3 vs. 1.3-1.8

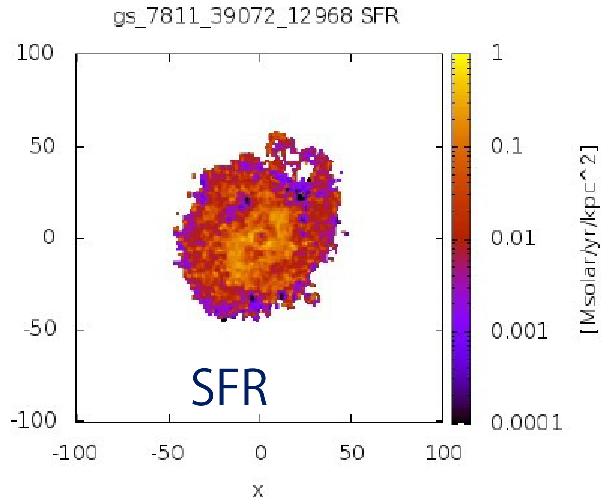
Distribution of stellar mass and SFR of galaxies at z=0.8-1.8 (Masuda master thesis)

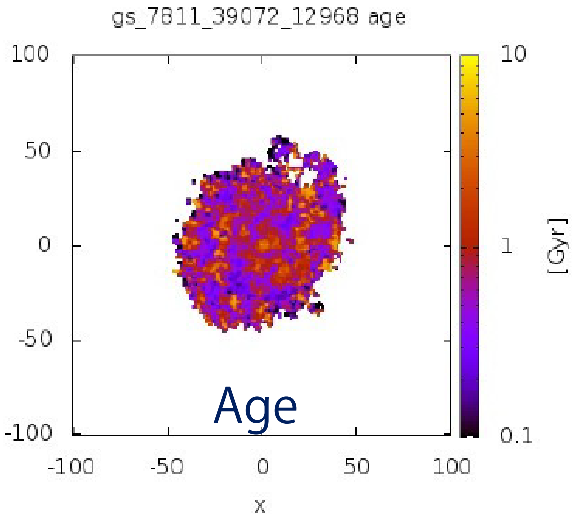
- Derived by pixel-to-pixel SED fitting for CANDELS 8-band HST dataset
- 0.18” FWHM with 0.06” sampling

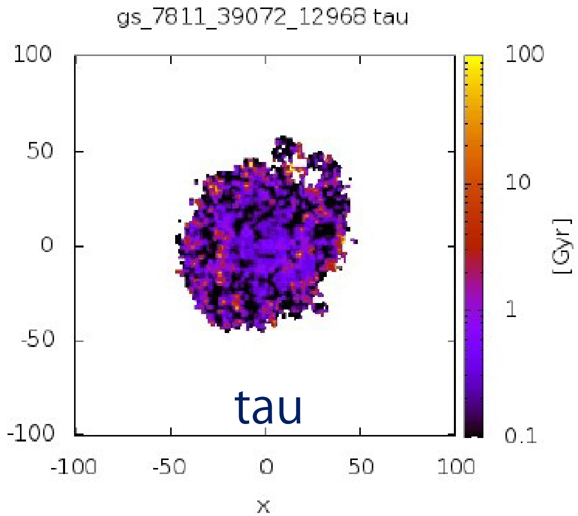


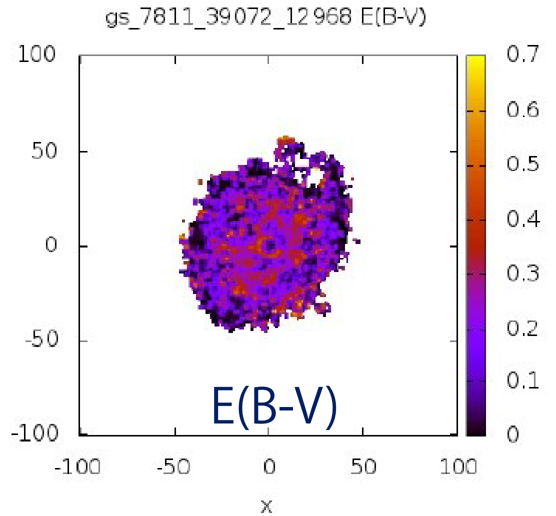
z=1.05, Ms=1.9x10^11Msolar





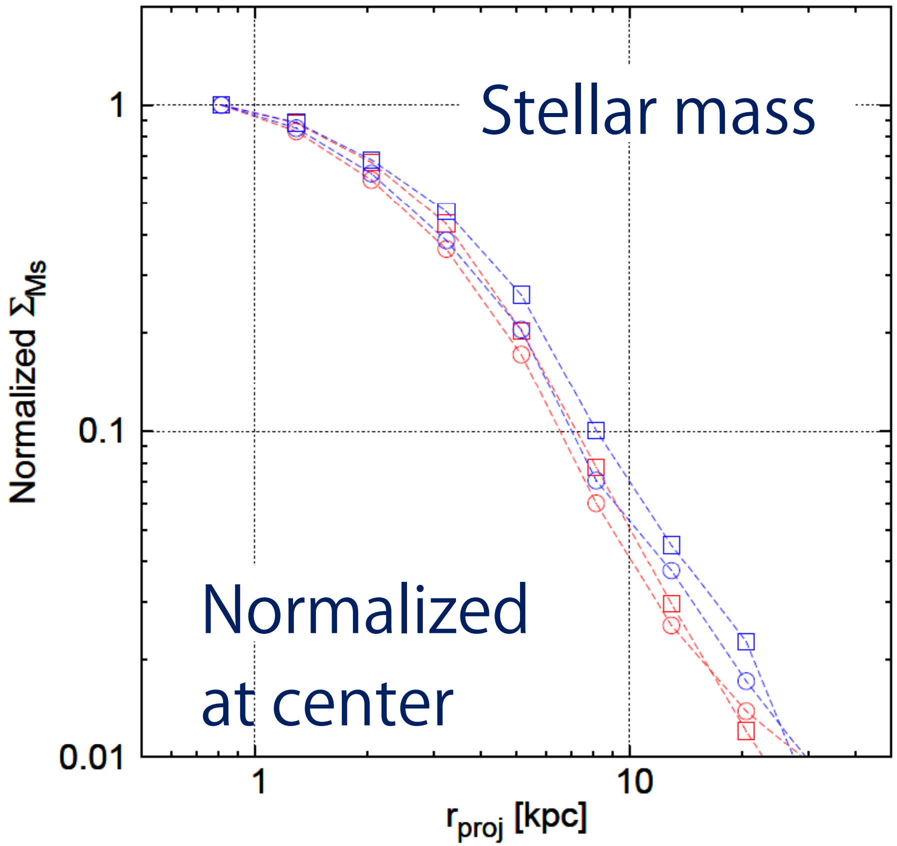


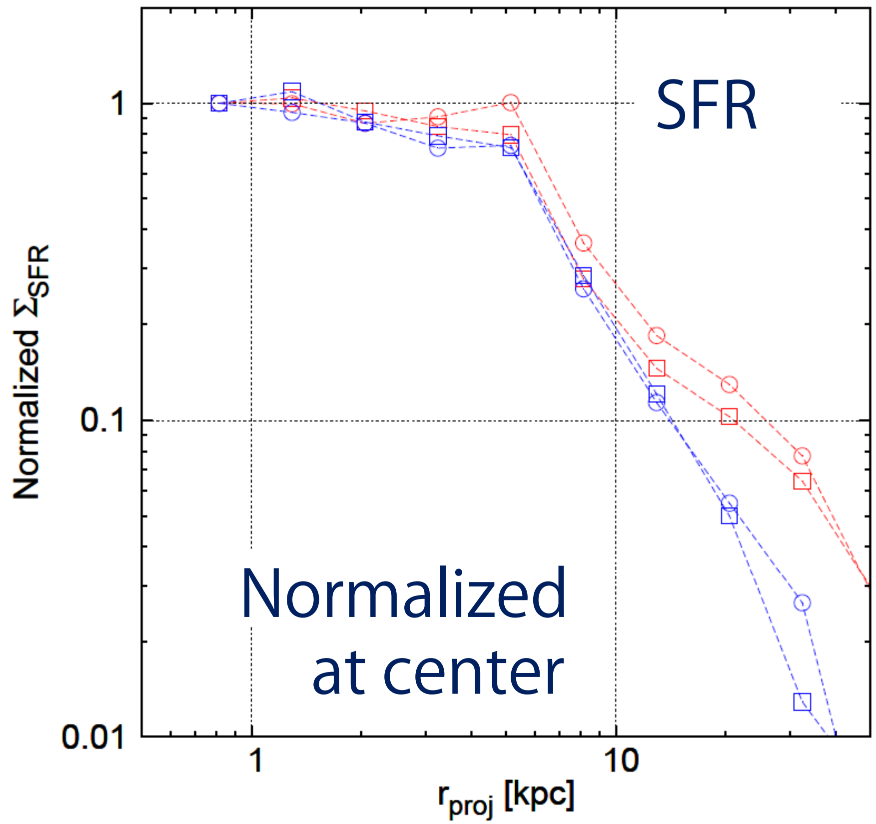




Sum of (projected) SFR and stellar mass profiles

- Samples at z=0.8-1.3 (red) and z=1.3-1.8 (blue)

