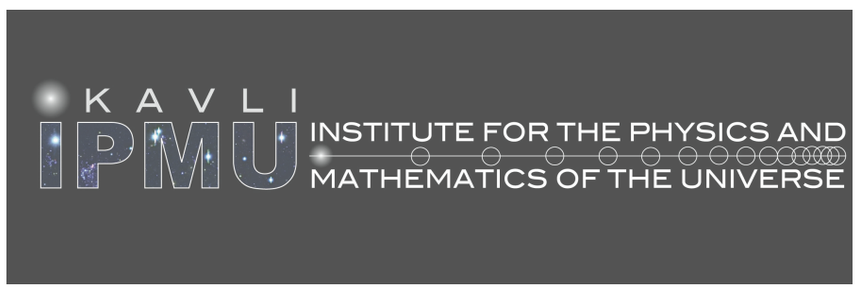
Rest-frame optical emission lines properties of high-z galaxies in different environments

John Silverman

Kavli IPMU

including the FMOS-COSMOS project



What are the drivers behind the formation and evolution of galaxies?

Internal

Dynamical instabilities

Supernova

AGN

stellar winds

gas exhaustion

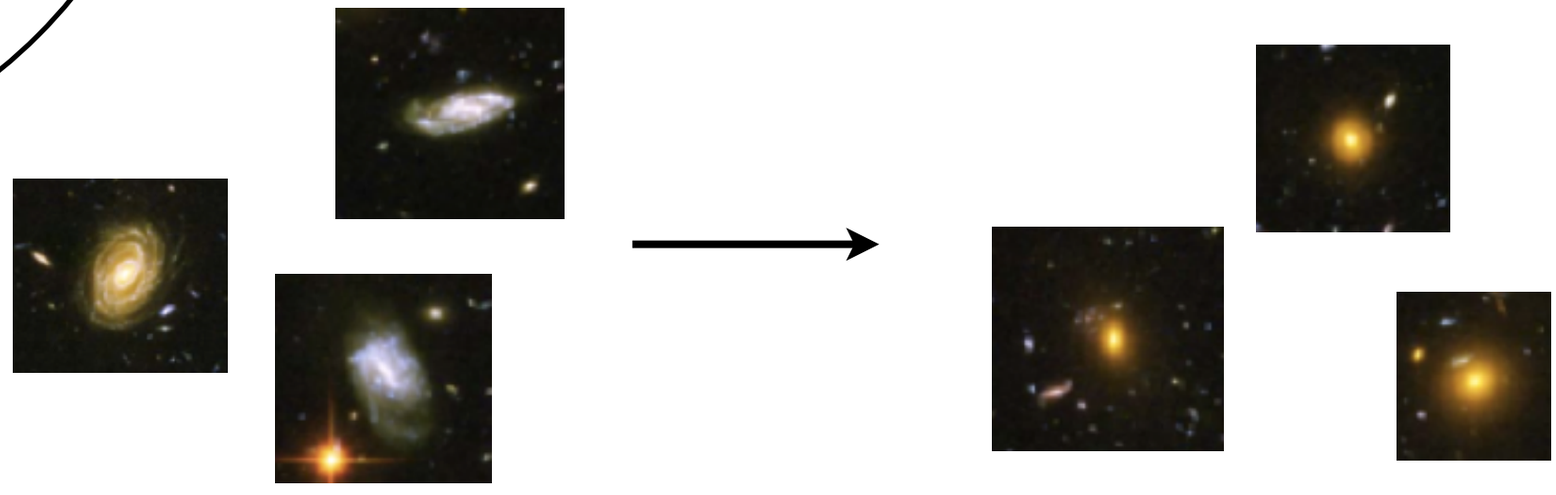
dark matter halo

tidal interactions

External

galaxy mergers

large-scale gas accretion

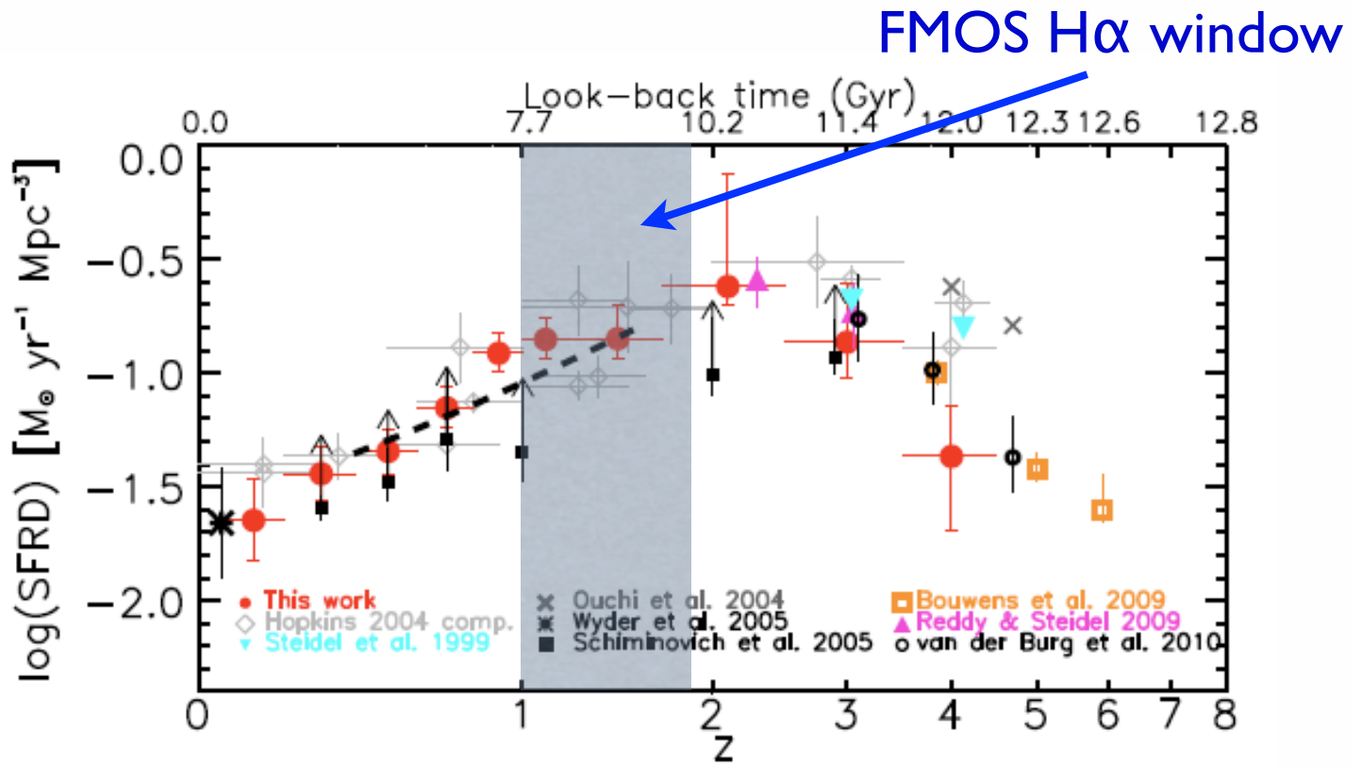


High multi-plex NIR spectroscopic era is here!

Subaru/FMOS
Wide area coverage

Keck/MOSFIRE
High sensitivity

VLT/KMOS
IFUs



VVDS: Cucciati et al. 2012

- How does the sfr - mass relation evolve with redshift?
- Is pristine gas accreting onto galaxies at high-z?
- Does the ionization conditions evolve with redshift?

(Kewley et al. 2013a,b)

Properties of the ISM

Rest-frame optical emission lines: Hα, Hβ, [NII]6584, [SII], [OII]3727, [OIII]5007

Star formation rates

Dust extinction

Chemical enrichment (i.e., metallicity)

Ionization state (stars vs. AGN)

Excitation

Density, pressure

Star-forming galaxies and AGN at $1 < z < 2$

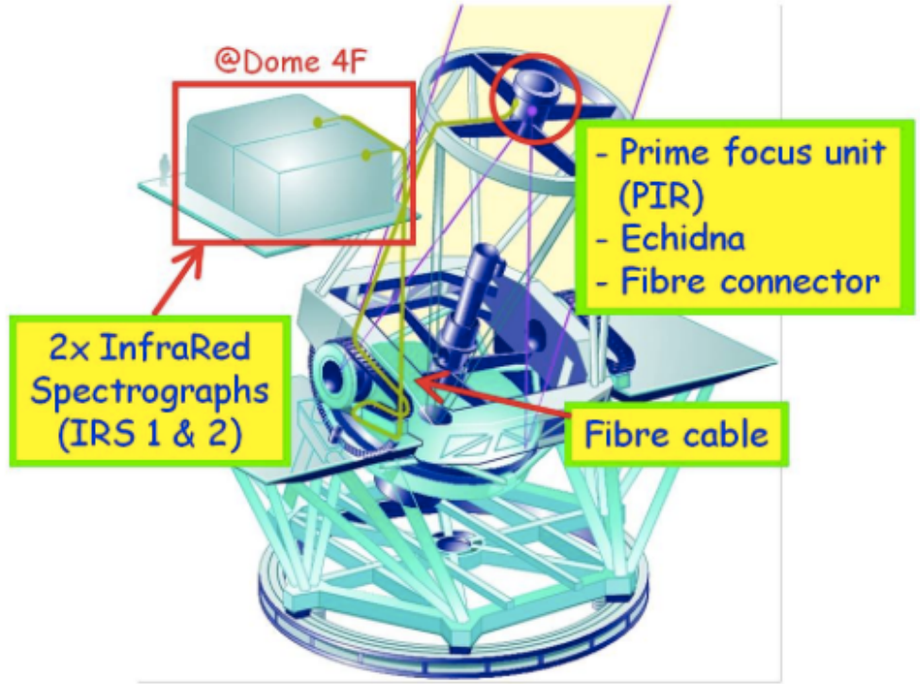
Review of FMOS-COSMOS

Black hole - host galaxy mass relations at $z > 0.5$

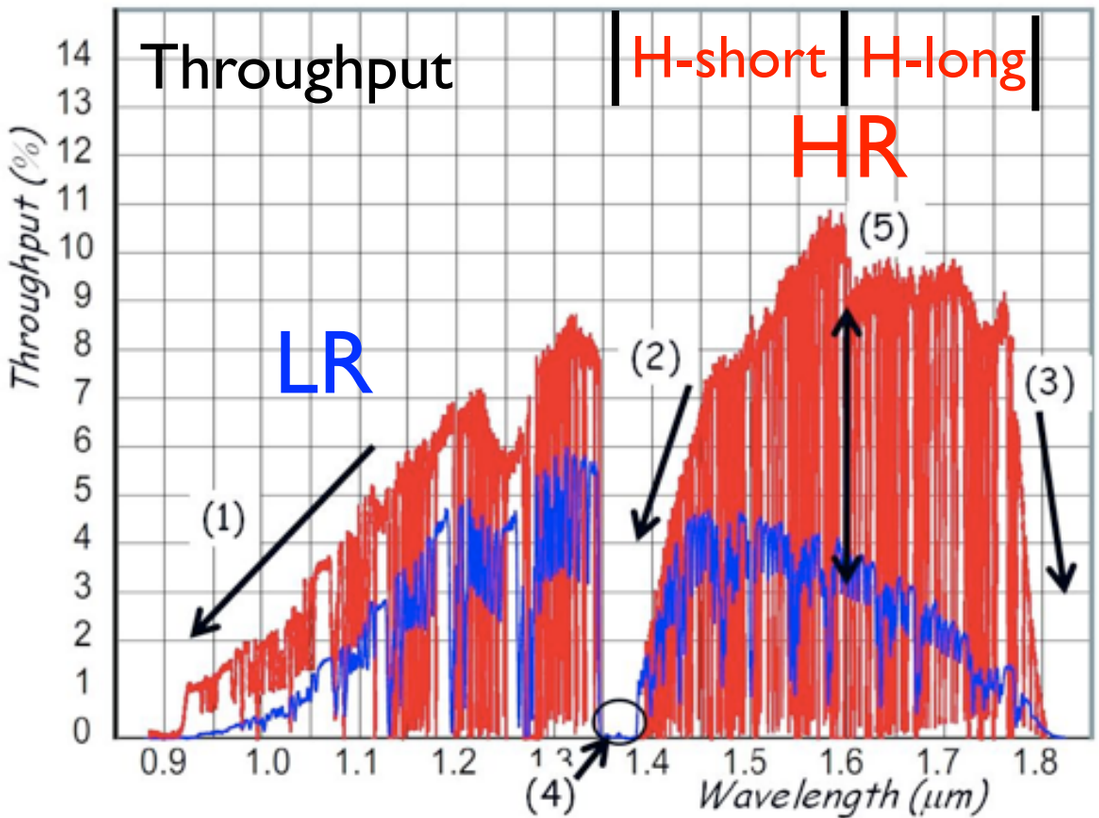
Use of TAO-SWIMS

Subaru - Fiber Multi-object Spectrograph (FMOS)

- Built by Kyoto University, UK & NAOJ (PI: T. Maihara)
- commissioned in 2007



- 0.9 - 1.8 μm
- 400 fibers; 1.2″ diameter
- 30′ diameter FOV
- Airglow/OH suppression system (Iwamuro et al. 2006)
- Low (R=500) and high (R=2200) resolution
- 2048x2048 HgCdTe Hawaii-2 detectors
- Cross-beam switching (~200 fiber pairs can be assigned)
- two spectrographs (irs1 and irs2)



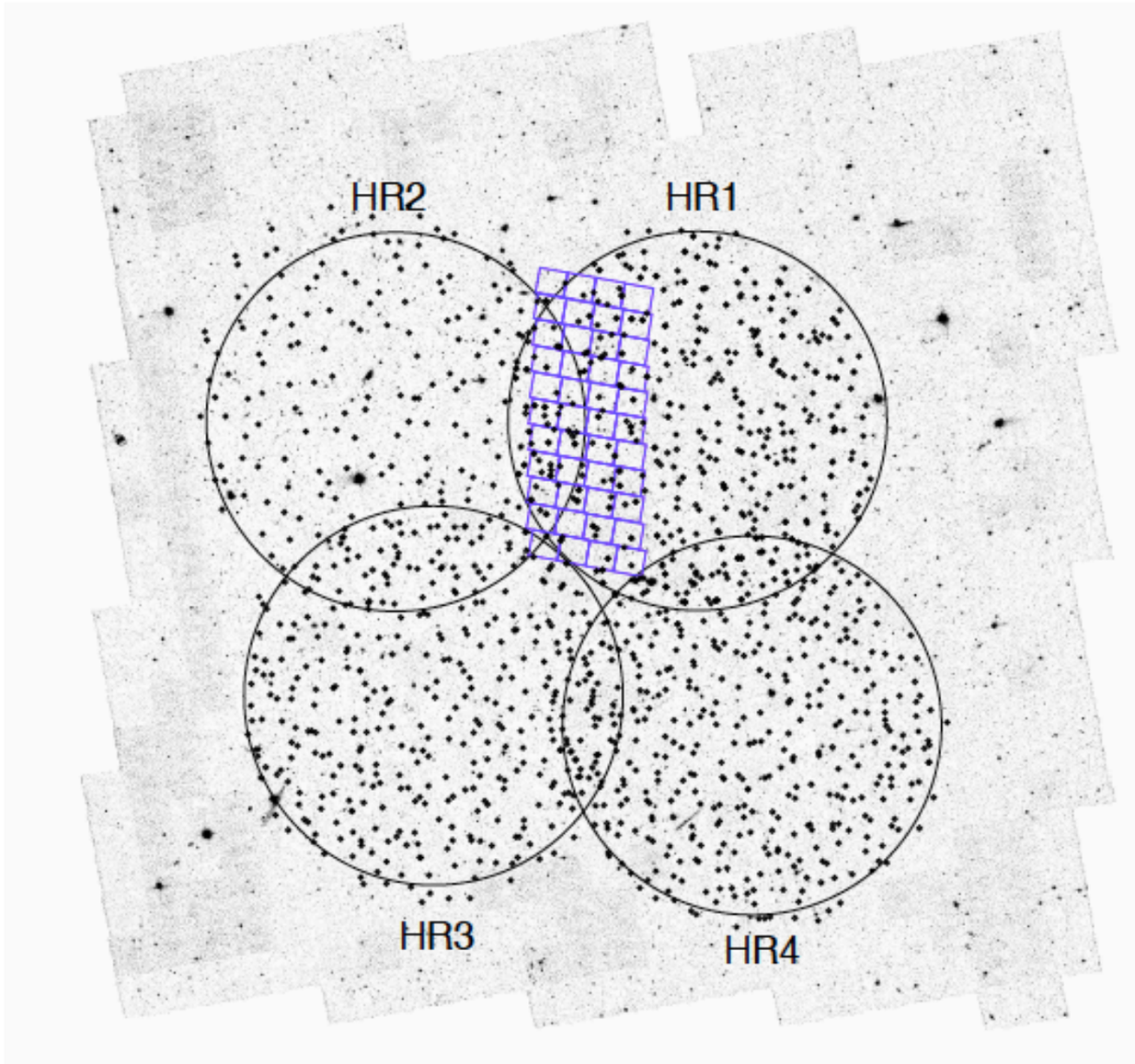
A Subaru/FMOS NIR survey of SF galaxies at z ~ 1.6