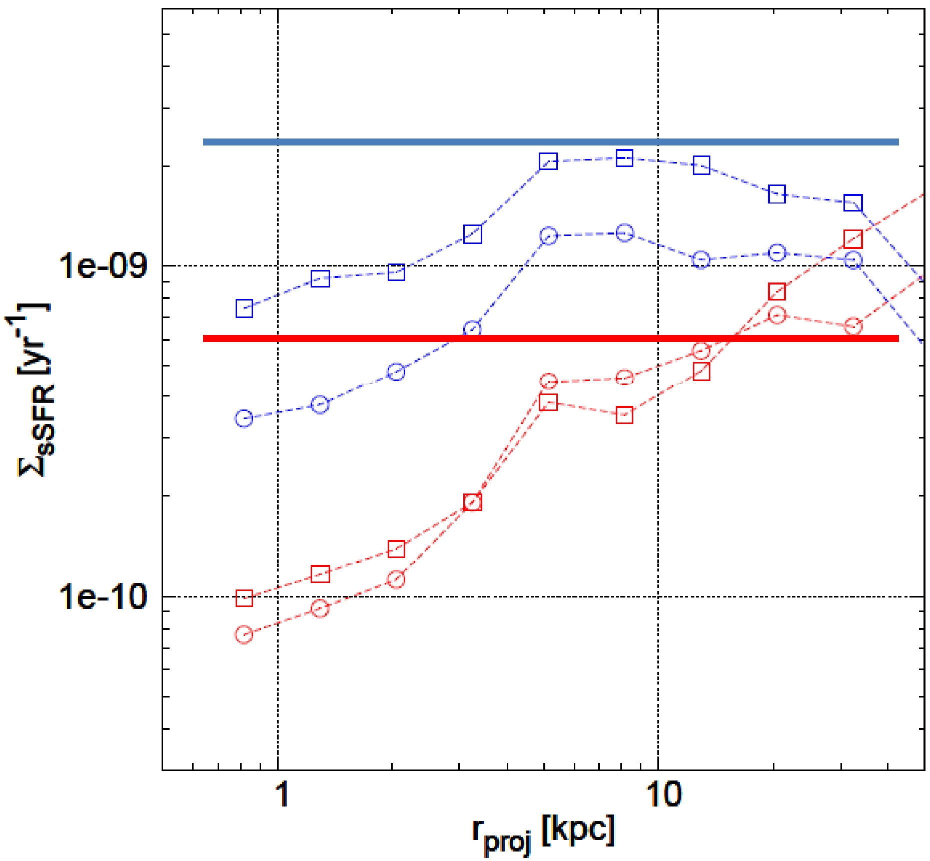




Square: GOODS-N sample
Circle: GOODS-S sample

SFR profile / Ms profile

- Higher specific star formation rate at outer region than that in the inner region in lower redshift.



solid lines:

SF-MS relation in each redshift range

Red: z=0.8-1.3

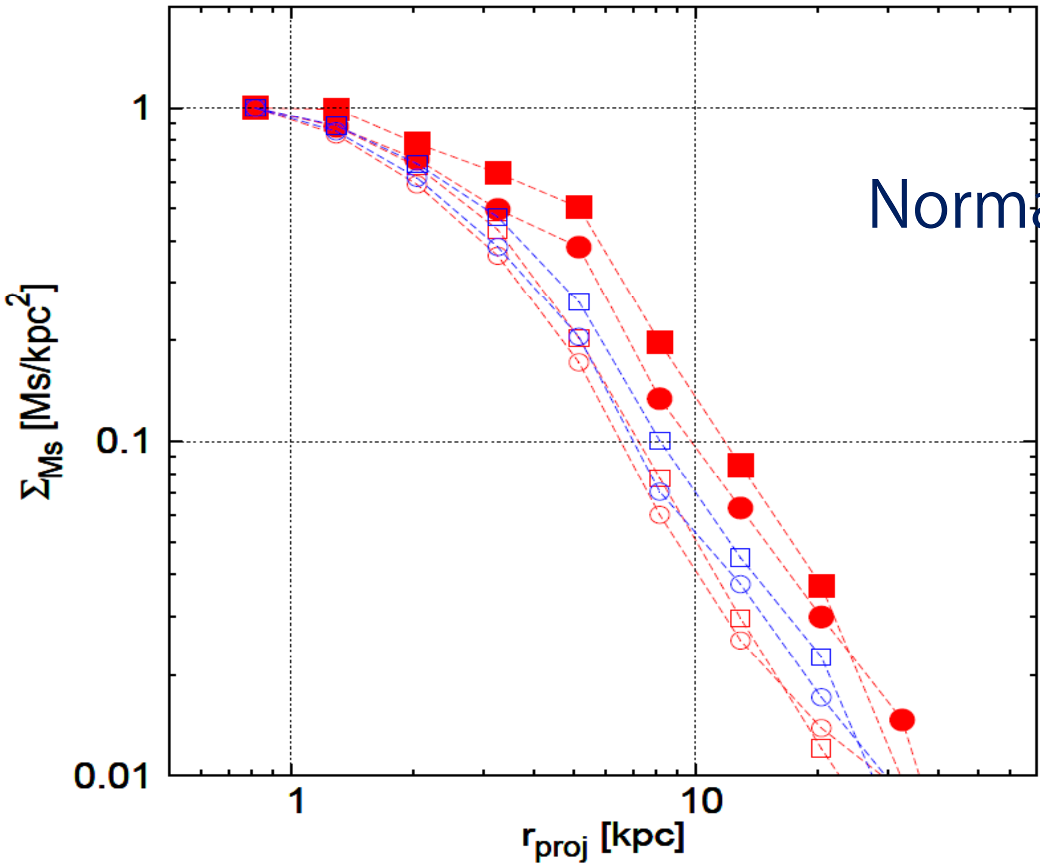
Blue: z=1.3-1.8

Square: GOODS-N

Circle: GOODS-S

Stellar mass profile + SFR profile

- Although stellar mass profile shows higher concentration in the lower redshift range (higher fraction of elliptical galaxy etc.), significant fraction of star-formation is on-going and specific SFR is higher in the outer region.



Normalized

Red: z=0.8-1.3

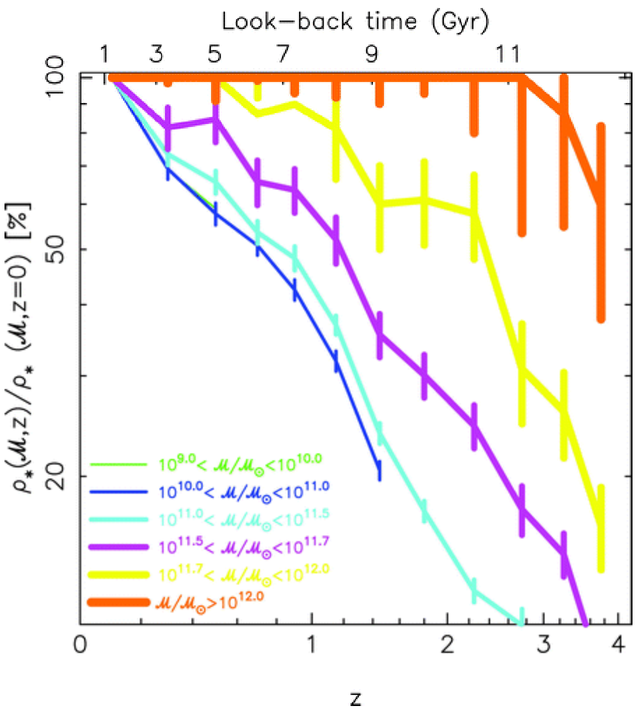
Blue: z=1.3-1.8

Square: GOODS-N

Circle: GOODS-S

Far-field archaeology ?

We would like to know the properties of resulting stellar population made through intensive star-formation at z~1-3, which is dominating stellar mass density in the local universe.



Perez-Gonzalez et al. 2008

star-formation in turbulent gas disks at z~1-2

Forster-Schreiber et al. 2009

high surface density disks ?

Akiyama et al. 2008

bar-like structure ?

Yuma et al. 2011, 2012

elliptical / disk galaxies at z~0

Far-field archaeology ?

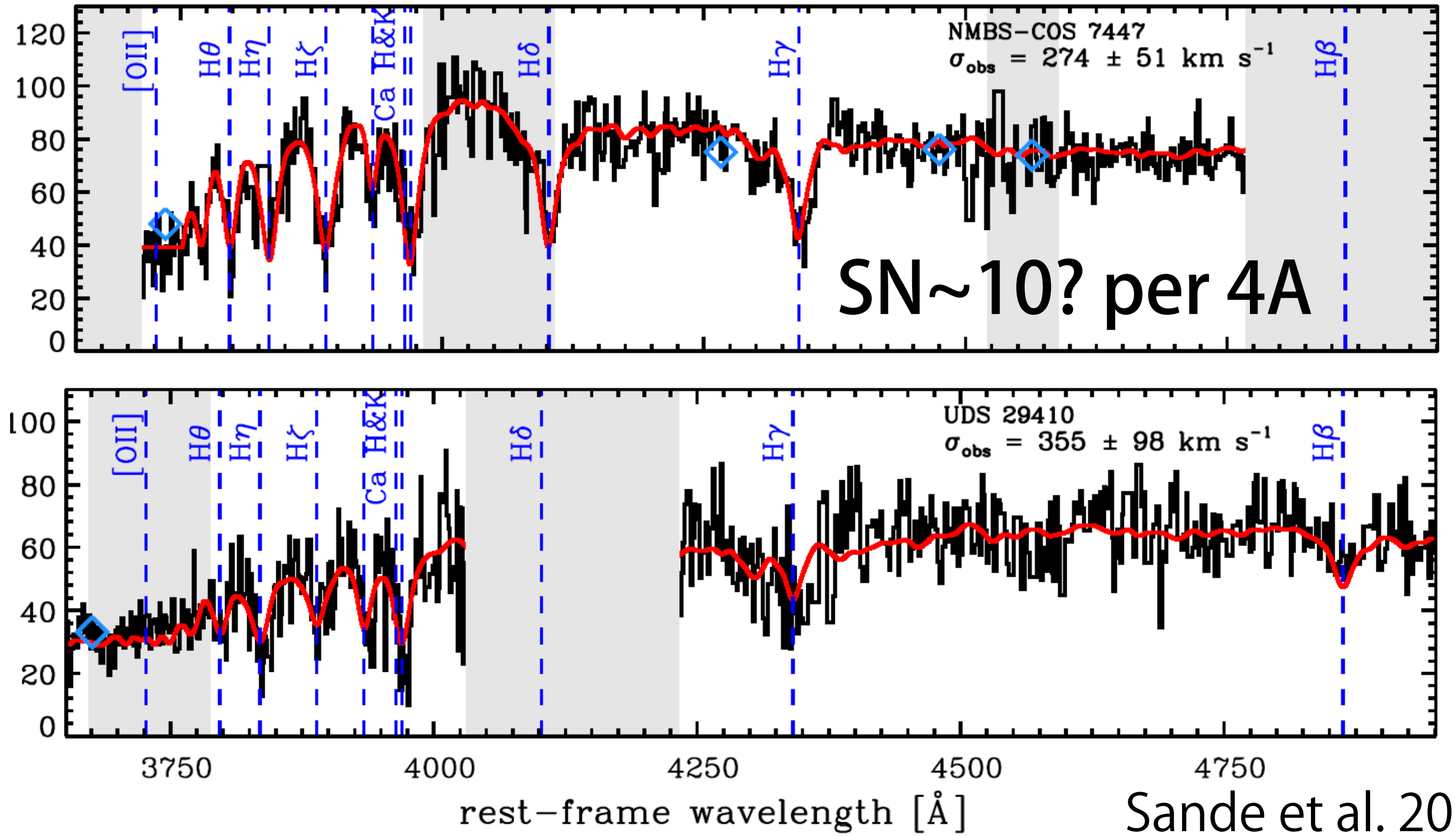
- Measure stellar dynamics (rotation curve and velocity dispersion) of z~1-2 (disk) galaxies with absorption line, and conduct far-field archaeology.
- In order to resolve disk – bulge regions of z~1-2 galaxies, 0.1-0.2" resolution is necessary.
- In order to measure velocity dispersion of disk galaxies, 10 km/s accuracy is necessary. Require high spectral resolution (R~5,000-10,000?) and high SN.

	h_z(kpc)	σ_R(km/s)	σ_z(km/s)	$\langle V\phi \rangle$(km/s)
Thin disk	~0.3	34	18	~220
Thick disk	~1.0	61	39	~200

MW galaxy disk structure (Chiba 2014)

Stellar kinematics of z~2 quiescent massive galaxies

- Integrated stellar kinematics of quiescent massive galaxies at z~2.
- X-shooter 0.9″ slit with R=5100 @ 1.4um, 2hour integ. K=19.6, K=19.3



Sande et al. 2013

Figure 4. Rest-frame optical part of the spectrum focused on the Balmer break. As in Figure 3, the X-Shooter spectrum is shown in black, but this time in higher resolution (~4 Å observed, or ~100 km s^{-1} rest frame). The most prominent absorption and emission features are indicated by the blue dashed lines. The clear detection of absorption lines enables us to measure stellar velocity dispersions. We use pPXF to fit the best-fitting BC03 τ-model to the spectrum and find velocity dispersions that range from 275 to 435 km s^{-1}. The convolved best-fit BC03 template is shown in red.

0.2″x0.2″ detection limit : observational

	Cont. (Abmag)	Line (erg/s/cm2)
I-band (760)	25.38	5.5e-19
Y-band (998)	24.90	5.0e-19
J-band (1250)	24.85	3.3e-19
H-band (1650)	24.95	2.3e-19
K-band (2200)	25.05	1.6e-19

- Limits for SN=10 in 10hour (15min x 40) observation with R=3,000 and RON=1.0 e-. 0.2″ area is sampled with 3 pixels and SN is for 0.2″ area. Observation between strong OH lines.Total throughput=0.22
- Continuum limit : per resolution element (lambda/3000), each resolution elements are sampled with 3 pixels. Per 0.2″x0.2″.
- Line flux limit: assumed the line is not resolved with R=3,000. Per 0.2″x0.2″.

0.2"x0.2" detection limit : Ha line

	Ha Redshift	Size (kpc/0.2")	LHa (erg/s/kpc2)	SFR (Ms/yr/kpc2)
J-band (1250)	0.9	1.56	0.5e+39	0.004
H-band (1650)	1.5	1.69	1.1e+39	0.009
K-band (2200)	2.4	1.63	2.7e+39	0.020

– Ha – SFR relation (Kennicutt et al. 1994) SFR=Lha/1.26e+41

0.2″x0.2″ detection limit : 4000A break

	4000 A Redshift	Size (kpc/0.2″)	Ms (Ms/kpc2)
I-band (760)	0.9	1.56	2.7e+8
Y-band (998)	1.5	1.69	6.7e+8
J-band (1250)	2.1	1.66	1.8e+9
H-band (1650)	3.1	1.53	4.1e+9
K-band (2200)	4.5	1.32	8.7e+9

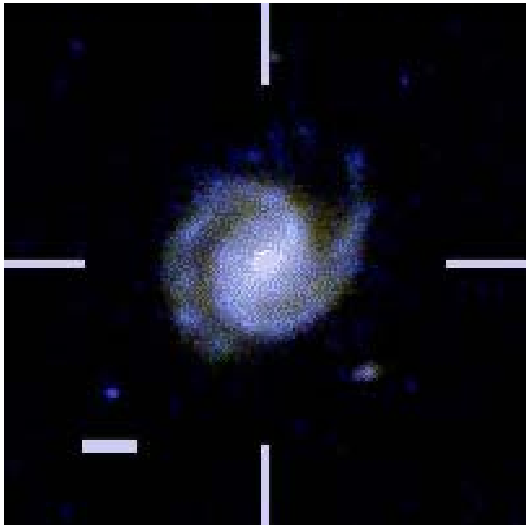
- Stellar mass vs. Magnitude relation for 1Gyr stellar population with no extinction with PEGASE
  - 1Ms I-band 47.44 @ z=0.9
  - 1Ms J-band 48.11 @ z=1.5
  - 1Ms J-band 49.09 @ z=2.1
  - 1Ms H-band 49.89 @ z=3.1
  - 1Ms K-band 50.50 @ z=4.5

0.2"x0.2" detection limit : with TMT

	Cont. (Abmag)	Line (erg/s/cm2)
J-band (1250)	26.40	0.8e-19
H-band (1650)	26.53	0.5e-19
K-band (2200)	26.68	0.4e-19

- 1.5 mag or 4 times deeper than ULTIMATE-Subaru.
- Limits for SN=10 in 10hour (15min x 40) observation with R=3,000 and RON=1.0. 0.2x0.2" area is sampled with 3x3 pixels and SN is for 0.2x0.2" area. Observation between strong OH lines.Total throughput=0.22
- Continuum limit : per resolution element (lambda/3000), each resolution elements are sampled with 3 pixels. Per 0.2"x0.2".
- Line flux limit: assumed the line is not resolved with R=3,000. Per 0.2"x0.2".