- Emission-line survey
  - 2 Intensive Subaru programs (PI JDS)
  - +IfA nights
  - H-long grating: Hα, [NII] and [SII]

•Followup J-long observations
  - J-long grating (Hβ, [OIII]5007)

• Prioritize Herschel/PACS detections

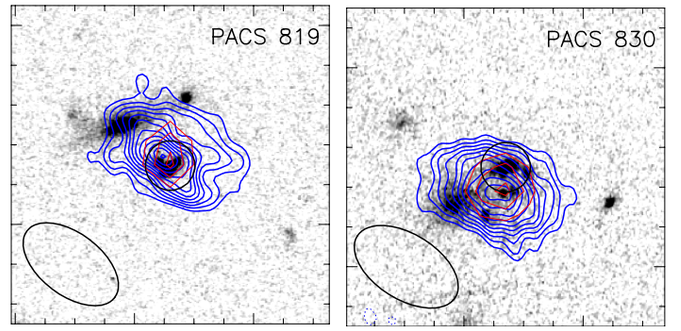
COSMOS



JDS et al. 2015, ApJS, 220, 12

Target selection

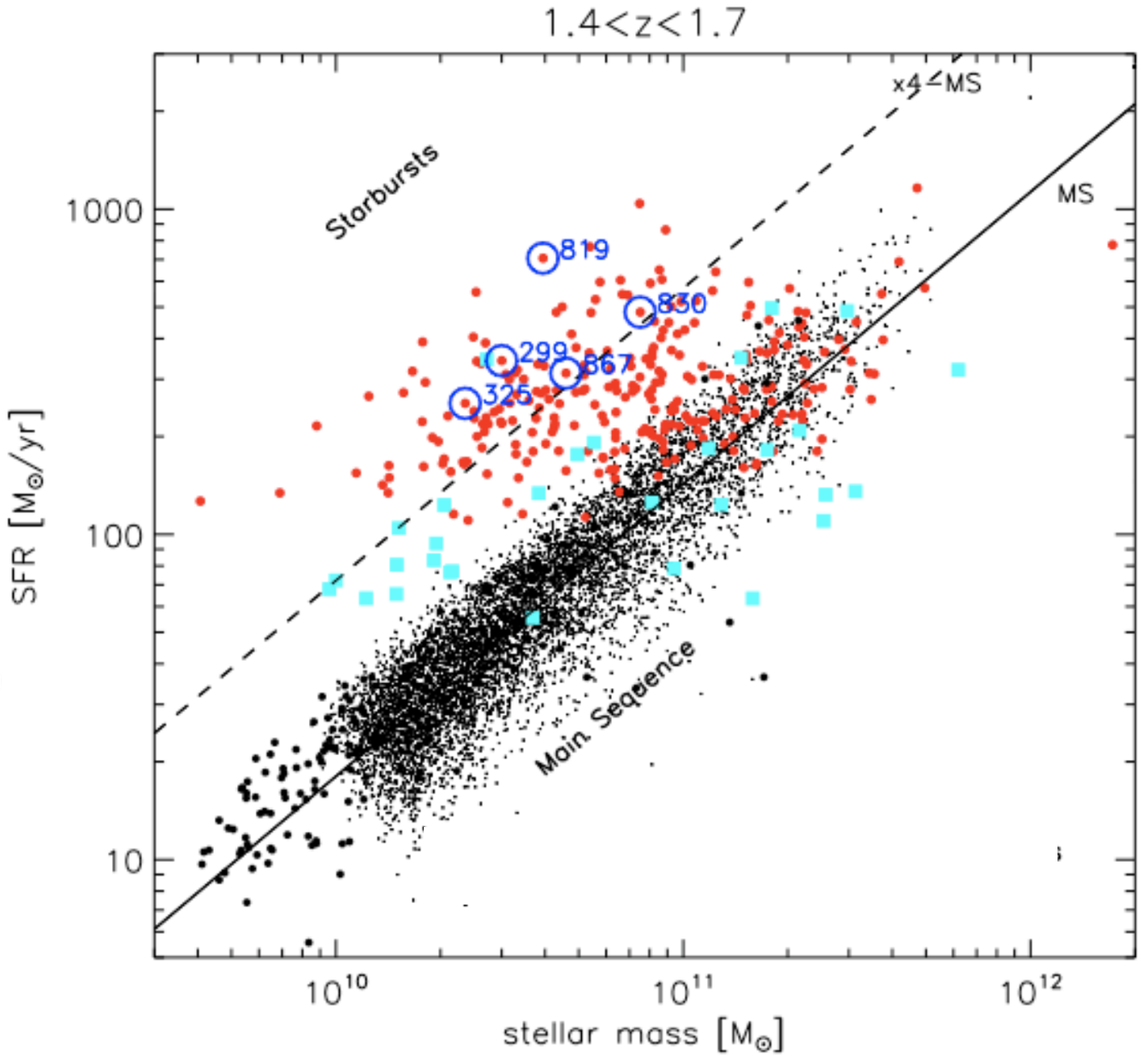
ALMA CO 2-1
JDS et al. 2015



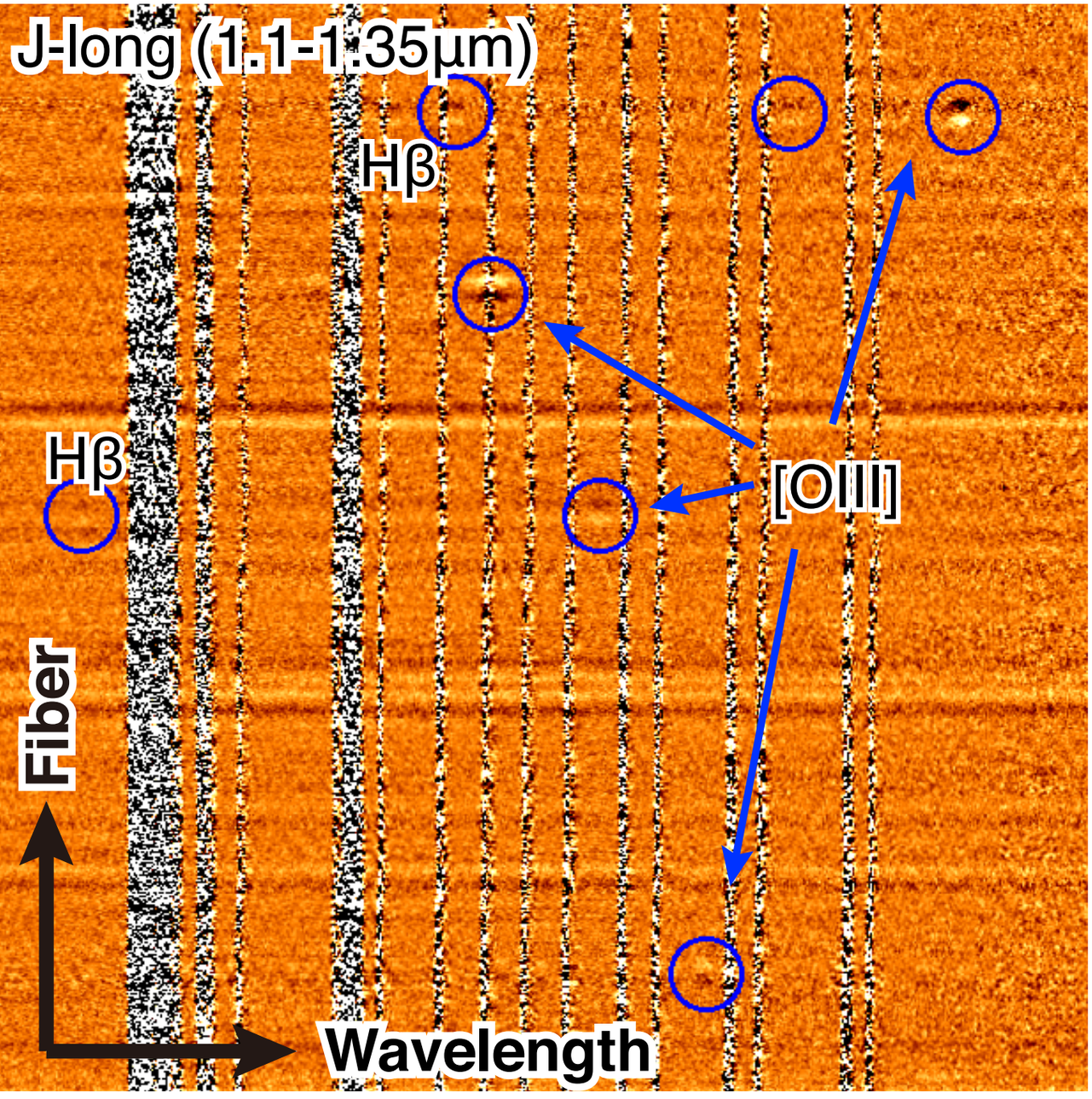
- star-forming galaxies
  - K-selected (K < 23.5)
  - $M_* > 10^{10}\ M_\odot$
  - sBzK
  - along the star-forming main sequence
  - $f_{H\alpha} > 4 \times 10^{-17}$ erg cm^{-2} s^{-1}
    - SFR: B-band
    - E(B-V): B-z color
    - $E(B-V)^{neb}=E(B-V)^{stellar}/0.44$ (Calzetti et al. 2000)

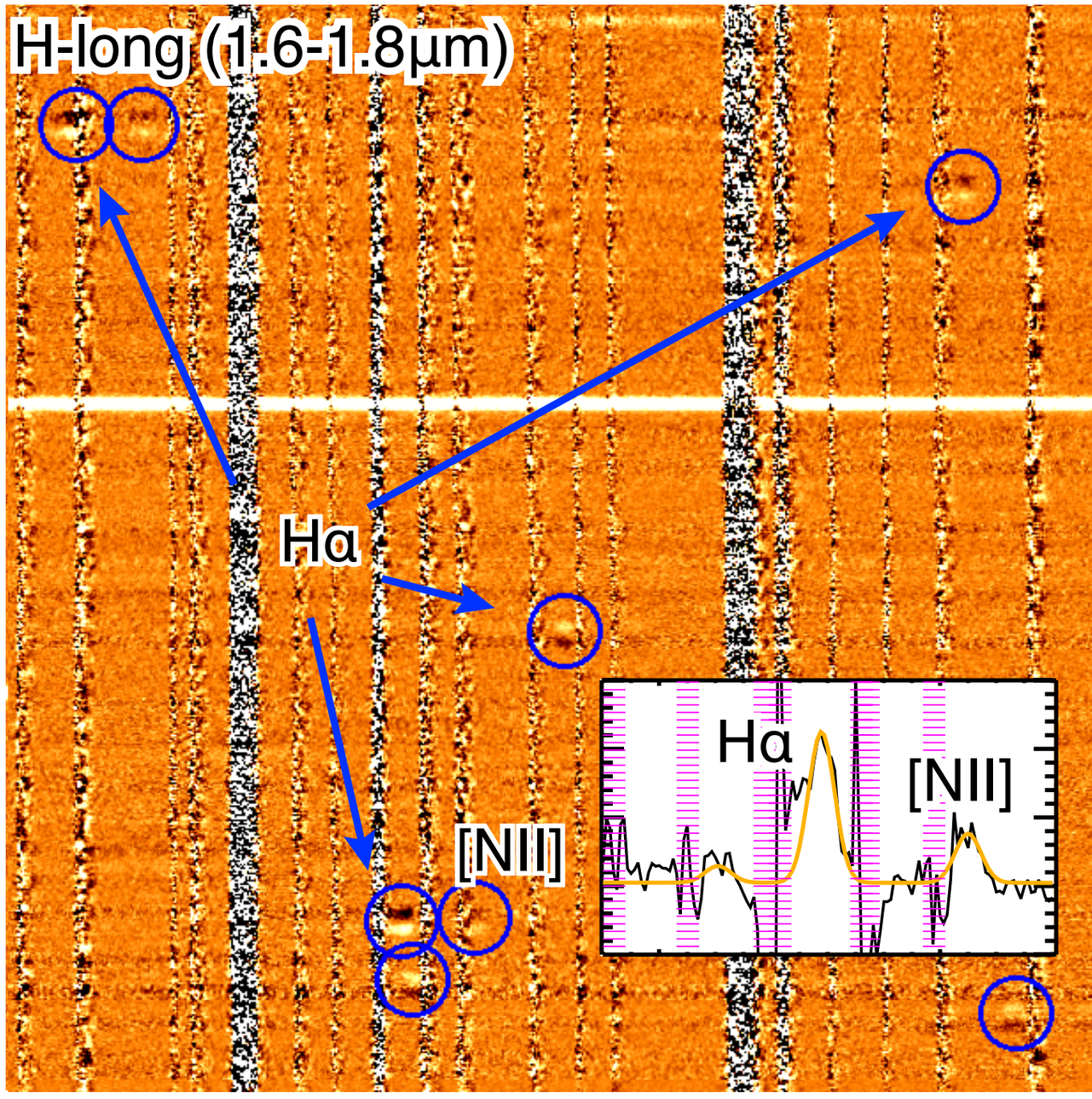
- Herschel/PACs sources
  - highly obscured SF galaxies
  - above or on M-S
  - near bright stars for future IFU/AO observations