Massive galaxy at z~1.0

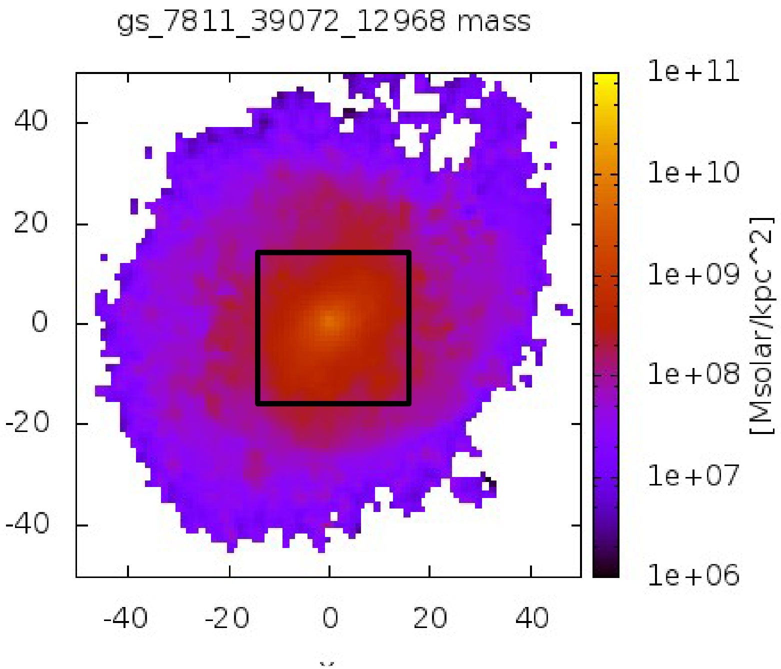


z=1.05, Ms=1.9x10^11Msolar galaxy

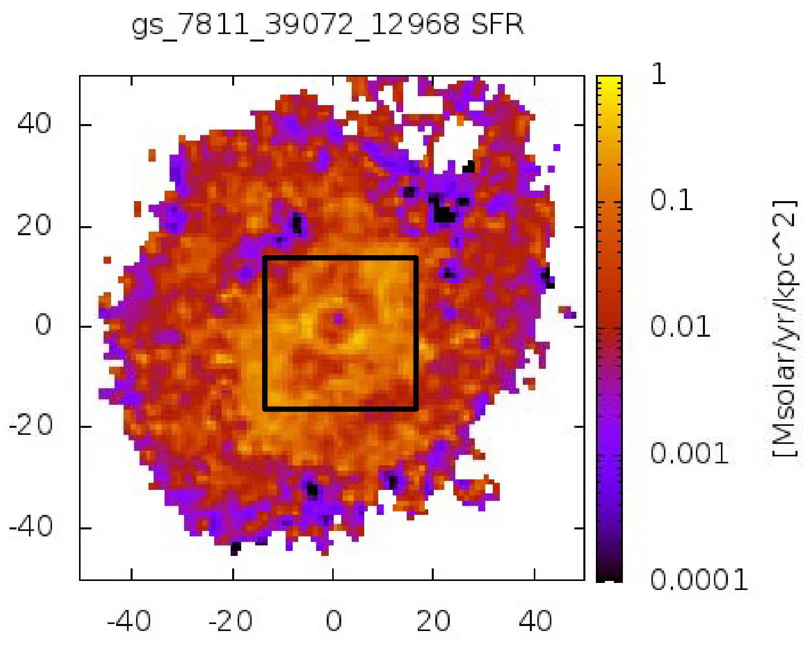
0.06″ pixel map with FWHM=0.18″ (HST H-band FWHM) 100x100 pixel = 6″ x 6″