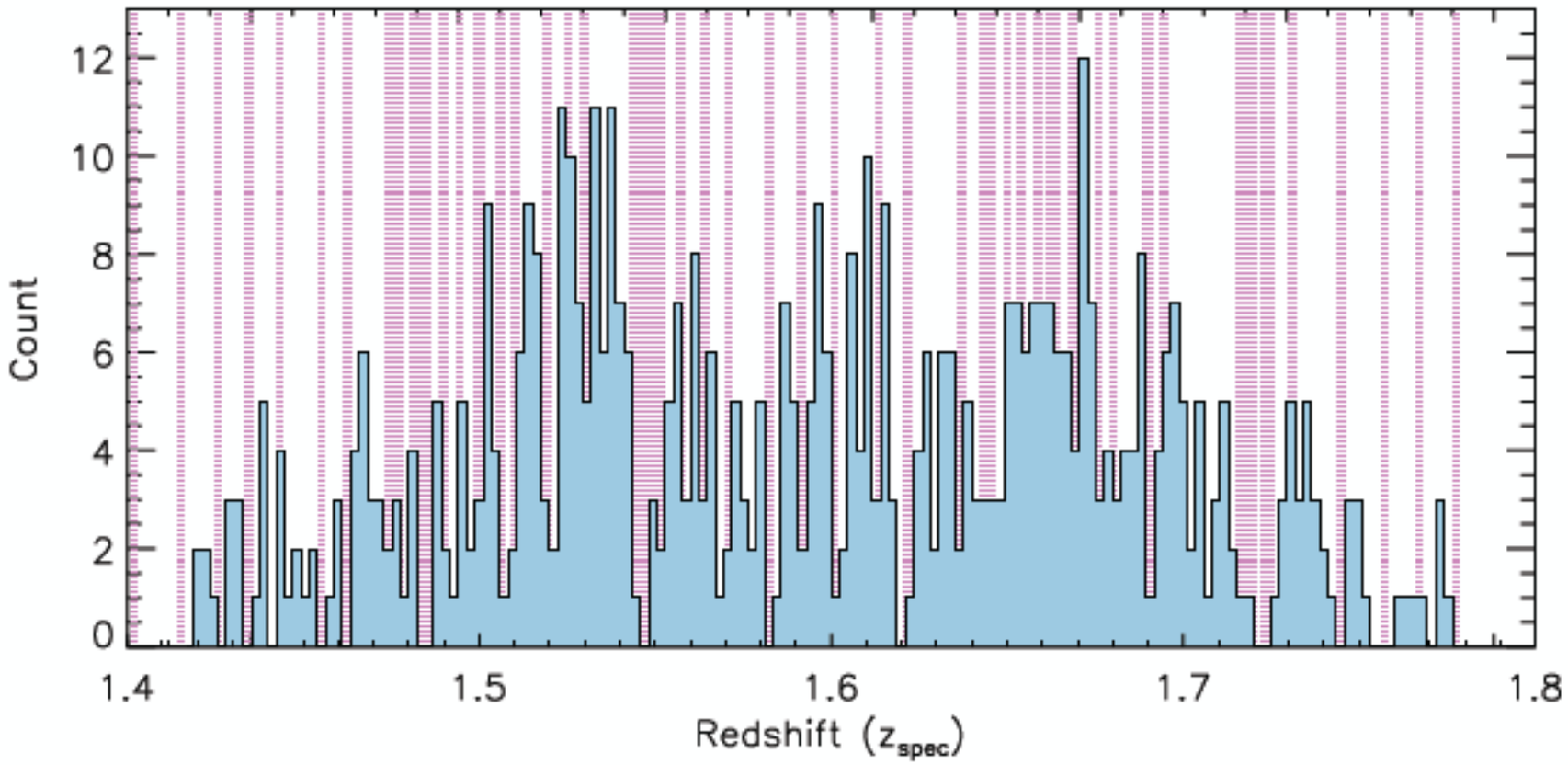
Filler targets: AGNs, low-mass galaxies



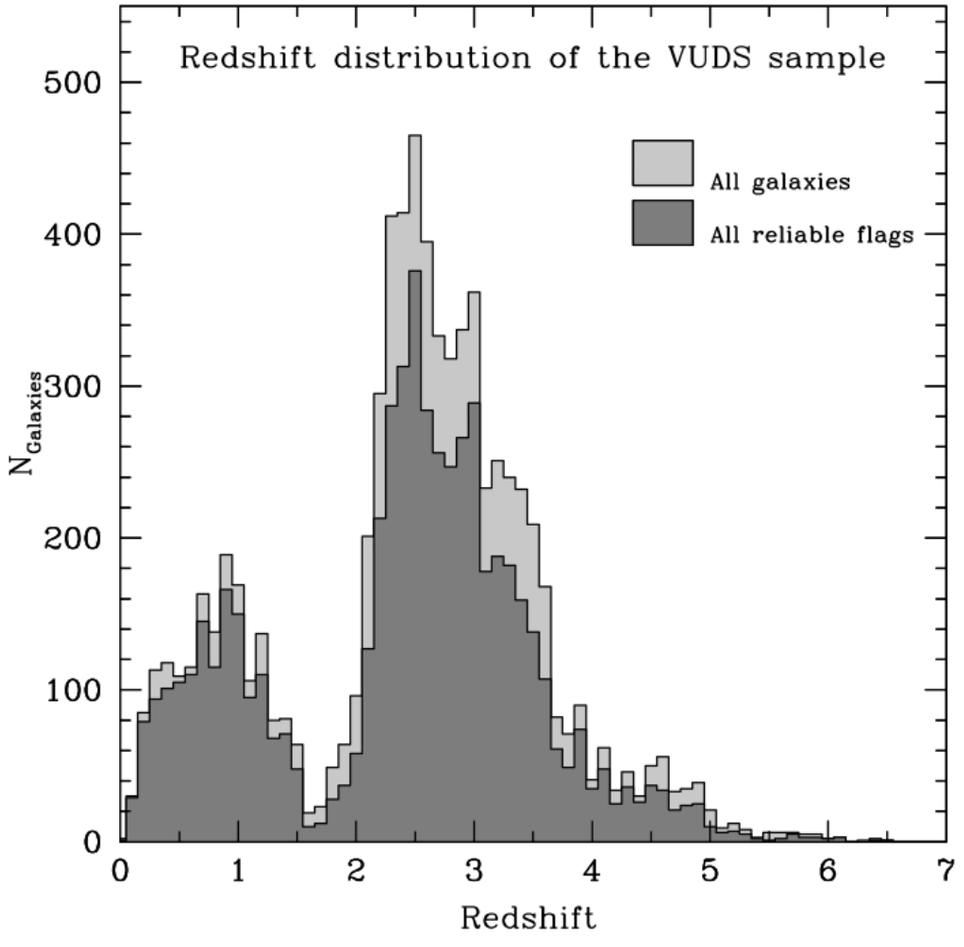
Rodighiero et al. 2010


J-long (1.1-1.35μm)
Hβ
Hβ
[OIII]
Fiber
Wavelength

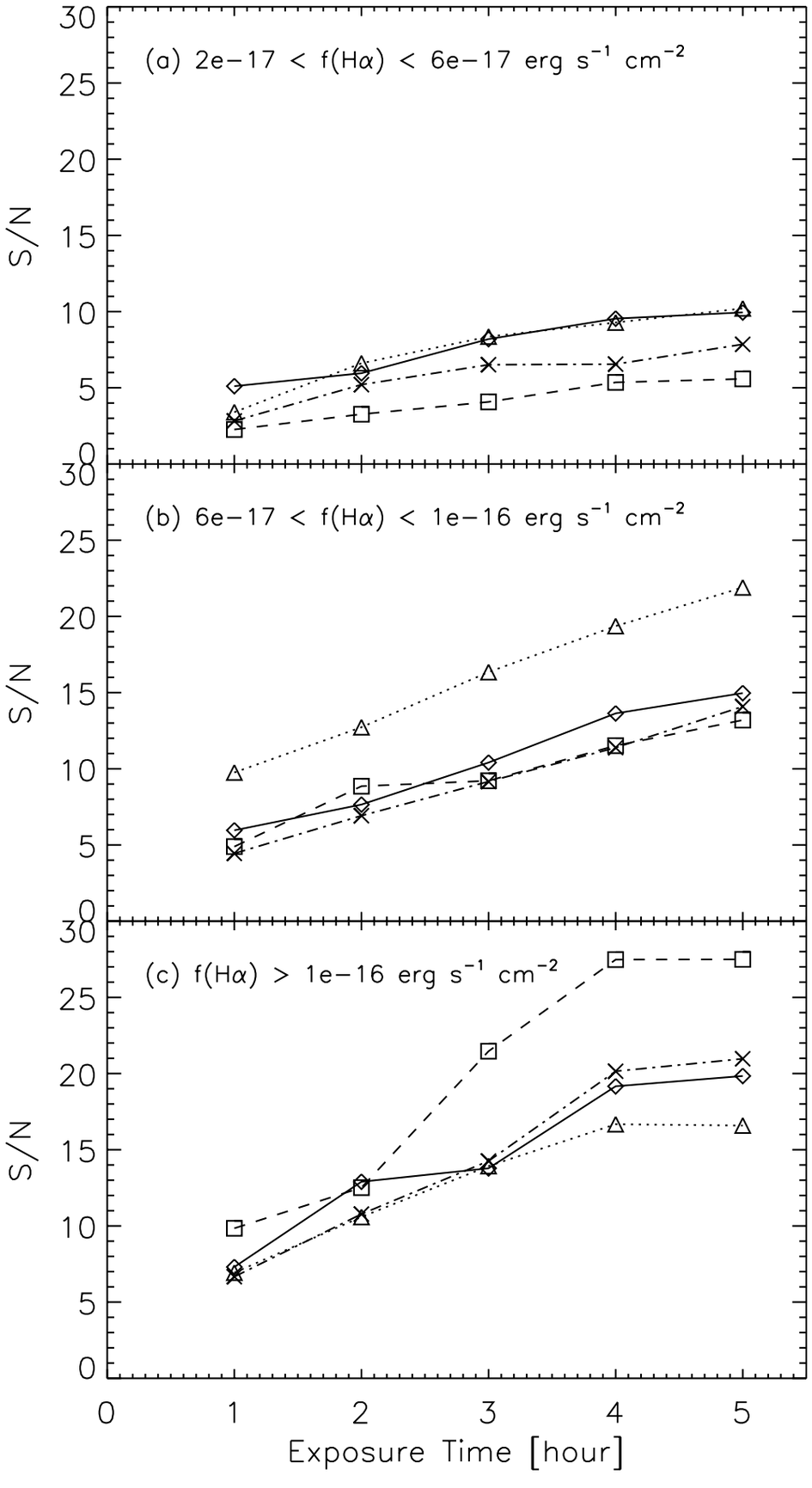

H-long (1.6-1.8μm)
Hα
[NII]
Hα
[NII]