Left) Stellar mass map, Right) SFR density map, square indicate 2″ FoV

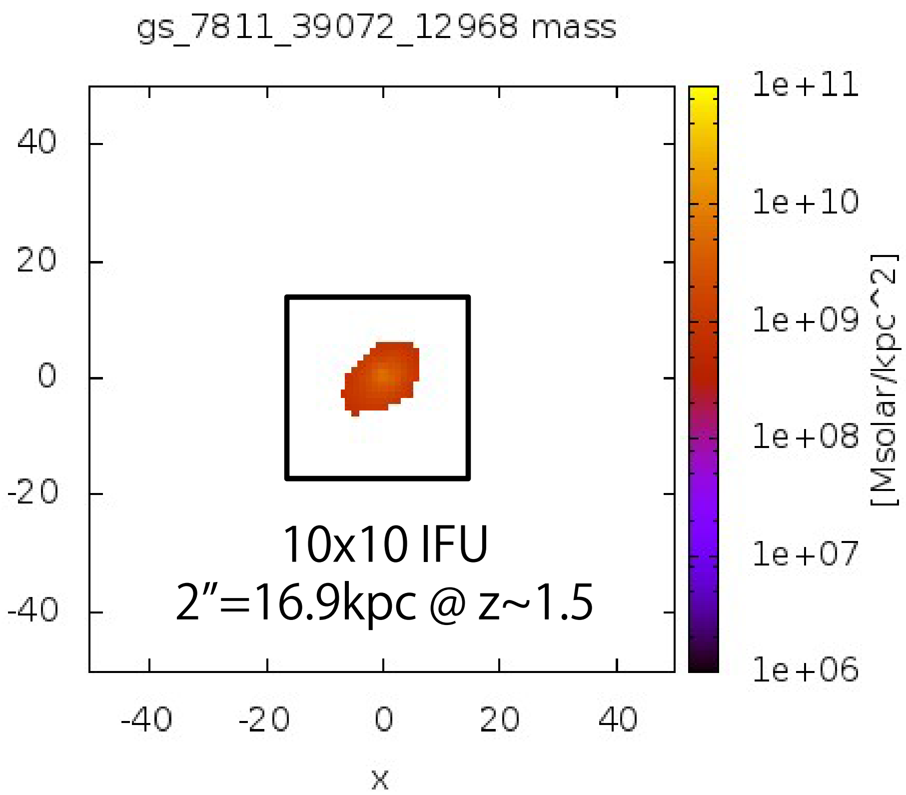
Stellar mass distribution

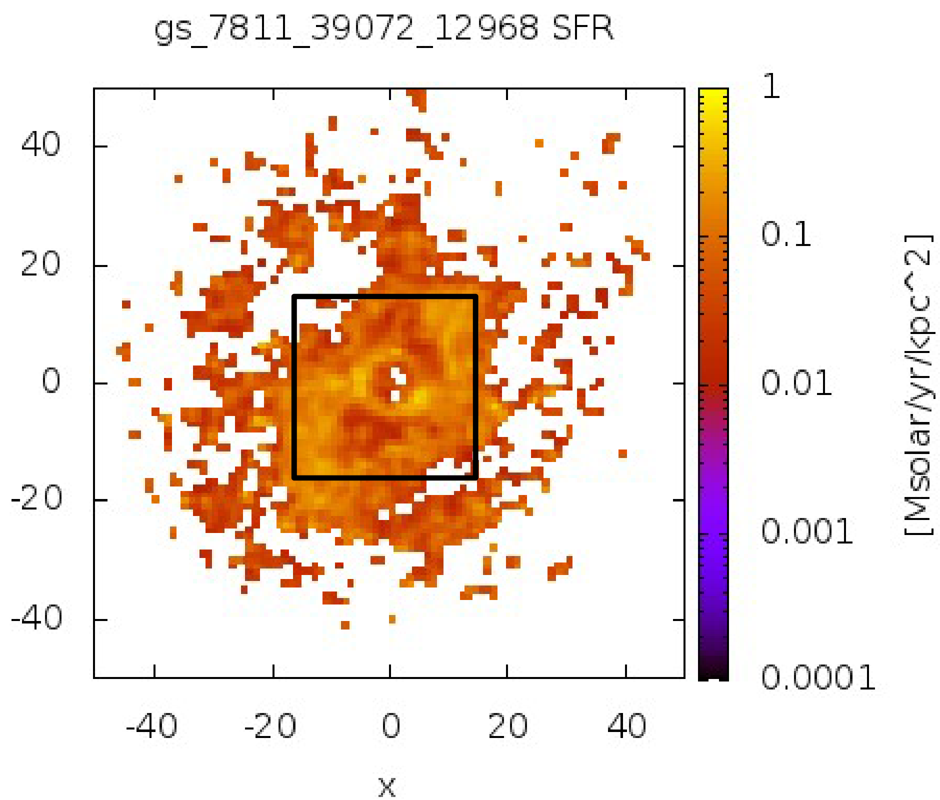


Star-formation rate distribution



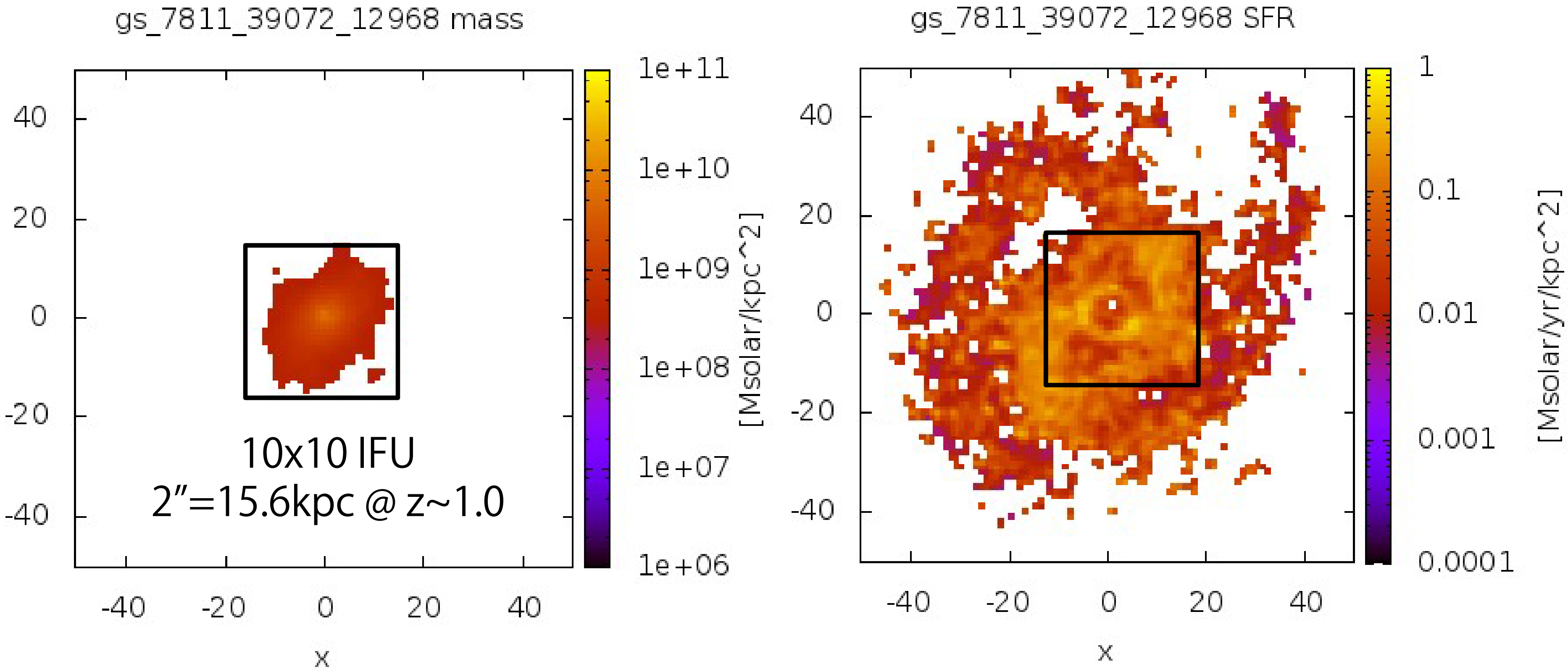
Region above z~1.5 10h detection limit: Ultimate-Subaru with 0.2″ resolution





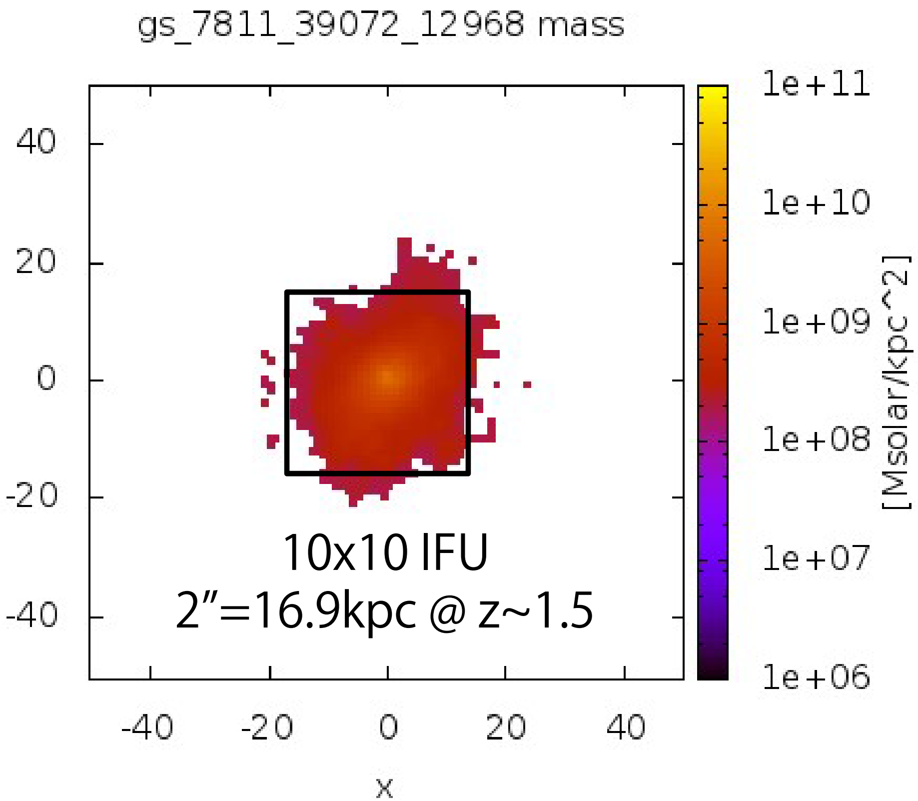
0.2″ corresponds to 3pixels

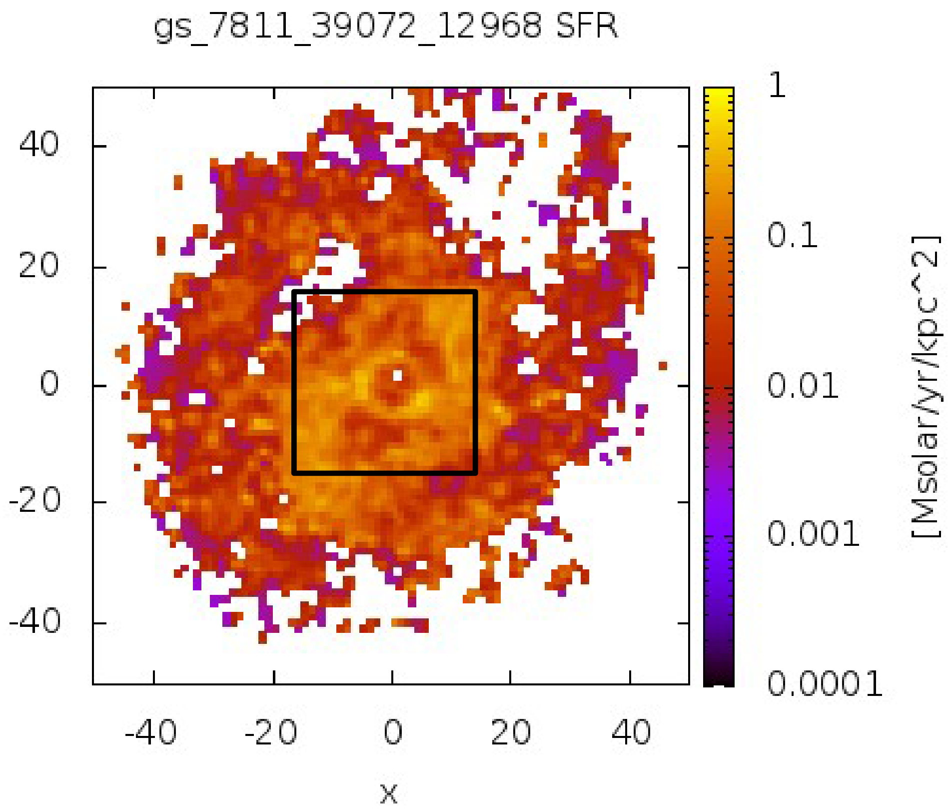
Region above z~1.0 10h detection limit
Ultimate-Subaru with 0.2″ resolution



0.2″ corresponds to 3pixels

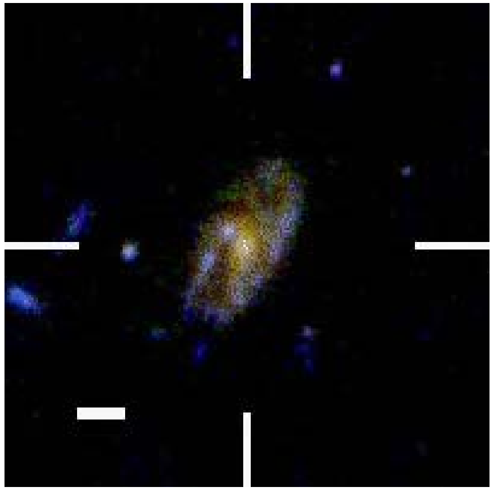
Region above z~1.5 10h detection limit
TMT-AGE with 0.2″ resolution