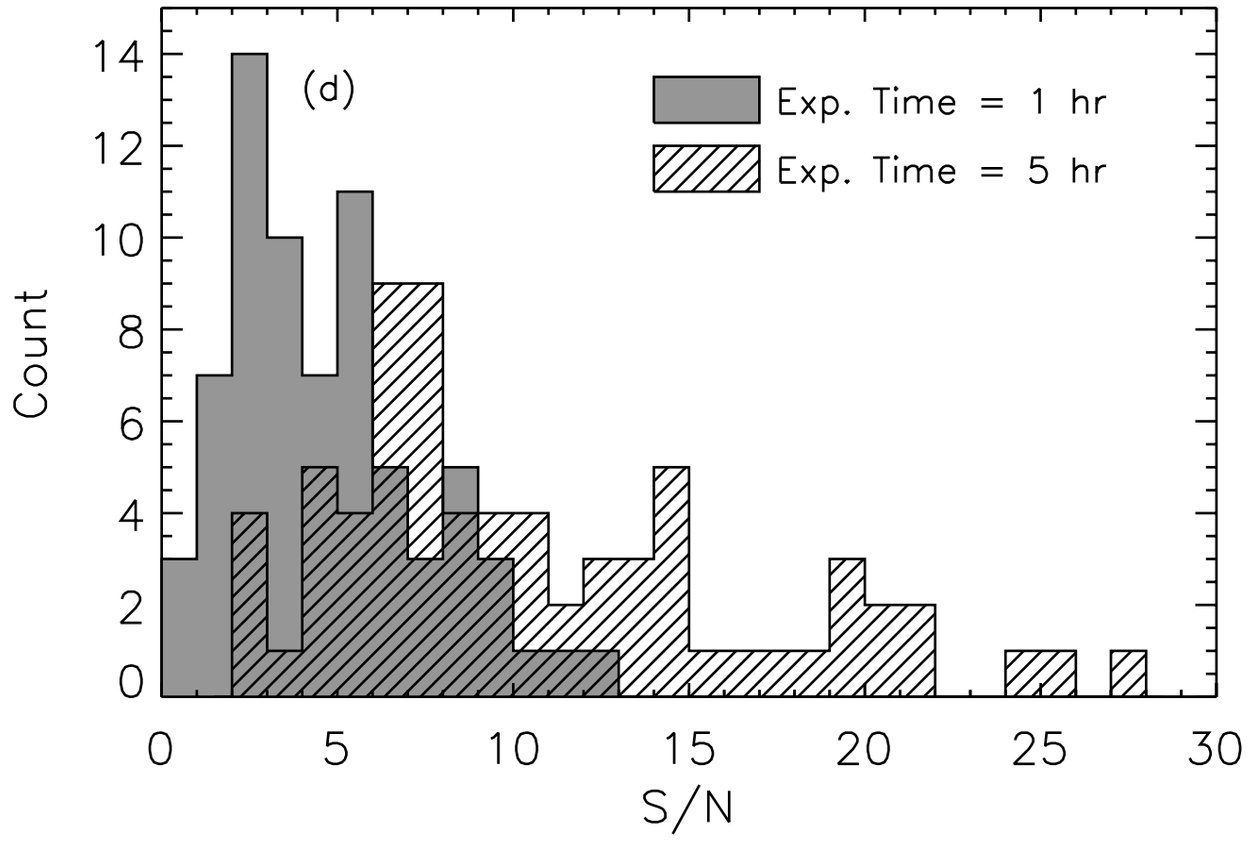


close to 1000 redshifts

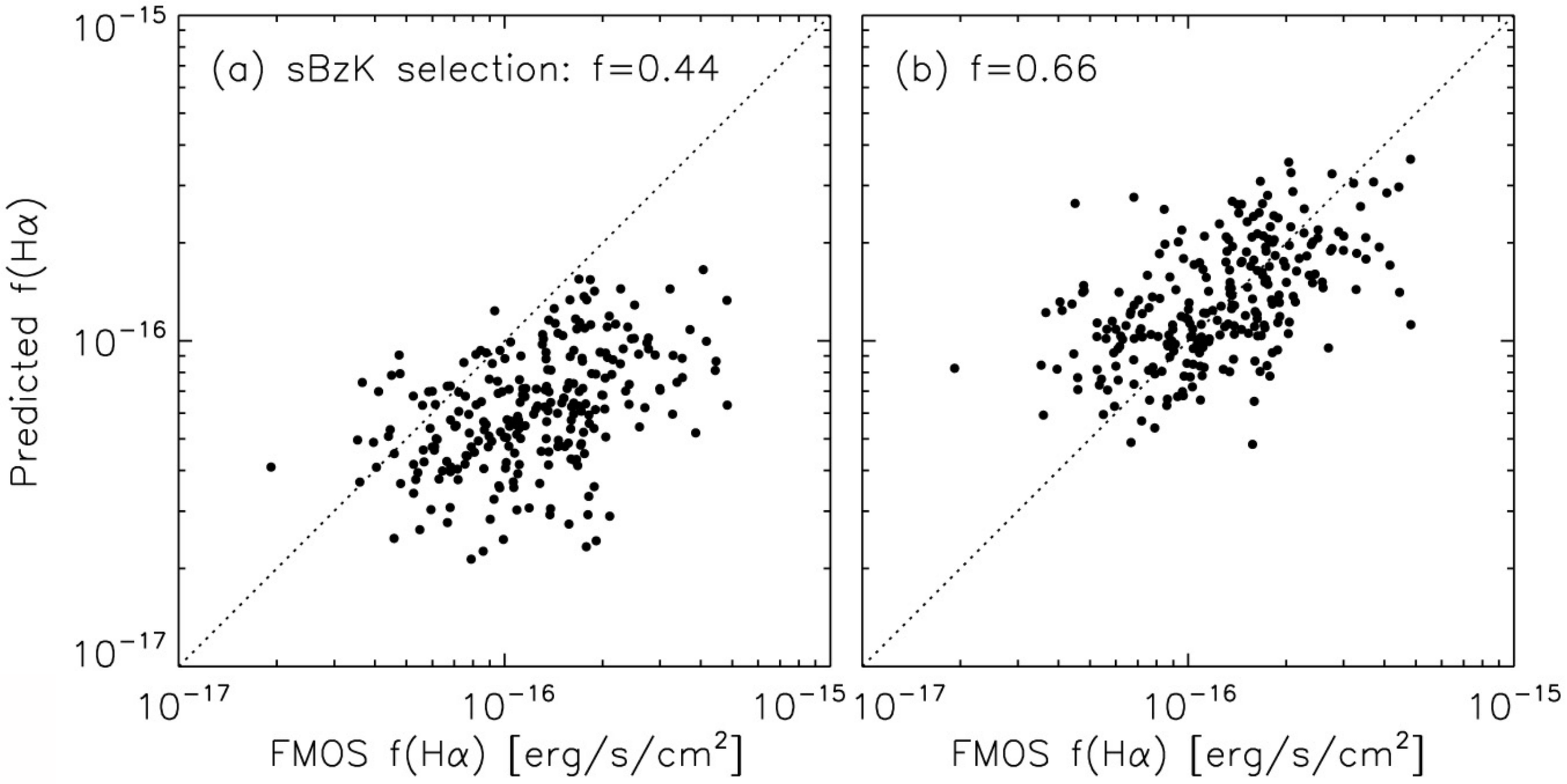


FMOS sensitivity

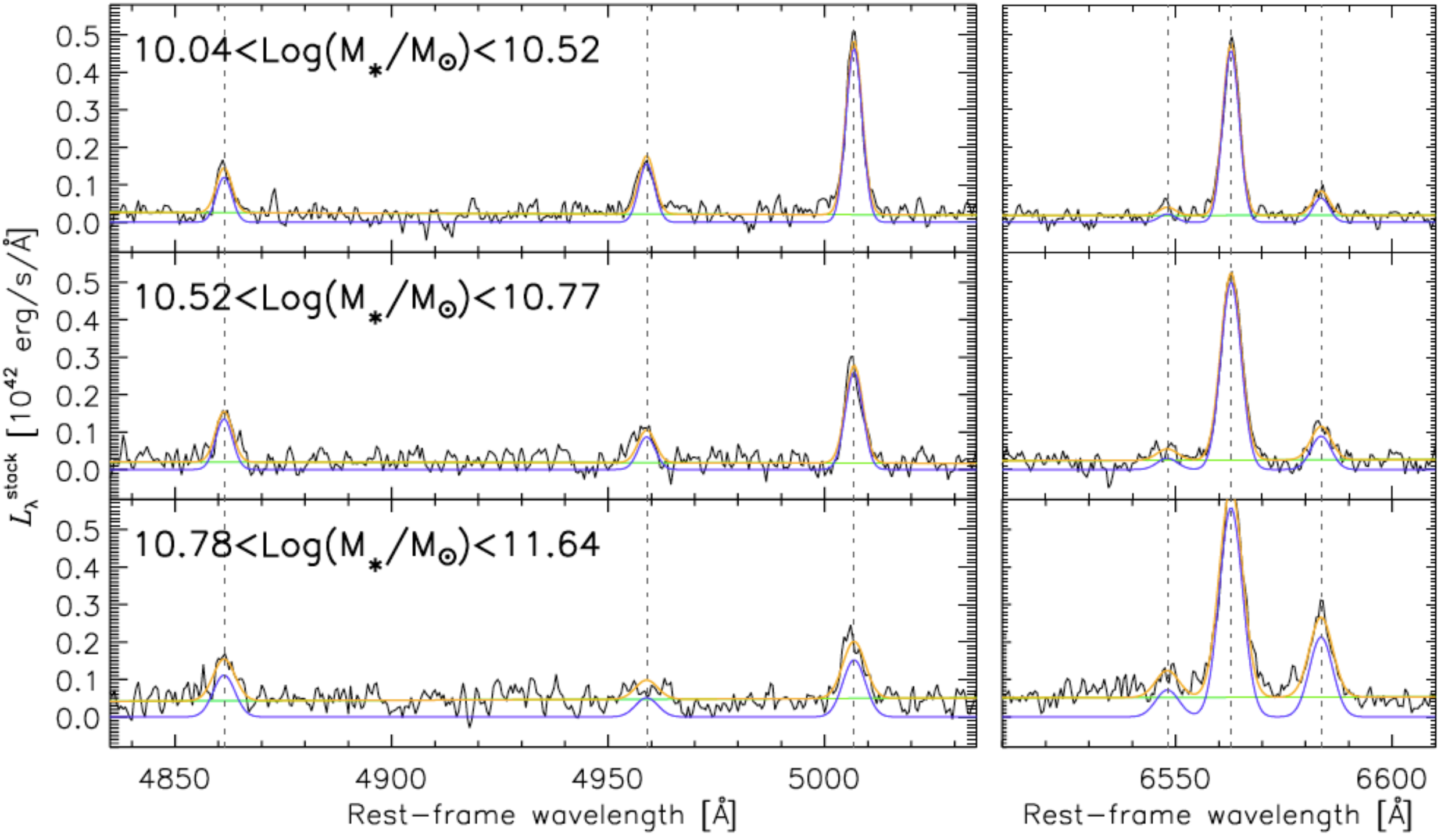




Predicted vs. Observed Hα flux

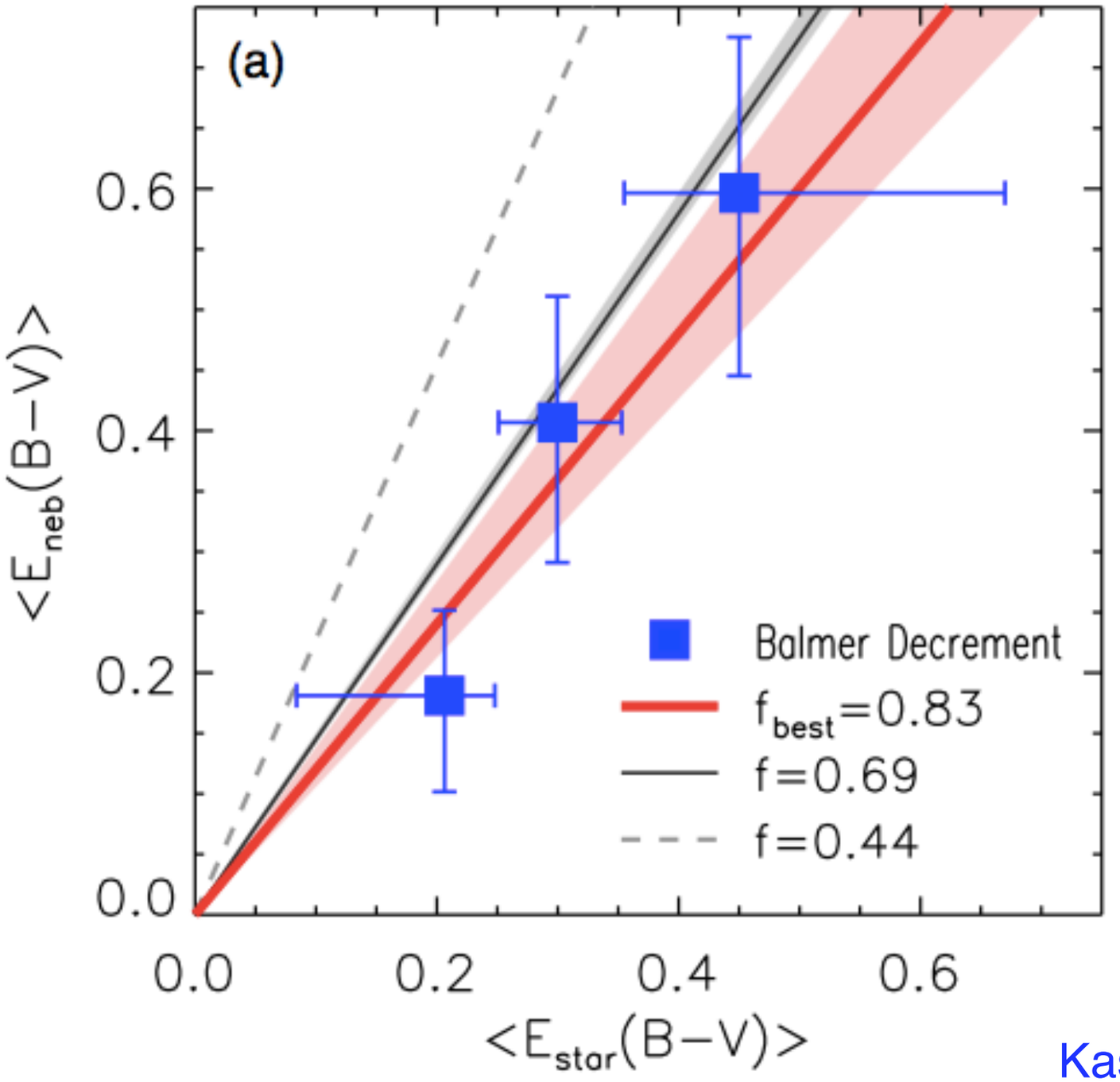


Stacking analysis



Dust extinction

based on Balmer decrement measured on stacked spectra

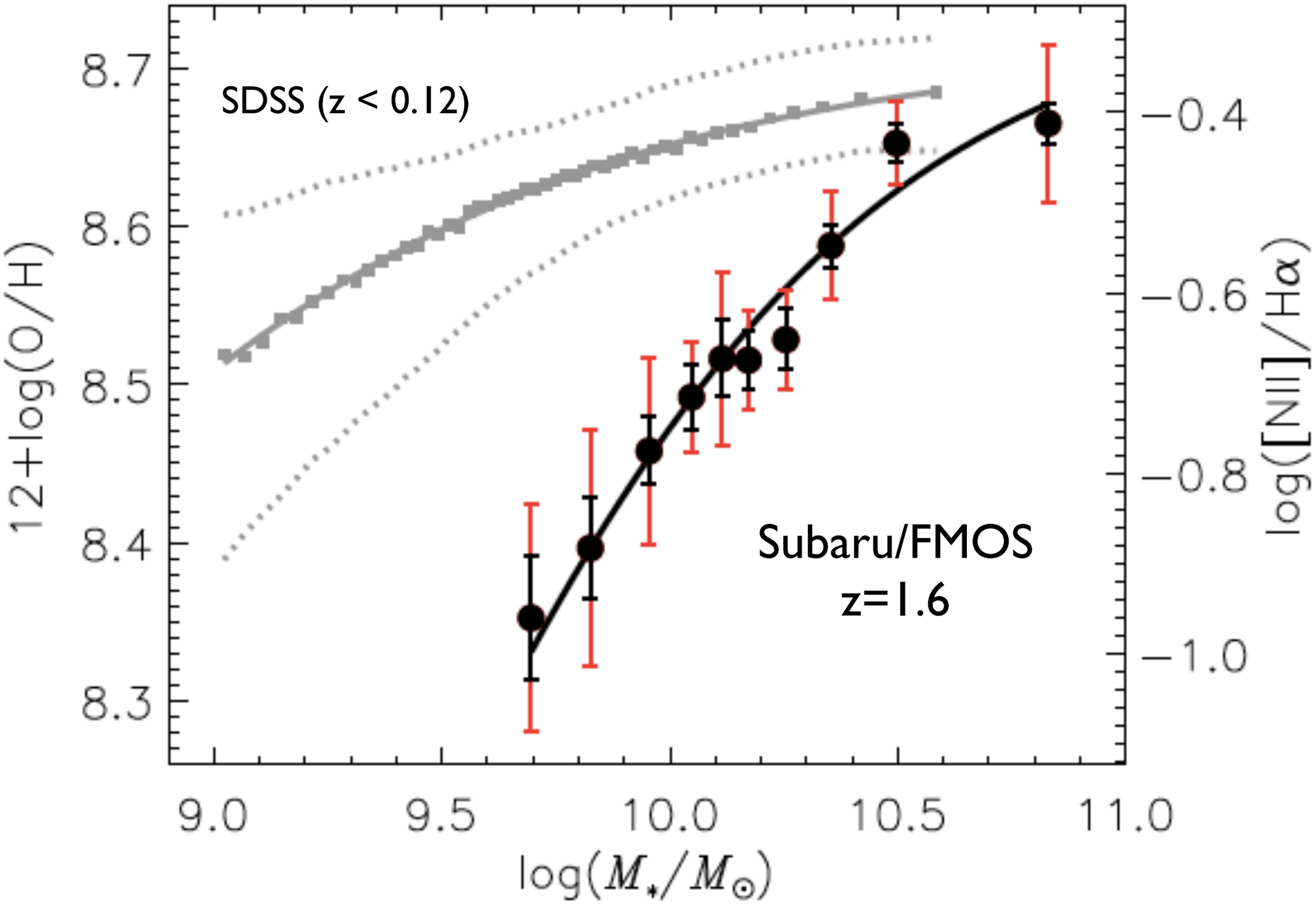


$f=E_{neb}/E_{star}$

Kashino, JDS et al. 2013

f-factor in disagreement with local starbursts - Calzetti et al. (2000)

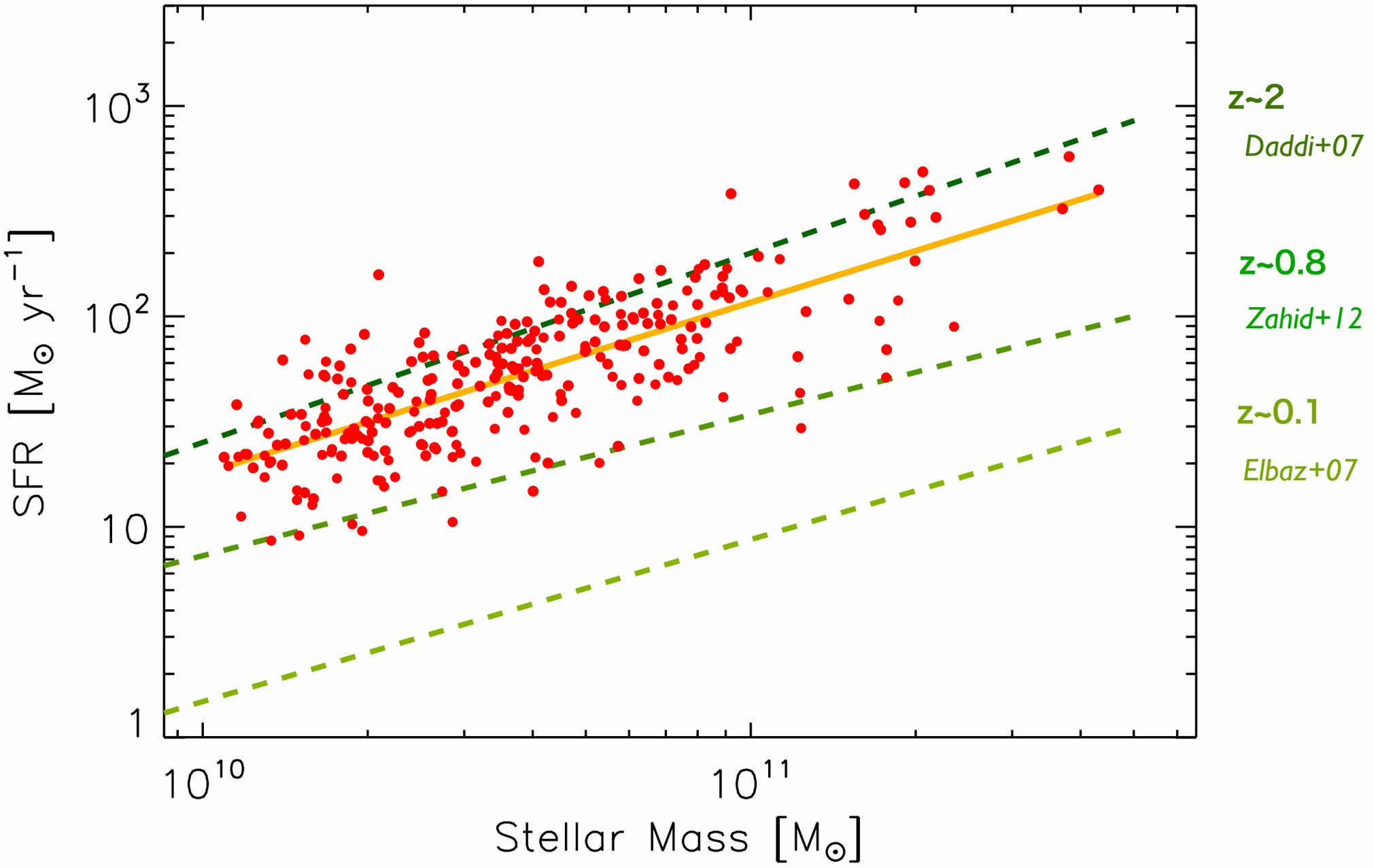
Mass-metallicity relation



Zahid, Kashino, JDS et al. 2014

MOSFIRE results: Steidel et al. 2014; Sanders et al. 2015

Star forming main sequence at z~1.6

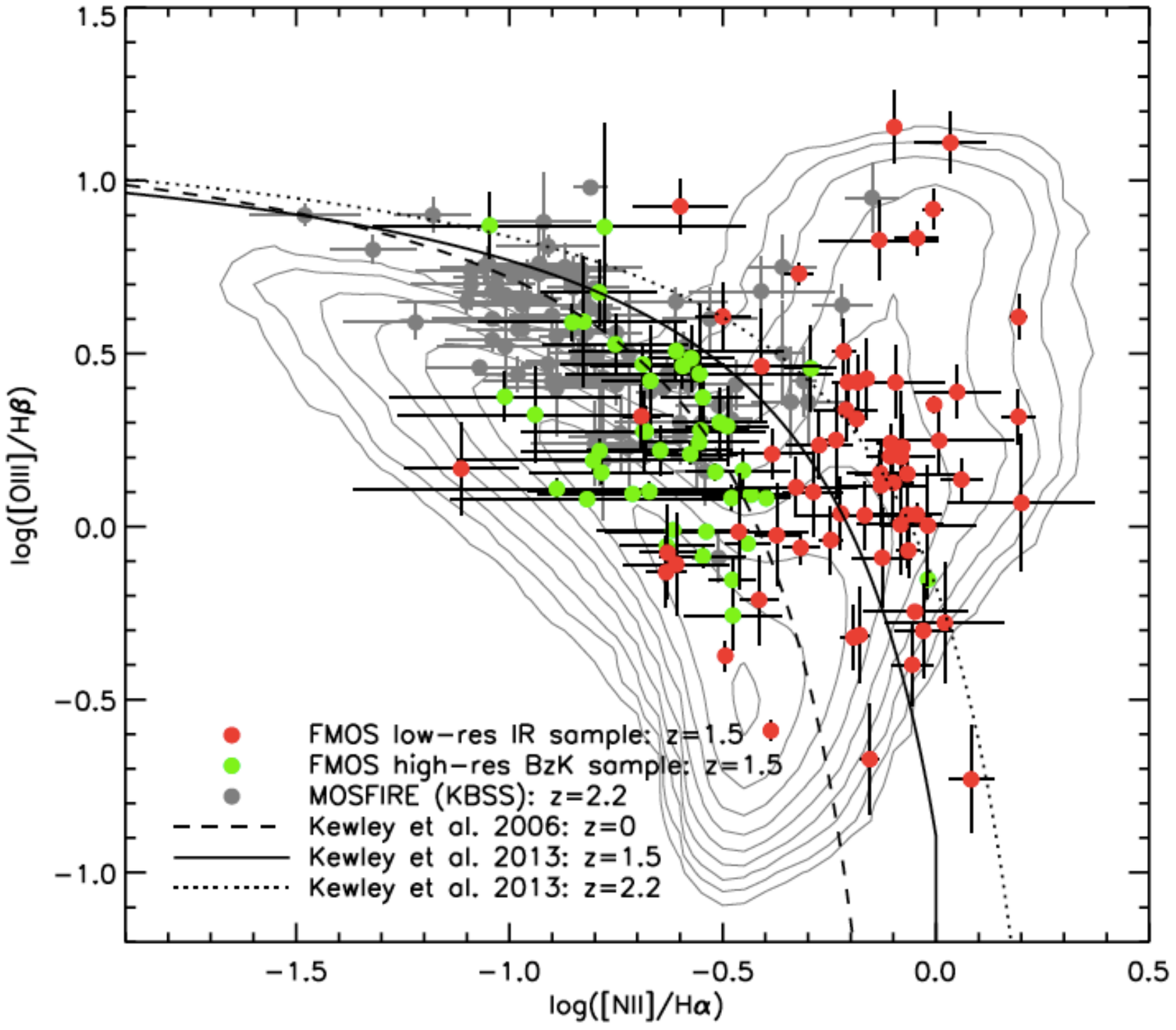


Kashino, JDS et al. 2013

$$\log \frac{SFR}{\mathrm{M}_\odot \mathrm{yr}^{-1}} = 1.25_{\pm 0.03} + 0.81_{\pm 0.04} \log \left[\frac{M_*}{10^{10} \mathrm{M}_\odot} \right]$$

sigma~0.22 dex

SF - AGN separation at high-z (BPT)

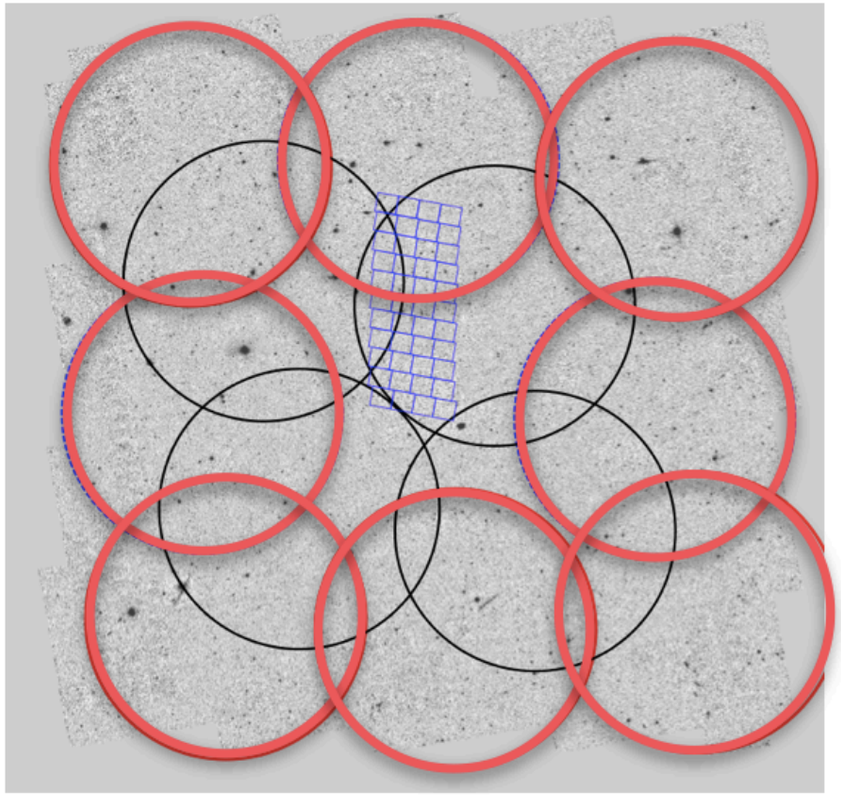


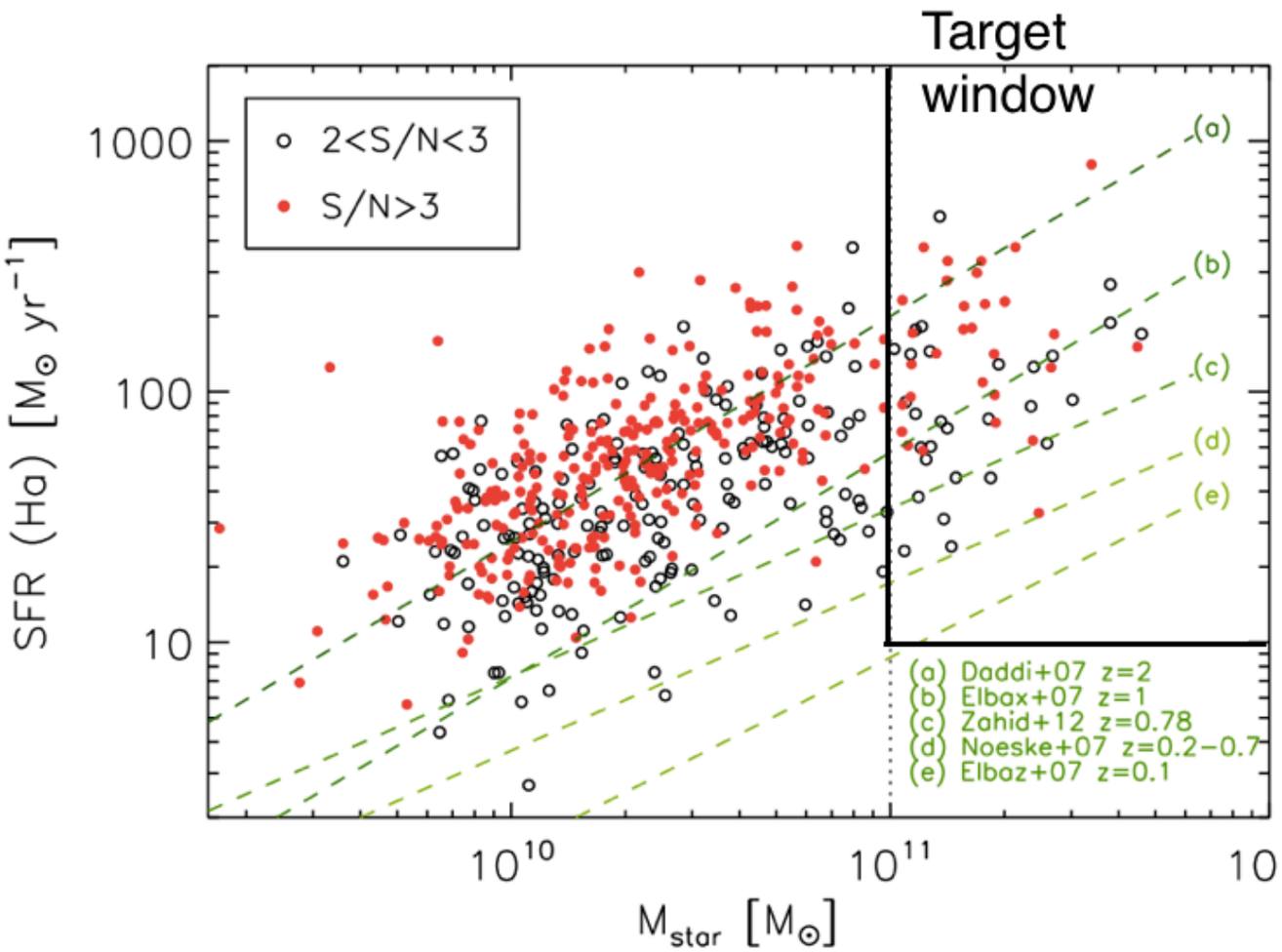
Kartaltepe, Sanders, JDS et al. 2015

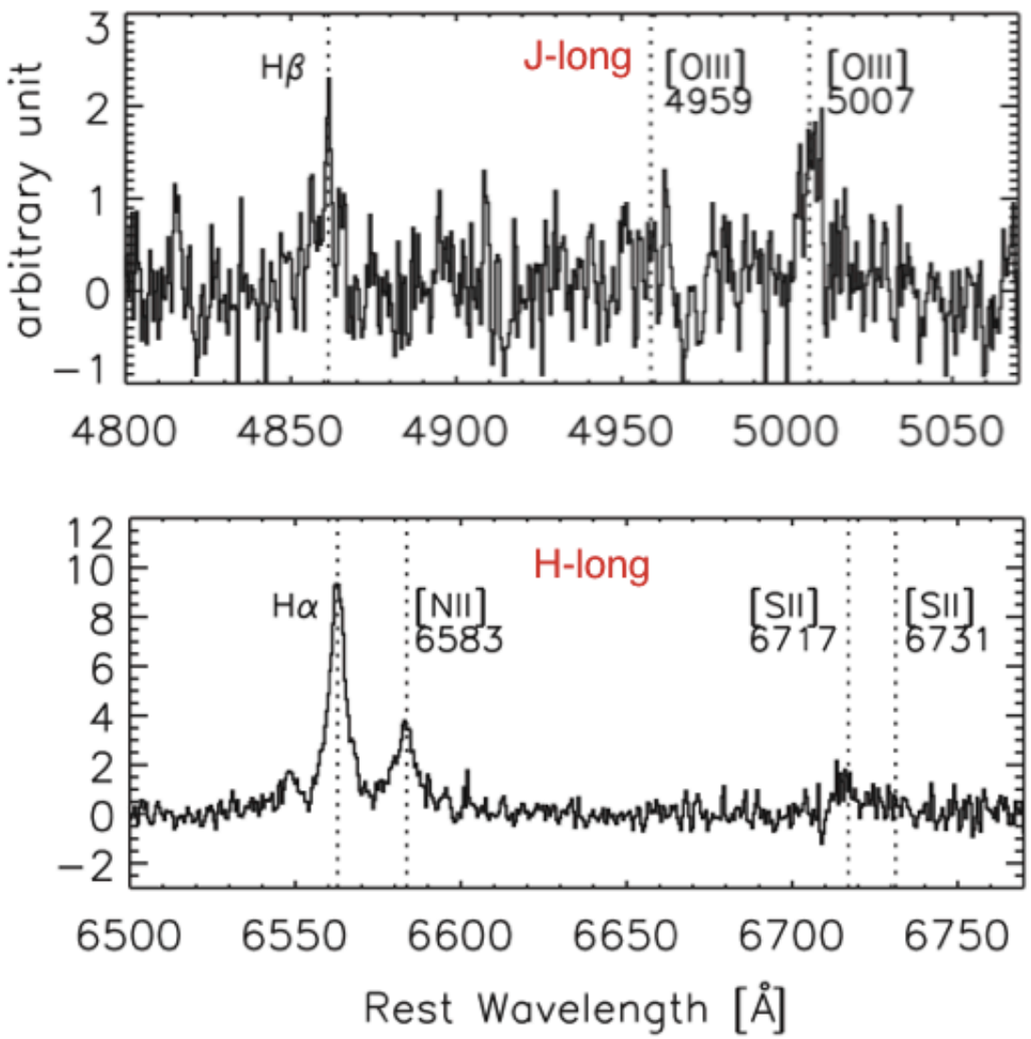
see Steidel et al. 2014; Coil et al. 2014; Shapley et al. 2015

Subaru intensive program II
S15 A and B

Focus on massive galaxies ($M_* > 10^{11}\ M_\odot$) and AGN

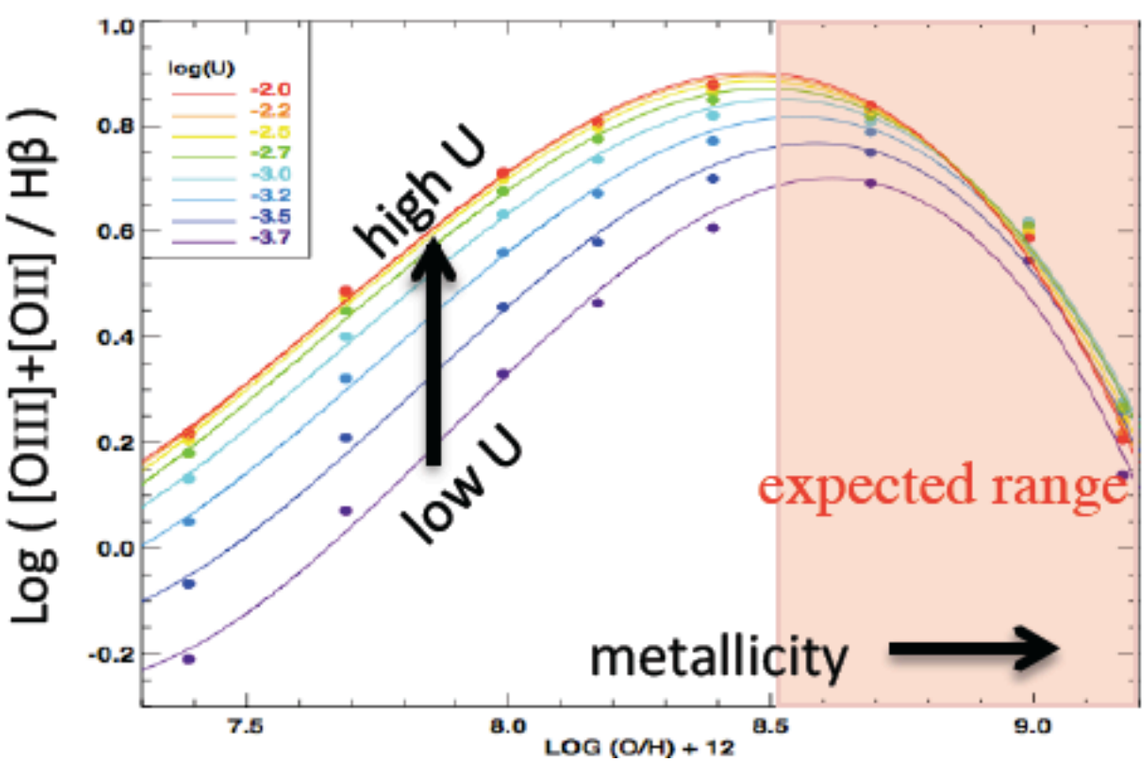


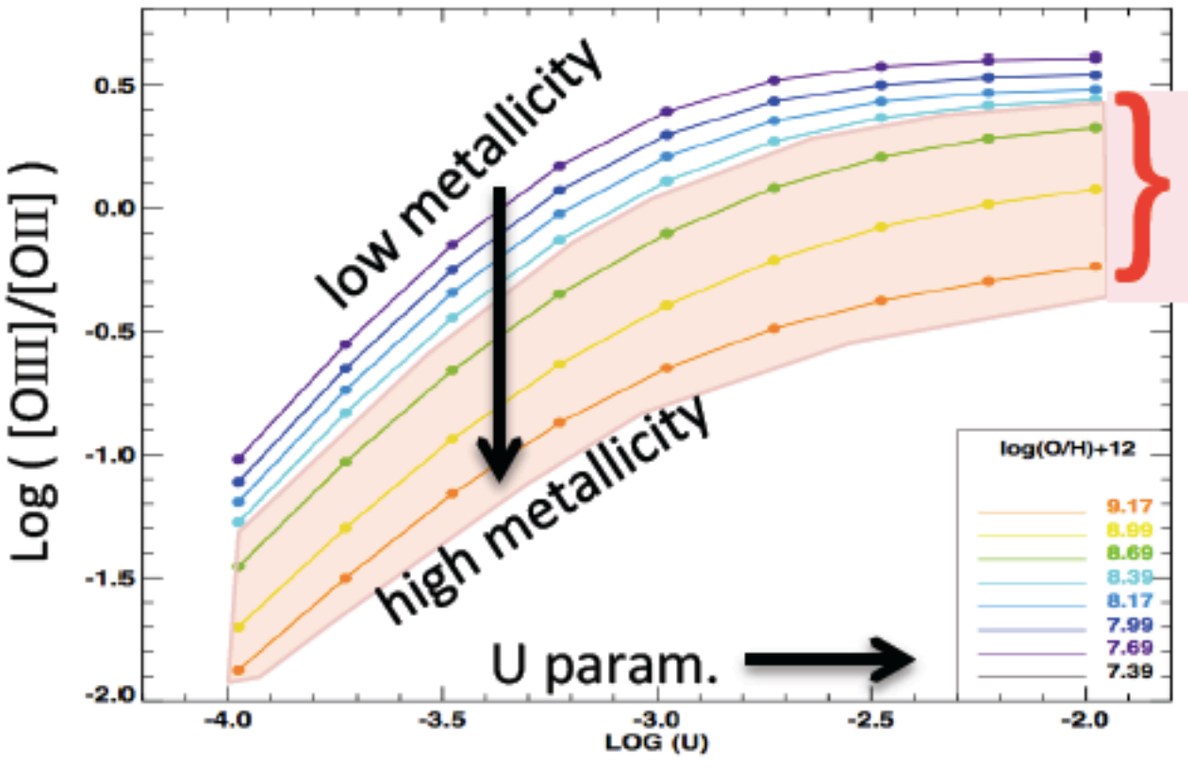




[OII] followup of FMOS galaxies

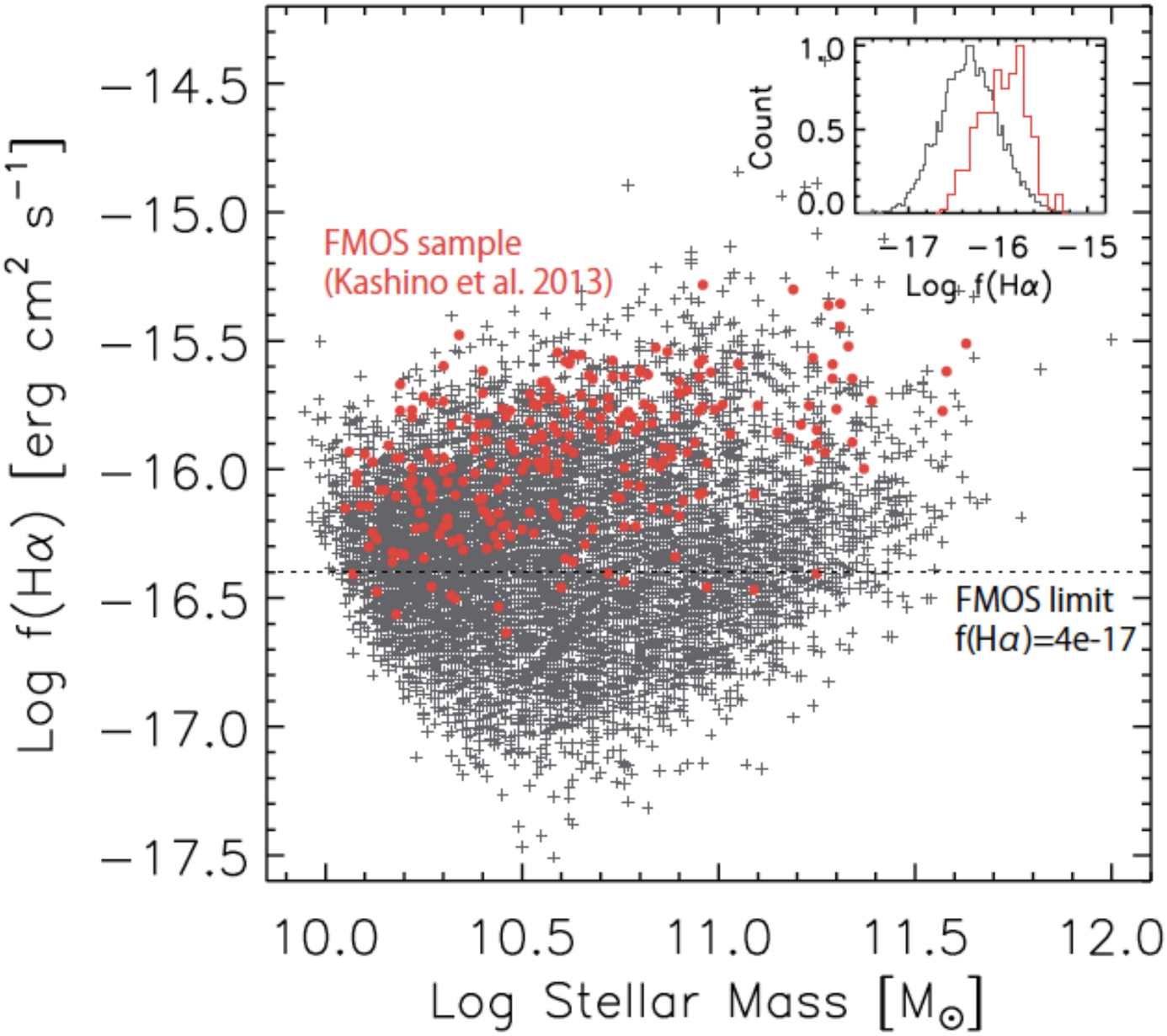
Keck/DEIMOS (PI Lisa Kewley)
VLT/VIMOS (PI Stephanie Juneau)