0.2″ corresponds to 3pixels

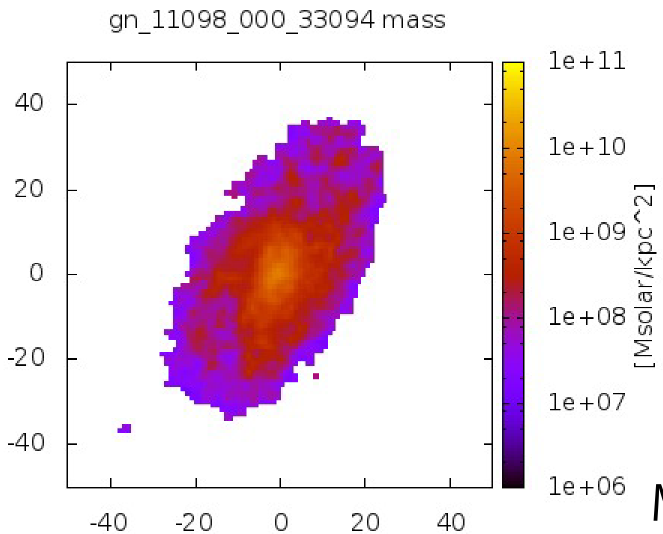
Another Massive Galaxy at z=1.3



A galaxy at z=1.3 with Ms=2.3x10^11 Msolar

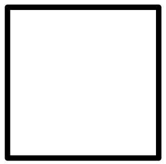
0.06" pixel map with FWHM=0.18" (HST H-band FWHM)

<u>Stellar mass distribution</u>



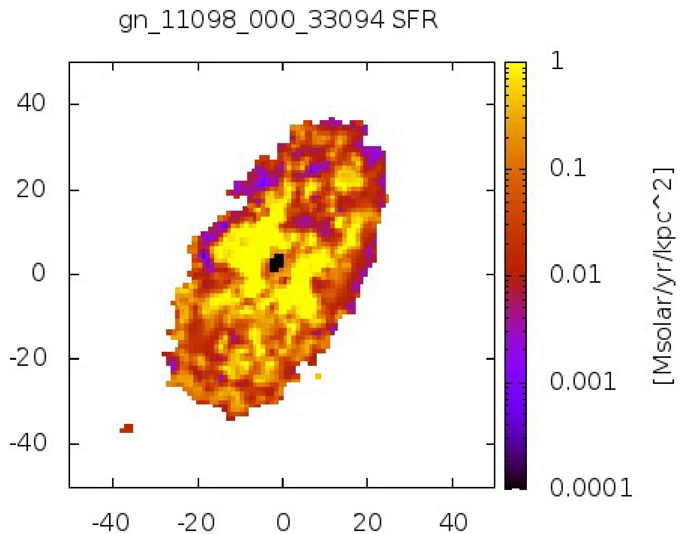
100x100 = 6"x6"

2" FoV



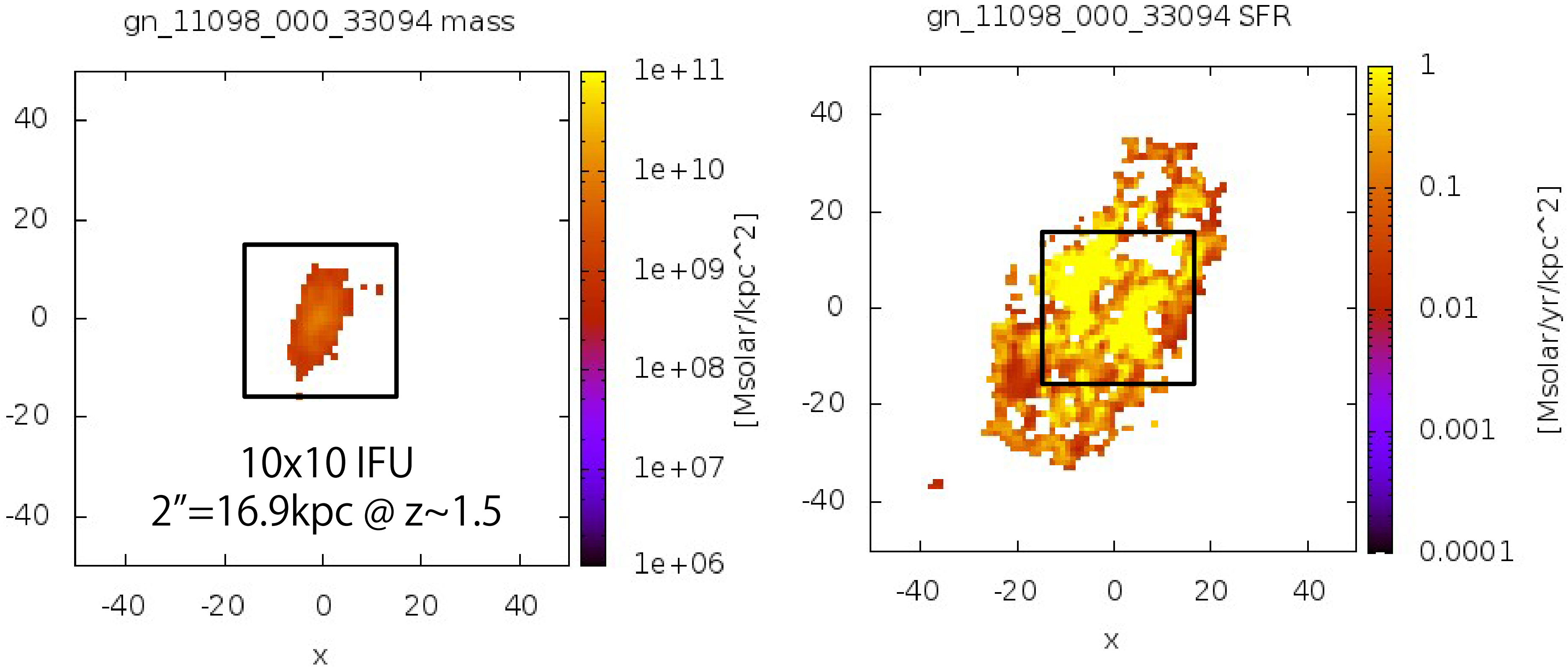
Masuda 2014
Master Thesis

<u>Star-formation rate distribution</u>



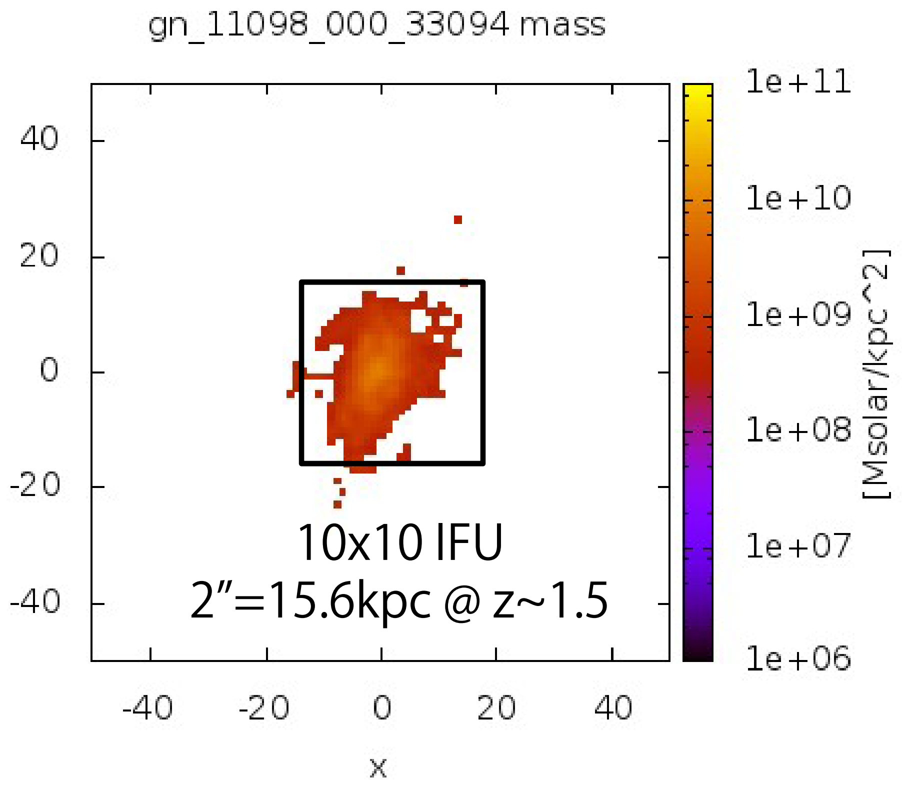
100x100 = 6"x6"

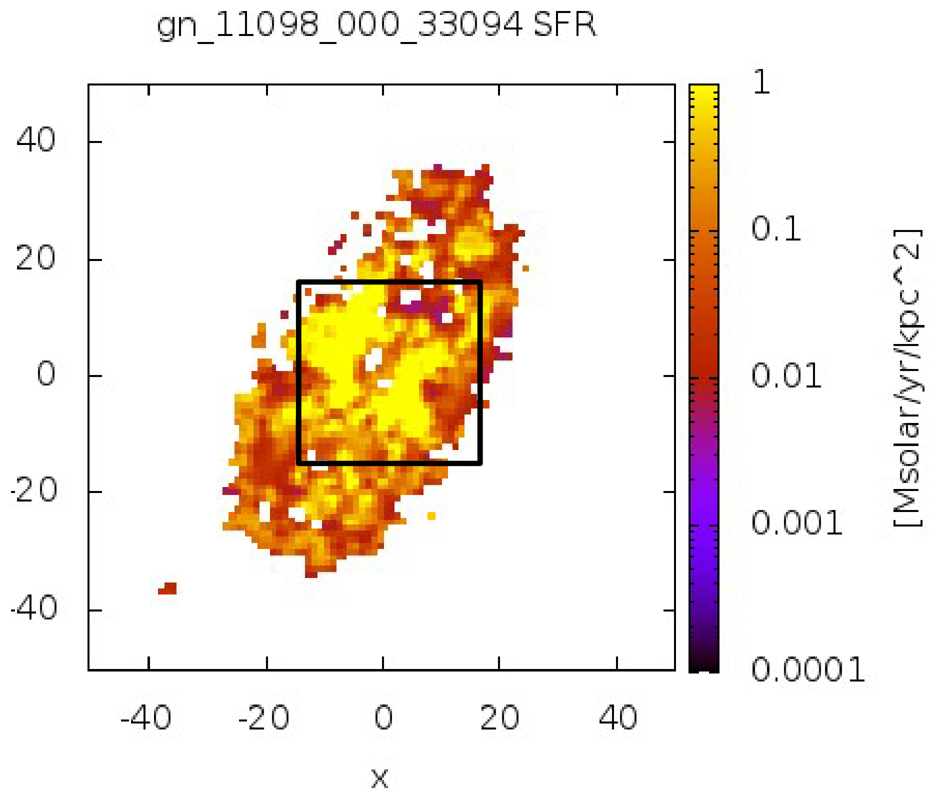
Region above z~1.5 10h detection limit
Ultimate-Subaru with 0.2" resolution



0.2" corresponds to 3pixels

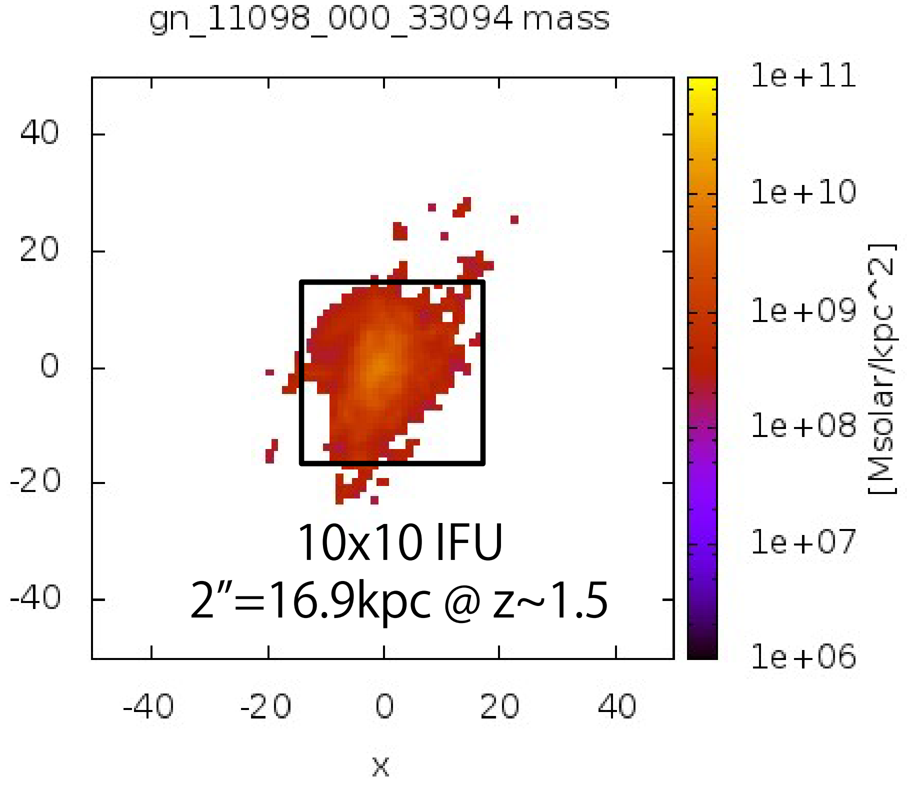
Region above z~1.0 10h detection limit
Ultimate-Subaru with 0.2″ resolution

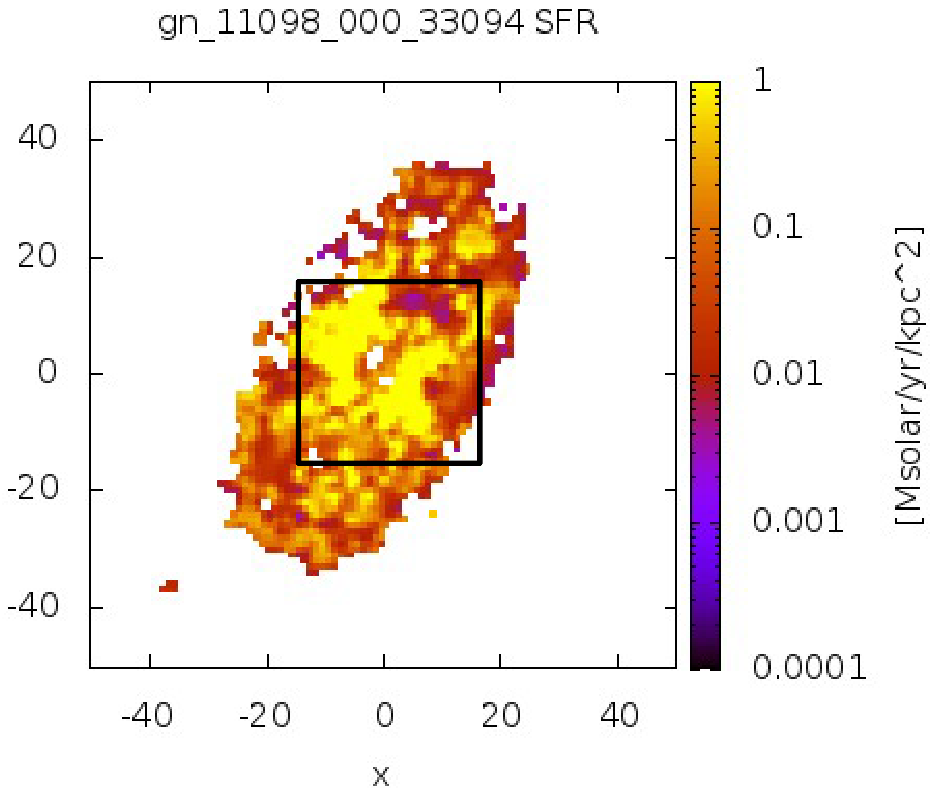




0.2″ corresponds to 3pixels

Above z~1.5 10h detection limit
TMT-AGE with 0.2" resolution





0.2" corresponds to 3pixels

Summary 1

Q1) What is the optimum spatial sampling and FoV of the bundle ?

- In order to achieve good SN, relatively low spatial sampling of 0.2" is fine.
- Size of the region above the detection limits is as large as 2.0". 1.8" FoV is preferred.