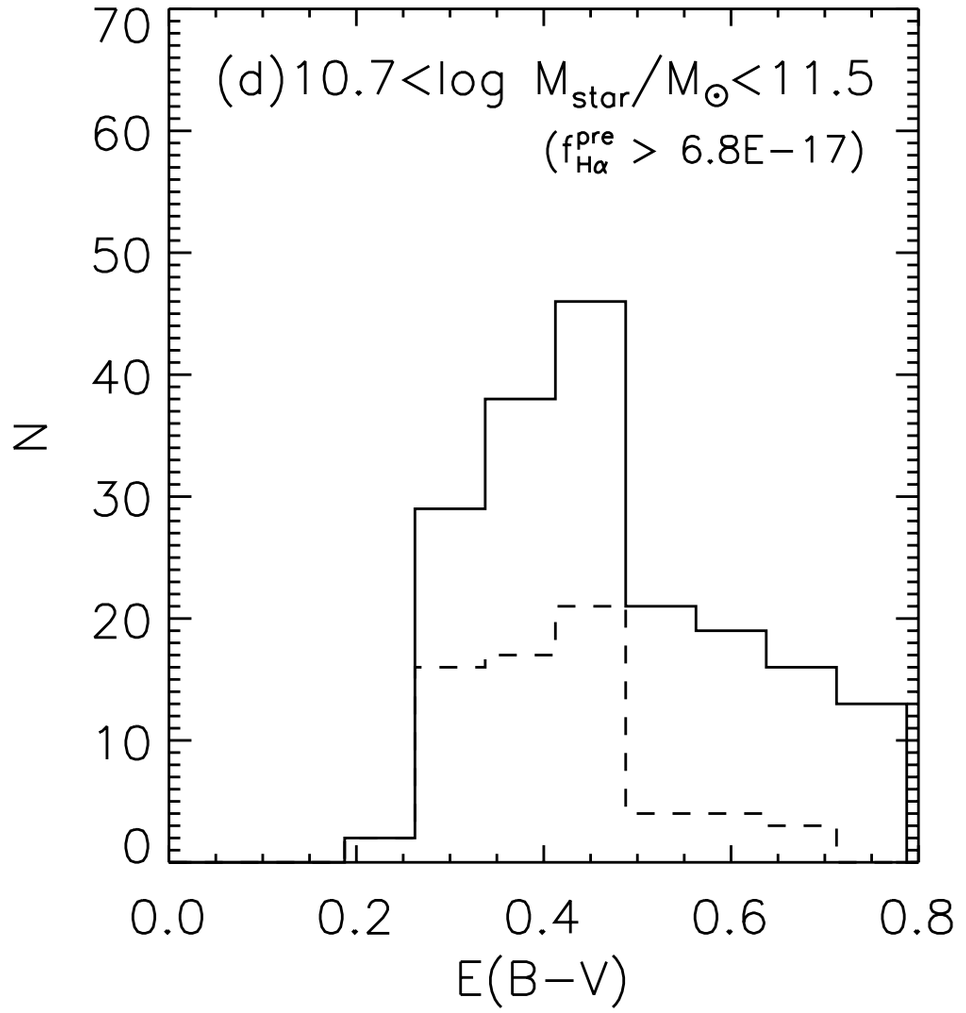




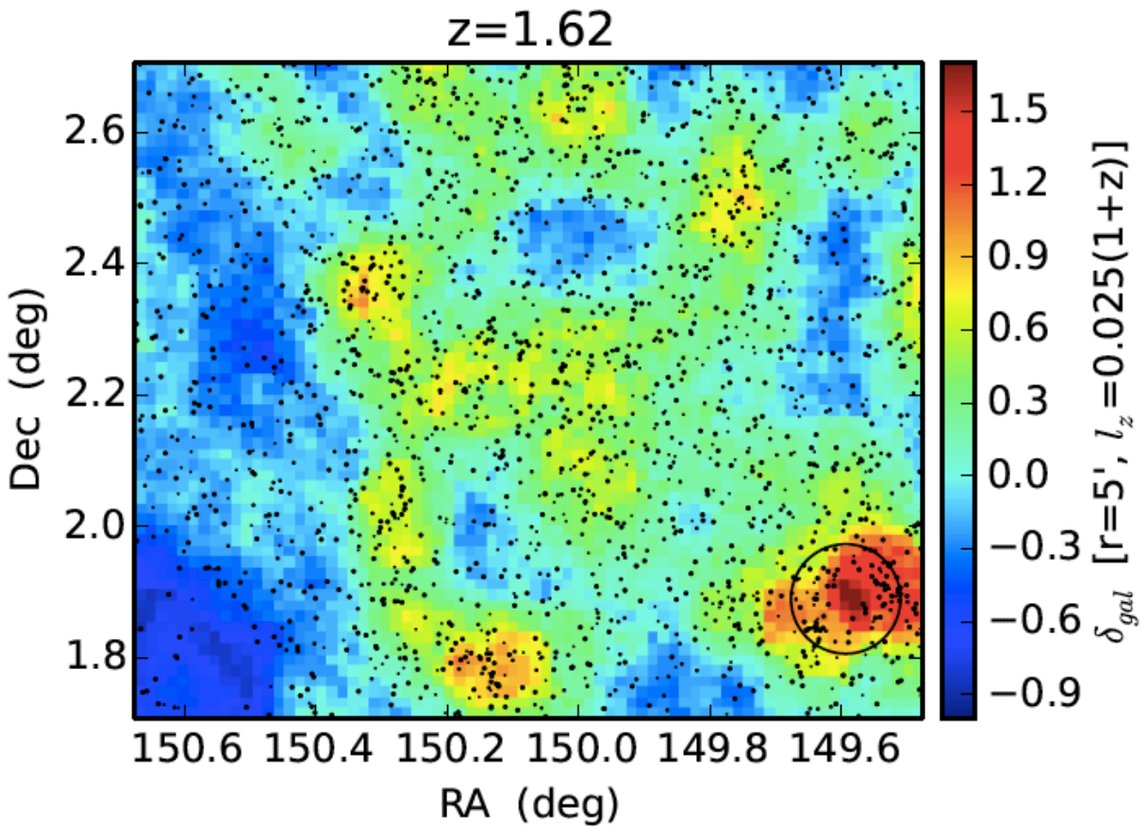
Break the degeneracy between metallicity and ionization parameter

Dust-obscured galaxies missed in FMOS-COSMOS

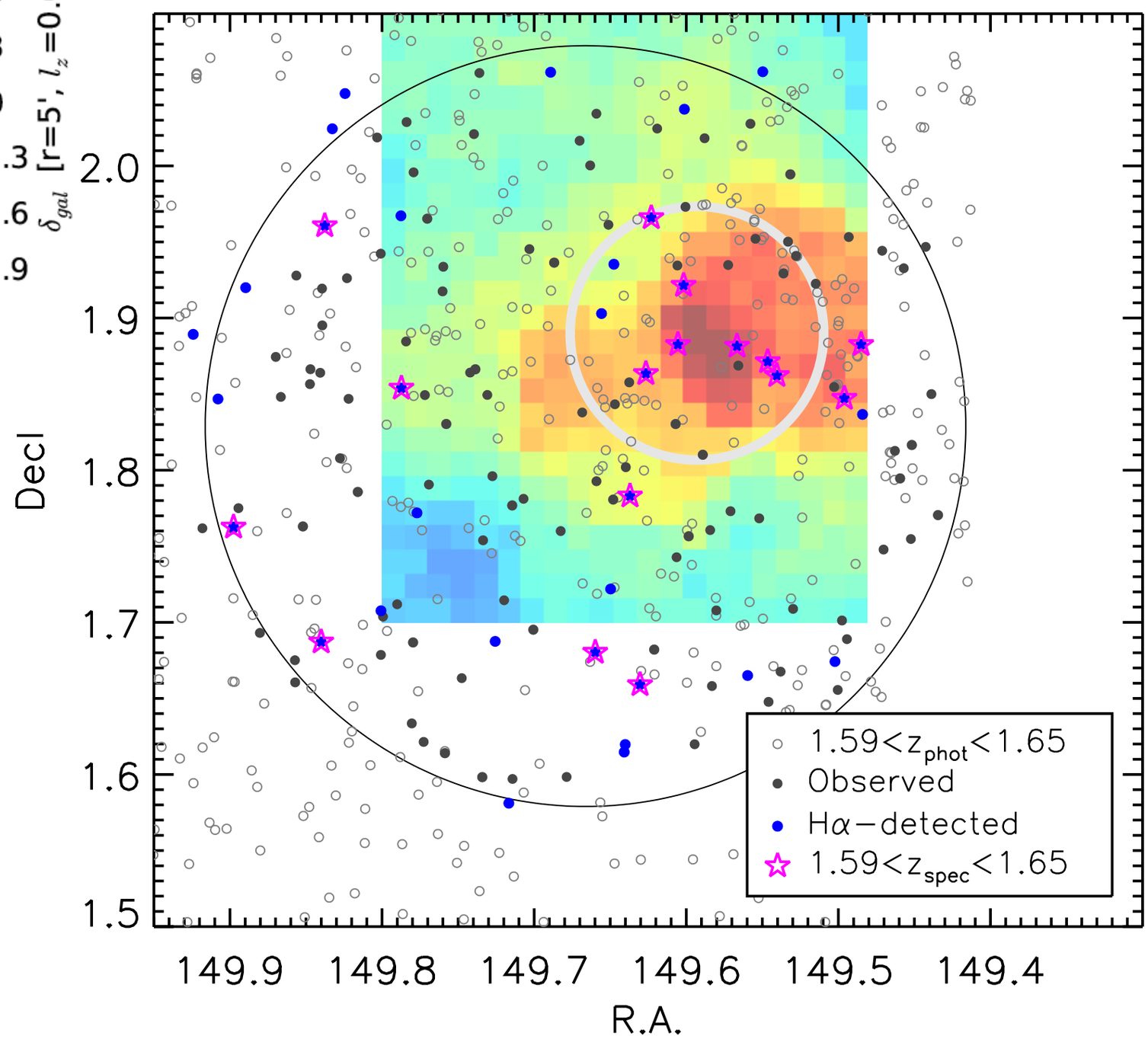


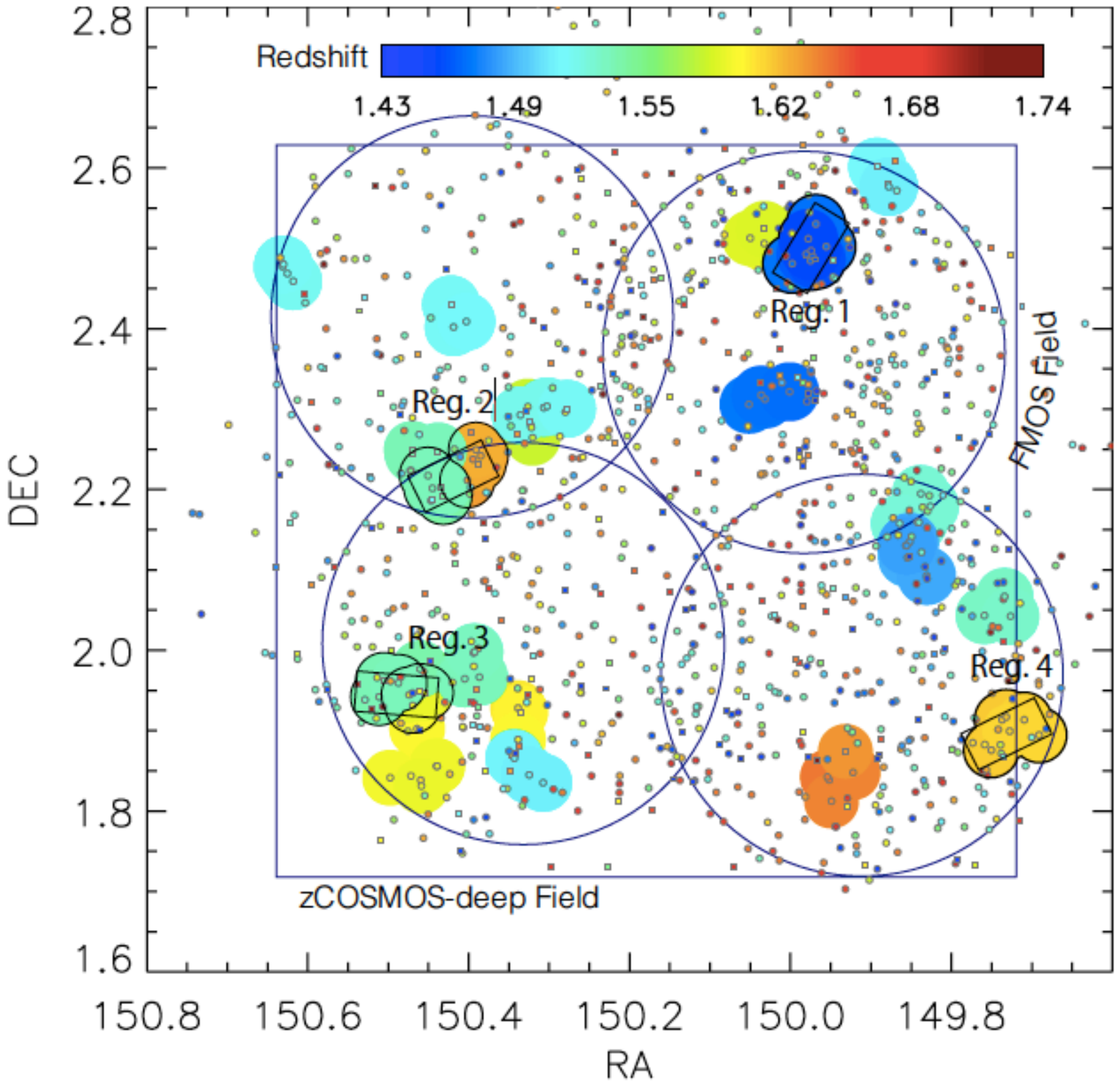


Confirming a galaxy overdensity in COSMOS at z ~ 1.6



Chiang, Overzier et al. 2015




Redshift
1.43
1.49
1.55
1.62
1.68
1.74
Reg. 1
Reg. 2
Reg. 3
Reg. 4
FMOS Field
zCOSMOS-deep Field
DEC
RA
2.8
2.6
2.4
2.2
2.0
1.8
1.6
150.8
150.6
150.4
150.2
150.0
149.8

FMOS-COSMOS current status

Have a 1k NIR spectroscopic catalog

(JDS et al. 2015, ApJS, 220, 12)

- Dust extinction is similar to low-redshift galaxies (Kashino et al. 2013, ApJL)
  - ★ Higher in high-mass galaxies
  - ★ More uniformly distributed

- SFR - M_* relation 'main sequence' (Kashino et al. 2013, ApJL)

- SFR indicators - UV, Hα and FIR (Rodighiero et al. 2014)

- Chemical enrichment (Zahid et al. 2014a; Zahid et al. 2014b)
  - ★ High-mass galaxies have metallicities reaching the local relation
  - ★ Steeper mass - metallicity relation
  - ★ mass-metallicity-SFR relation is not so fundamental

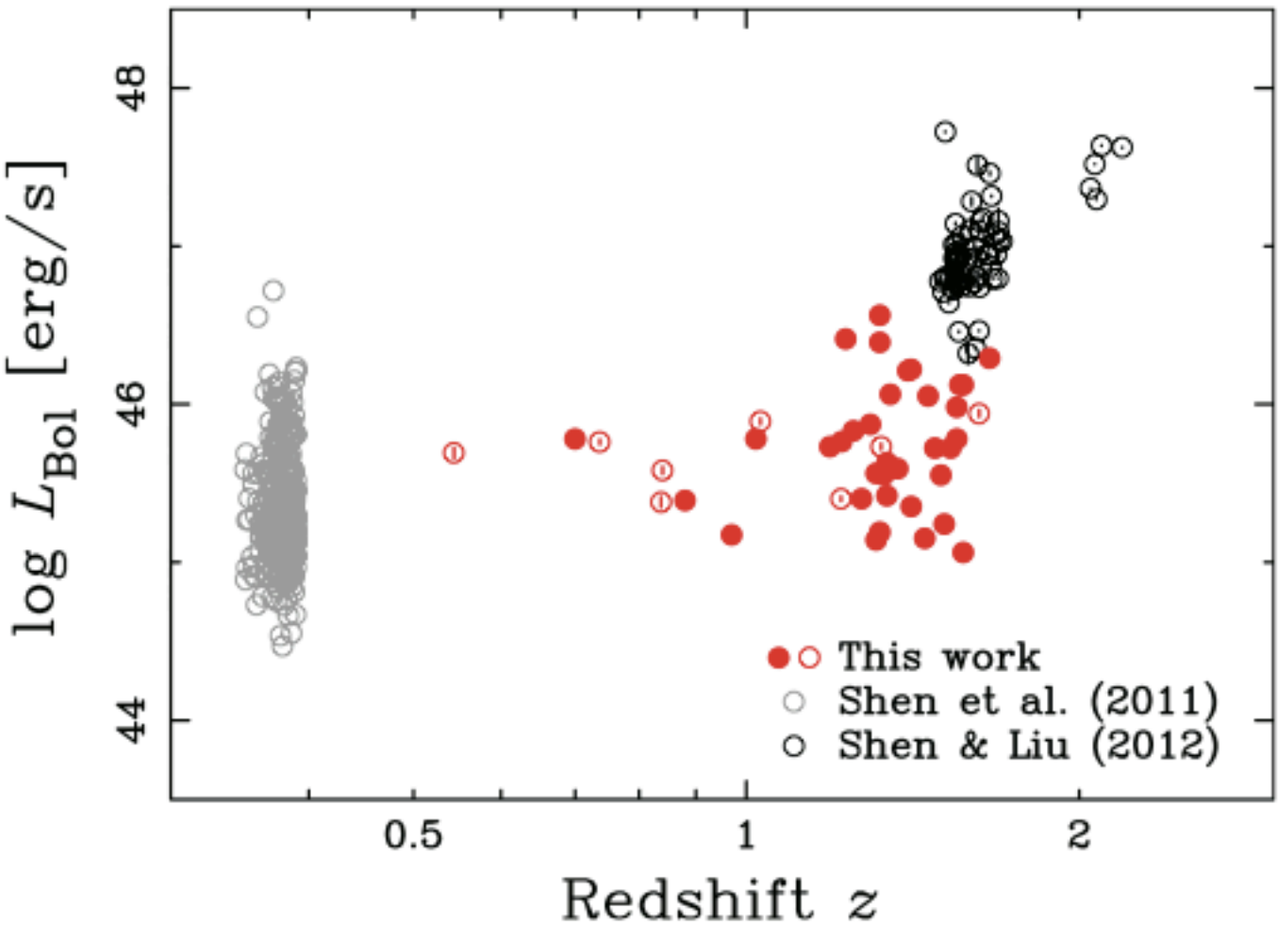
- Ionization state (BPT; Kartaltepe, Sanders, JDS et al. 2015; Kashino et al. in prep; Schulze et al.)

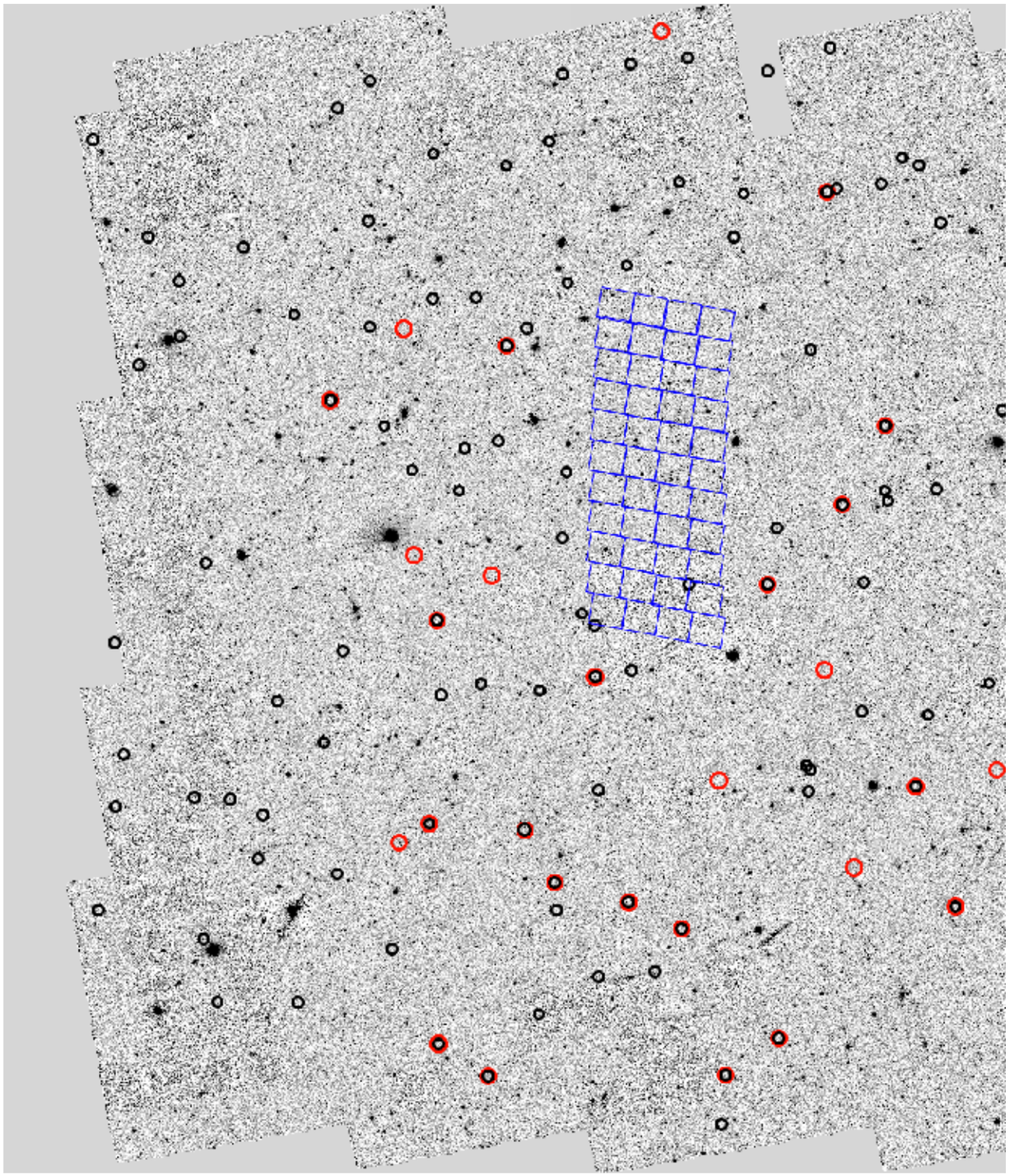
- Next: FMOS-COSMOS intensive program II; Keck + VLT spectroscopy - [OII]λ3727