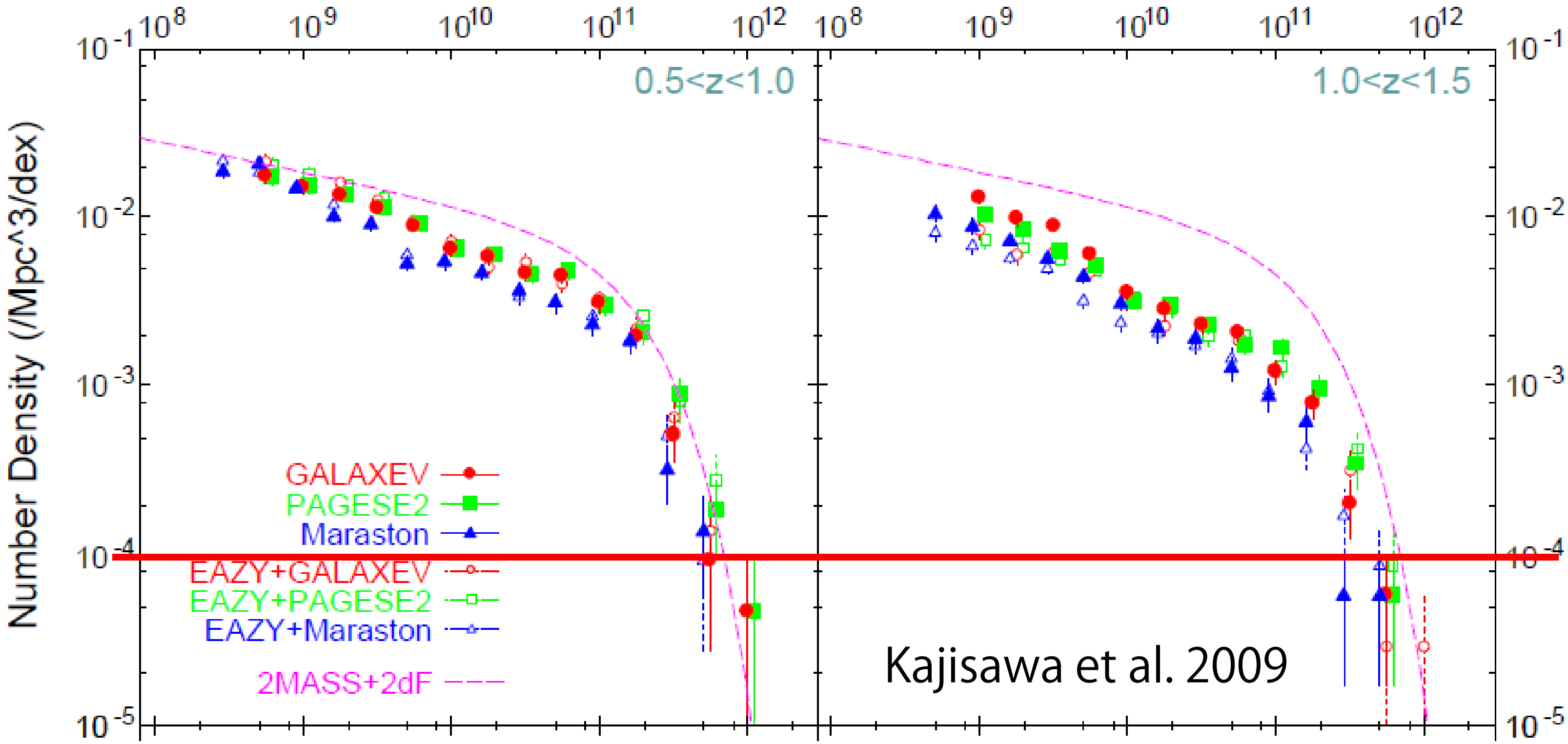
Q3) What is the critical wavelength range in near-infrared covered by the Starbug system ?

- 0.7-0.9um (red-optical) 1.15-1.35um (J)
- 4000A at z=0.75-1.25 in red-optical
- 3750A-4500A needs to be covered ?
- Ha at z=0.75-1.06 in J
- Hb at 8506A (z=0.75) – 10014A (z=1.06) (9500A, z=0.95)

Summary 2

Q2) What is the optimum and minimum number of the fiber bundles in the 13.6′ diameter FoV ?

- z=0.75-1.06 : 9.2e+4 Mpc3 -> 10 obj. : 1.1e-4 /Mpc3
- Trade-off between width of wavelength coverage and number of objects in FoV.



Summary 3

Q4) What is the optimum spectral resolution

- R~5,000-10,000?
- Trade-off between continuum SN, OH-line subtraction accuracy, and accuracy of velocity measurements.

Q5) What is the sensitivity requirement for the phase-I instrument ?

- Currently total throughput of 0.22 with RON of 1.0e is assumed.
- Total throughput of MUSE: 0.35 @ 7000A with RON of 2.3e (full-depletion CCD).

Summary 4

Q6) Describe a brief observation plan for your science case

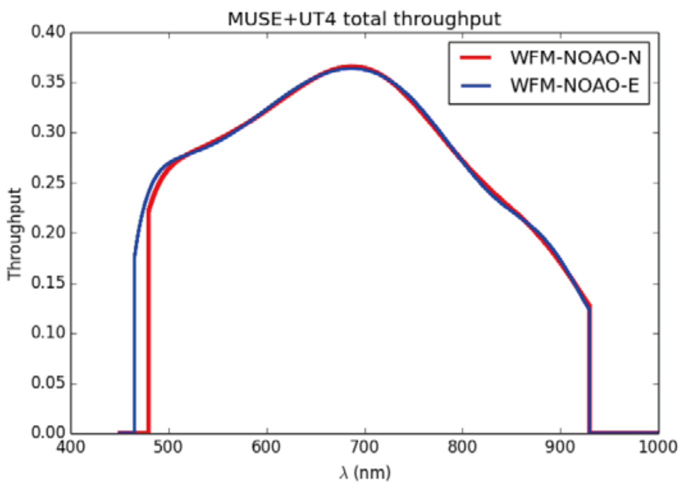
– >100 massive galaxies with 10h integration

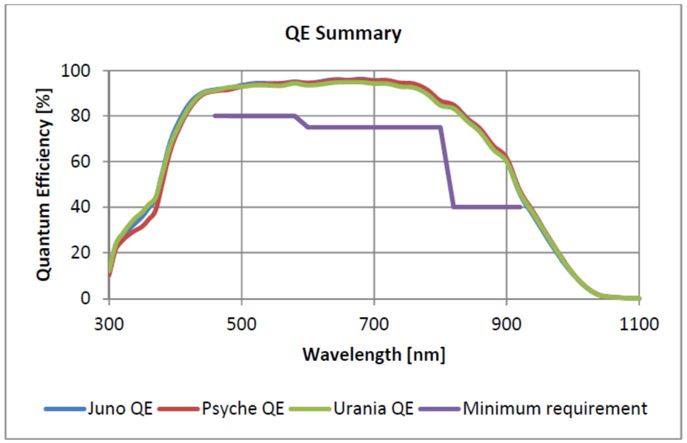
– VLT/KMOS follow-up for Ha emission line ?

Q7) How could the proposed science cases be competitive or complementary to the science with 30m class telescopes or space telescopes in 2020s ?

– The combination of high-spectral resolution (R~5,000-10,000), low-spatial resolution (0.2"), and short-wavelength range (<1um) can be unique.

– VLT/MUSE with adaptive 2ry ??





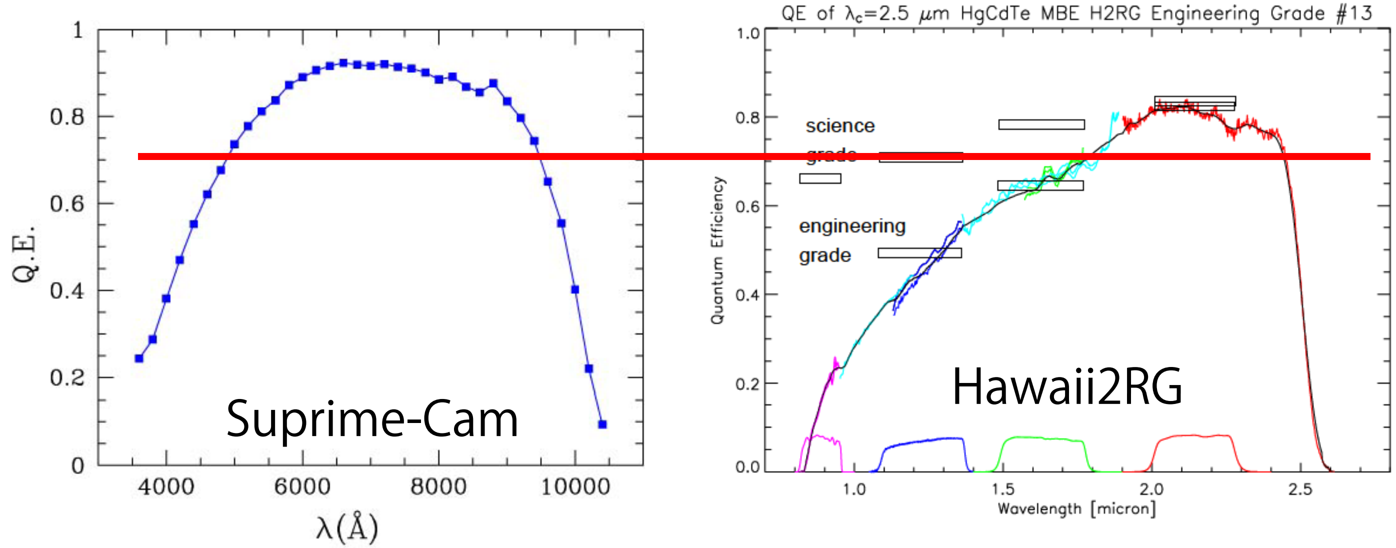
Summary 5

Q8) Please describe the requirements for Phase-II instrument to develop your science case.

– Feeding to optical moderately-high dispersion spectrograph even from Phase-I is necessary.

Q9) What is the unique point of the fiber bundle multi-object IFU with Starbugs compared to the imager or multi-object slit spectrograph ?

– Bench-mount optical spectrograph is relatively "easy" to be build.



MW archaeology

Halo + Bulge + Thin and Thick disks
MW: Mbulge~2x10^10Ms and Mdisk~6x10^10Ms

	h_z(kpc)	σ_R(km/s)	σ_z(km/s)	<Vϕ>(km/s)
Thin disk	~0.3	34	18	~220
Thick disk	~1.0	61	39	~200

MW galaxy disk structure
Young thin disk – Old (>10Gyr) thick disk
(from Chiba 2014 summary)