AGN: Black hole masses at high-z

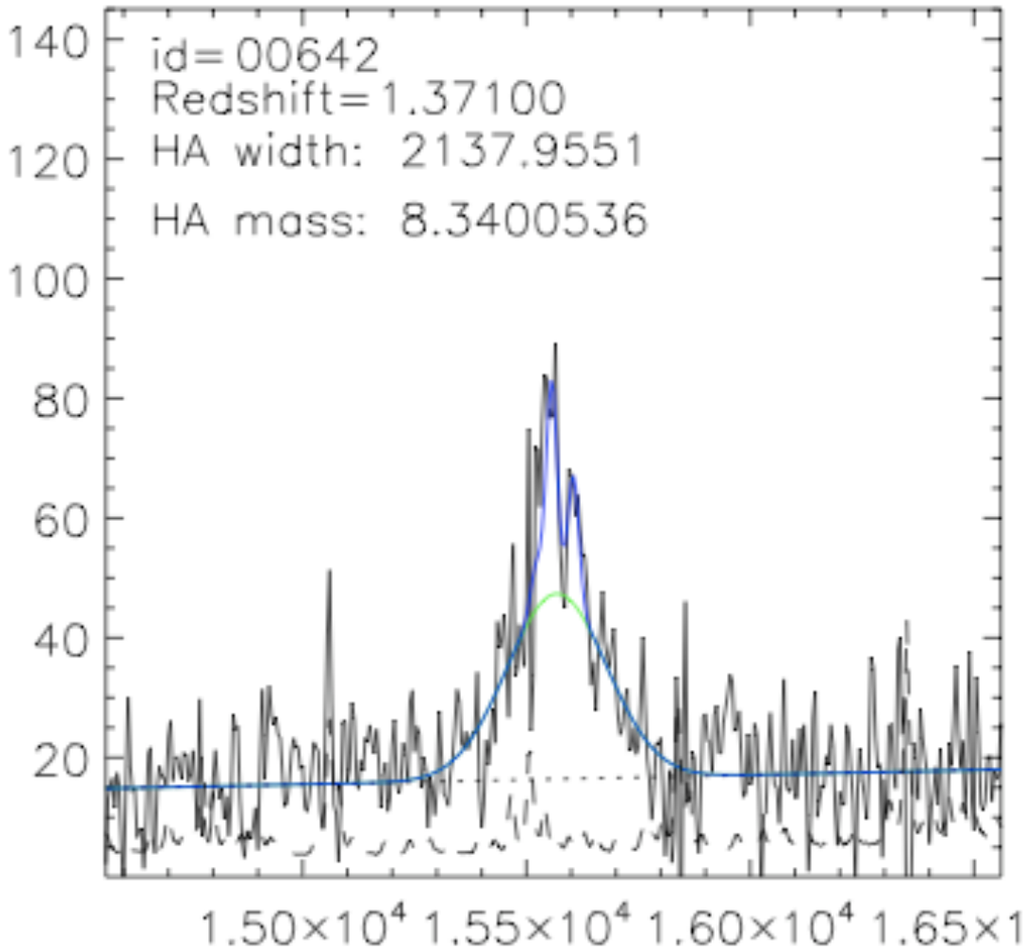
X-ray selected AGNs in COSMOS

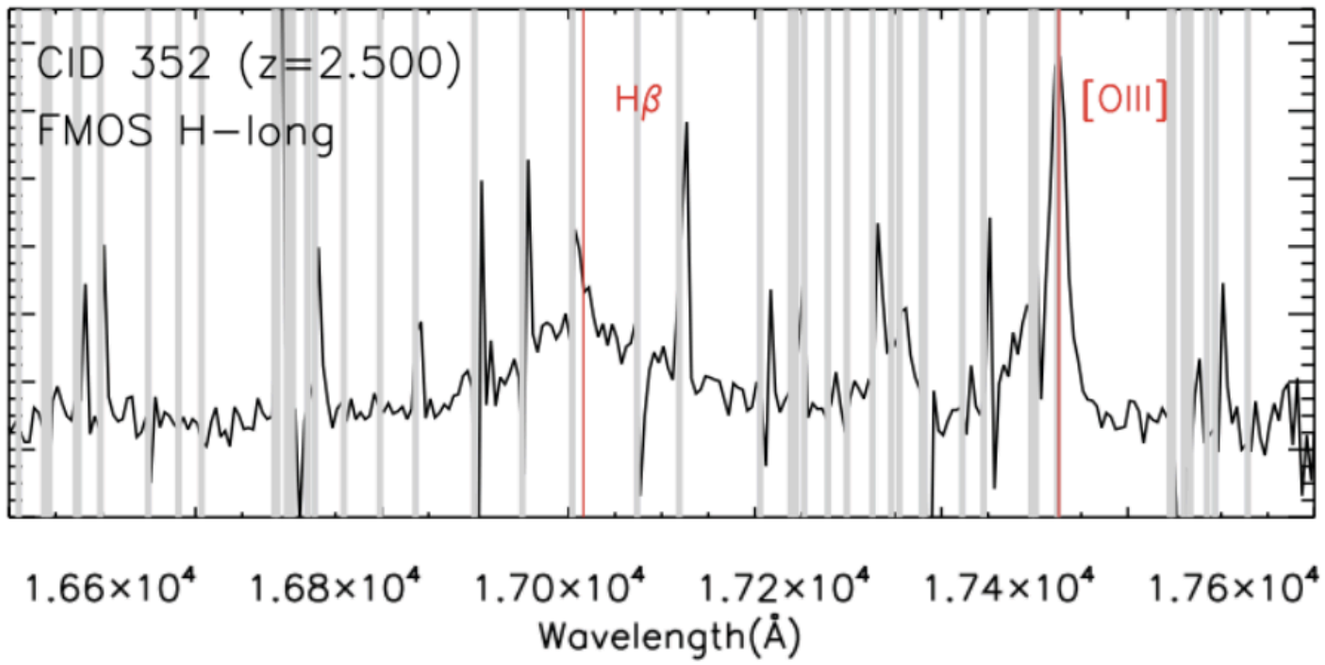
Matsuoka, JDS





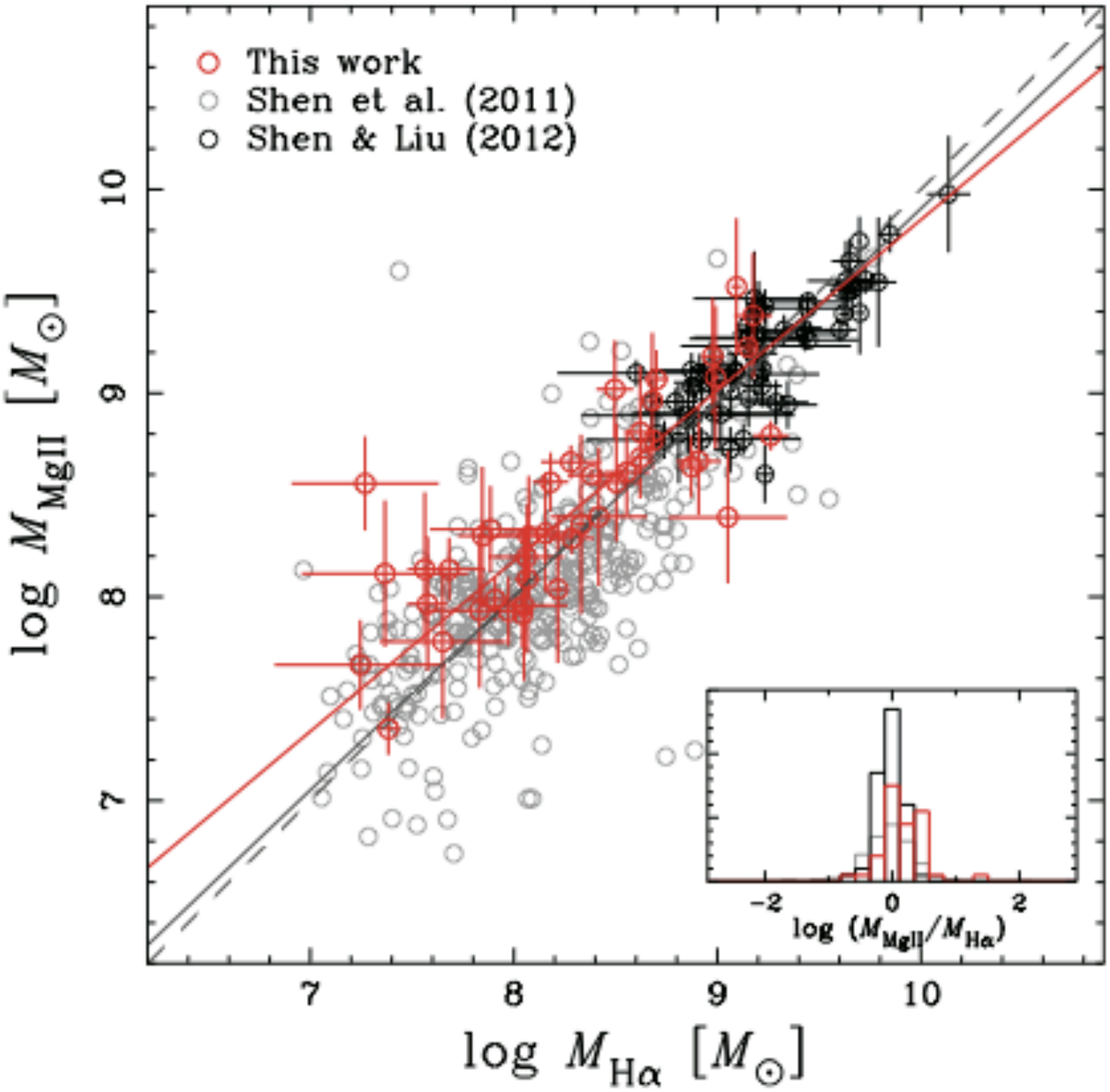
AGN: Black hole masses at high-z





Matsuoka, JDS et al. 2013

AGN: Black hole masses at high-z



BH - bulge relation at high-z

18 type 1 AGNs (0.5 < z < 1.2) in the *Chandra* Deep Field South Survey

- X-ray selection

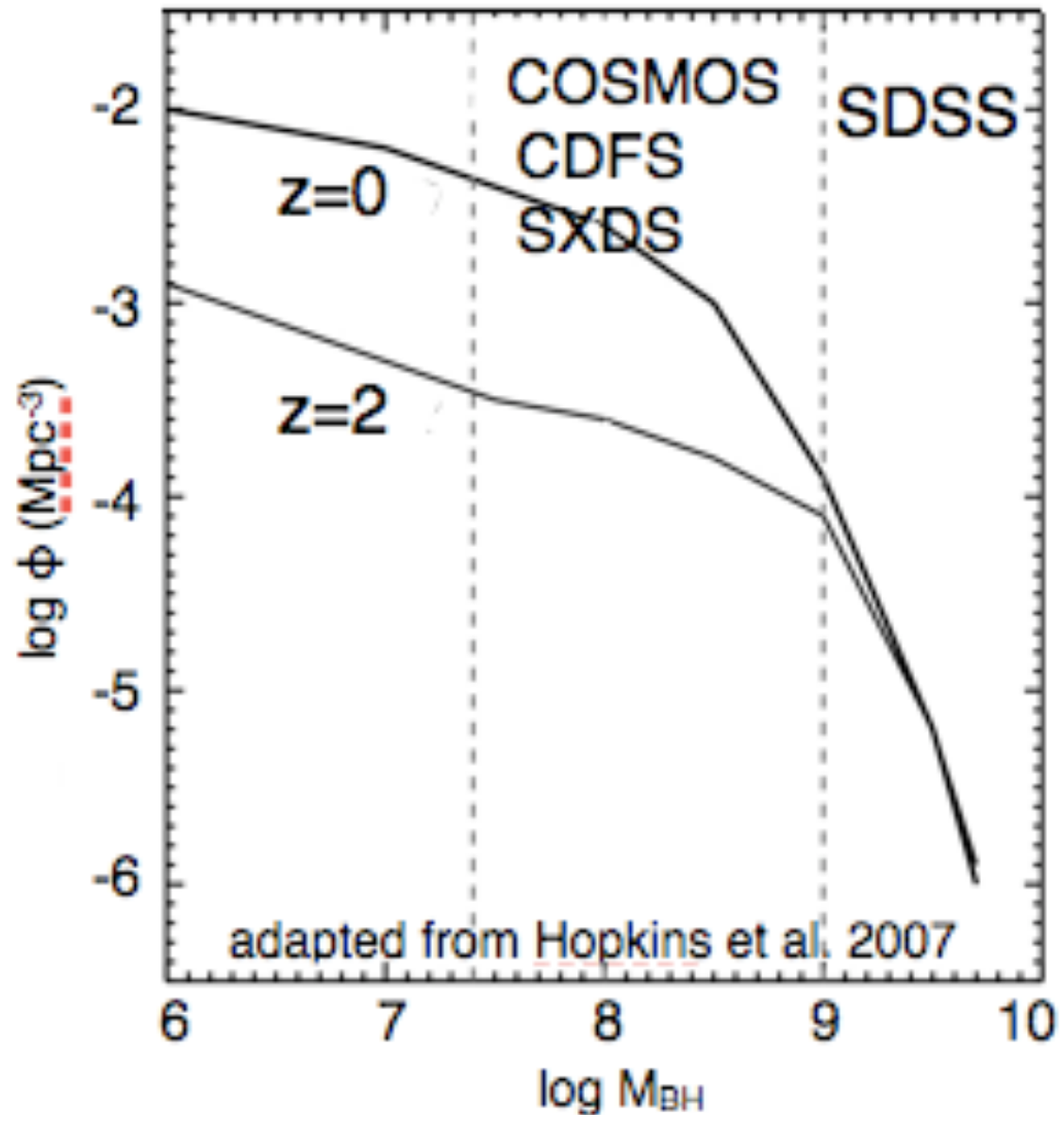
  - AGN selected to be below the knee of the black hole mass function

  - optically underluminous

- Two HST bands that bracket the 4000 Å break: F606W (V-band) and F850LP (z-band)

- Direct PSF/Bulge/disk decomposition
  - Nuclear / host ratio < 2 (14/18 AGN)

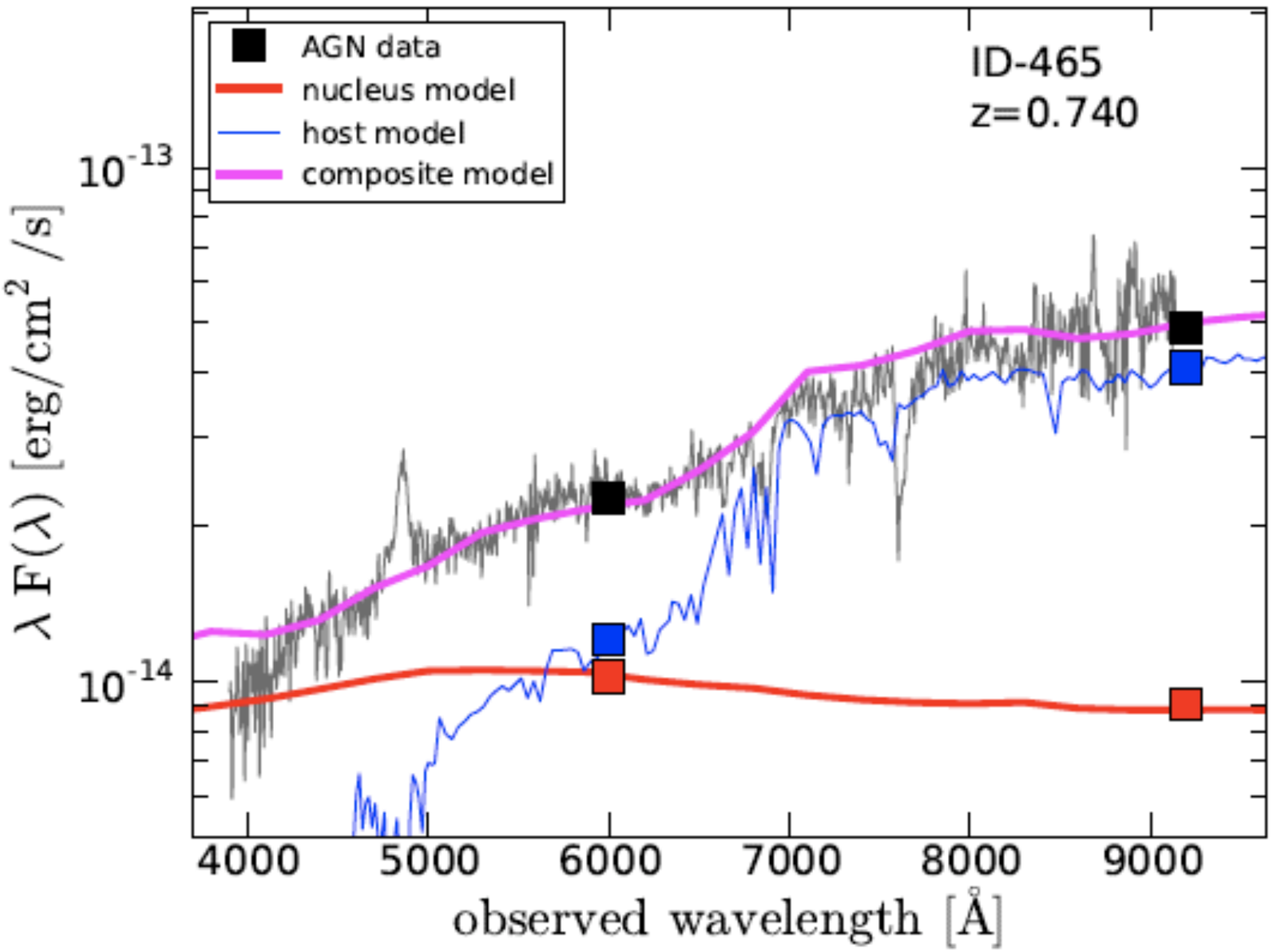
- Bulge mass estimates through simulations
  - Nuclear / host ratio > 2



BH - bulge relation at high-z

18 type 1 AGNs (0.5 < z < 1.2) in the Chandra Deep Field South Survey

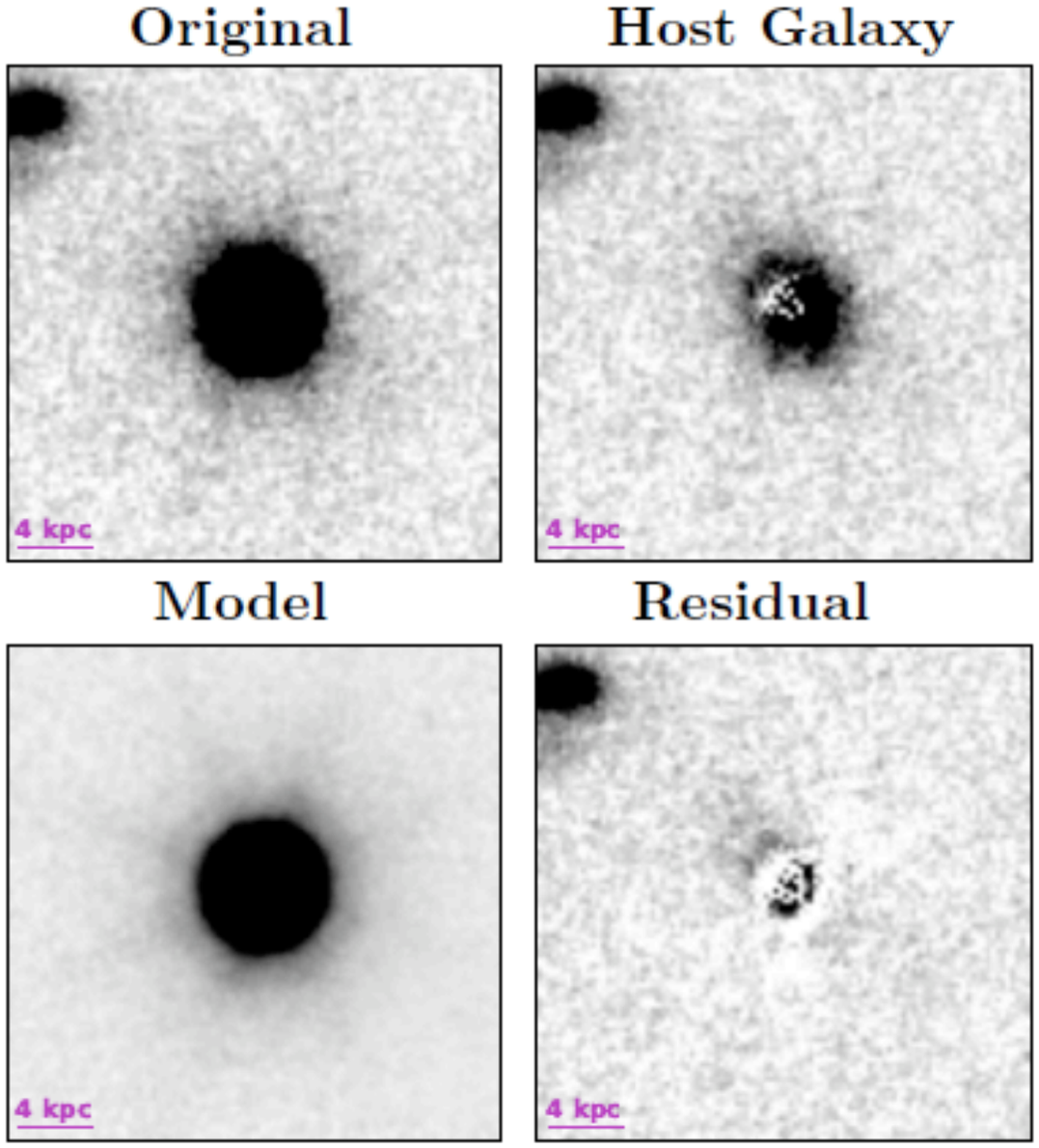
F606W (V-band) and F850LP (z-band)

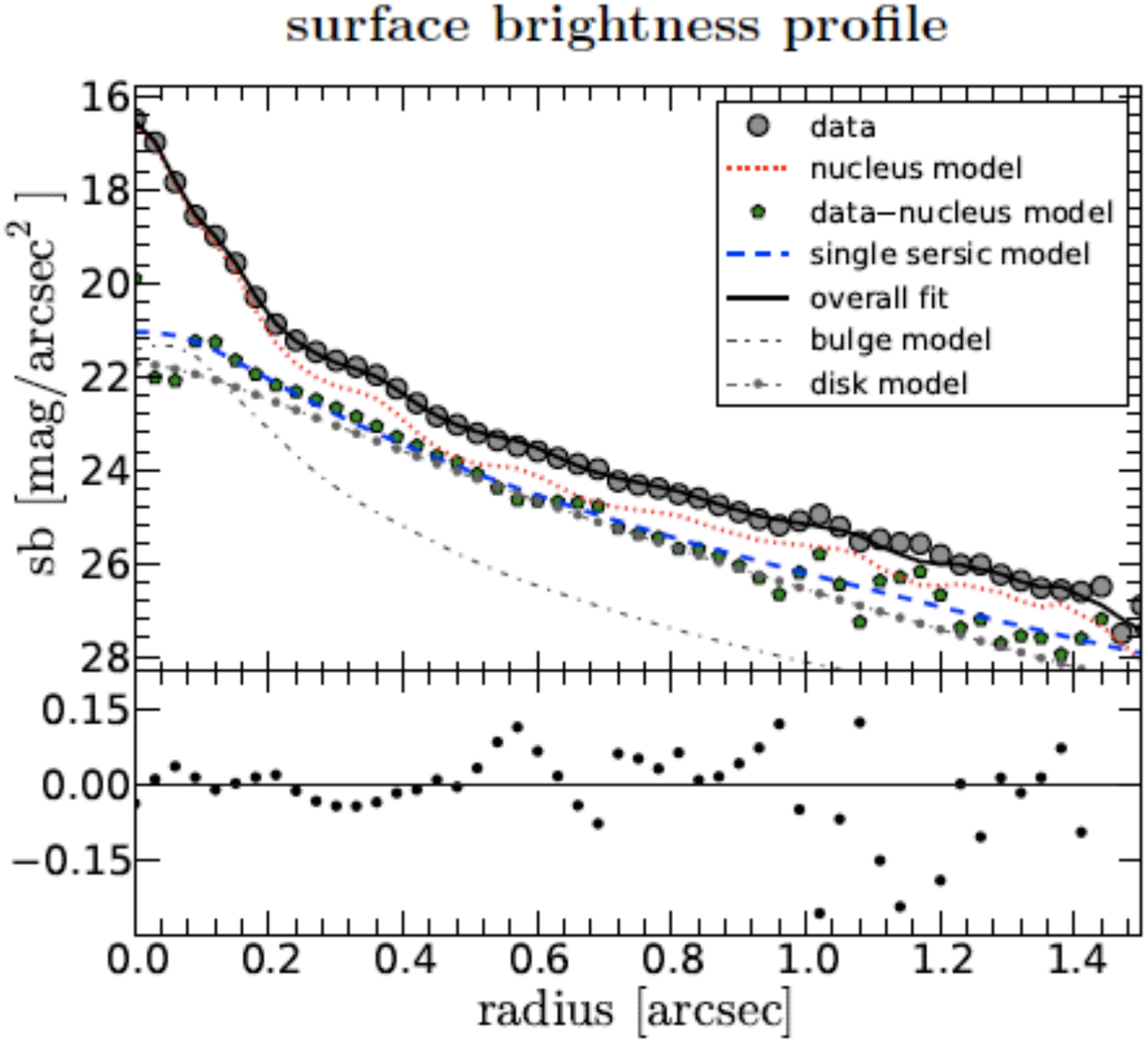


AGN: Black hole - host mass relation at high-z

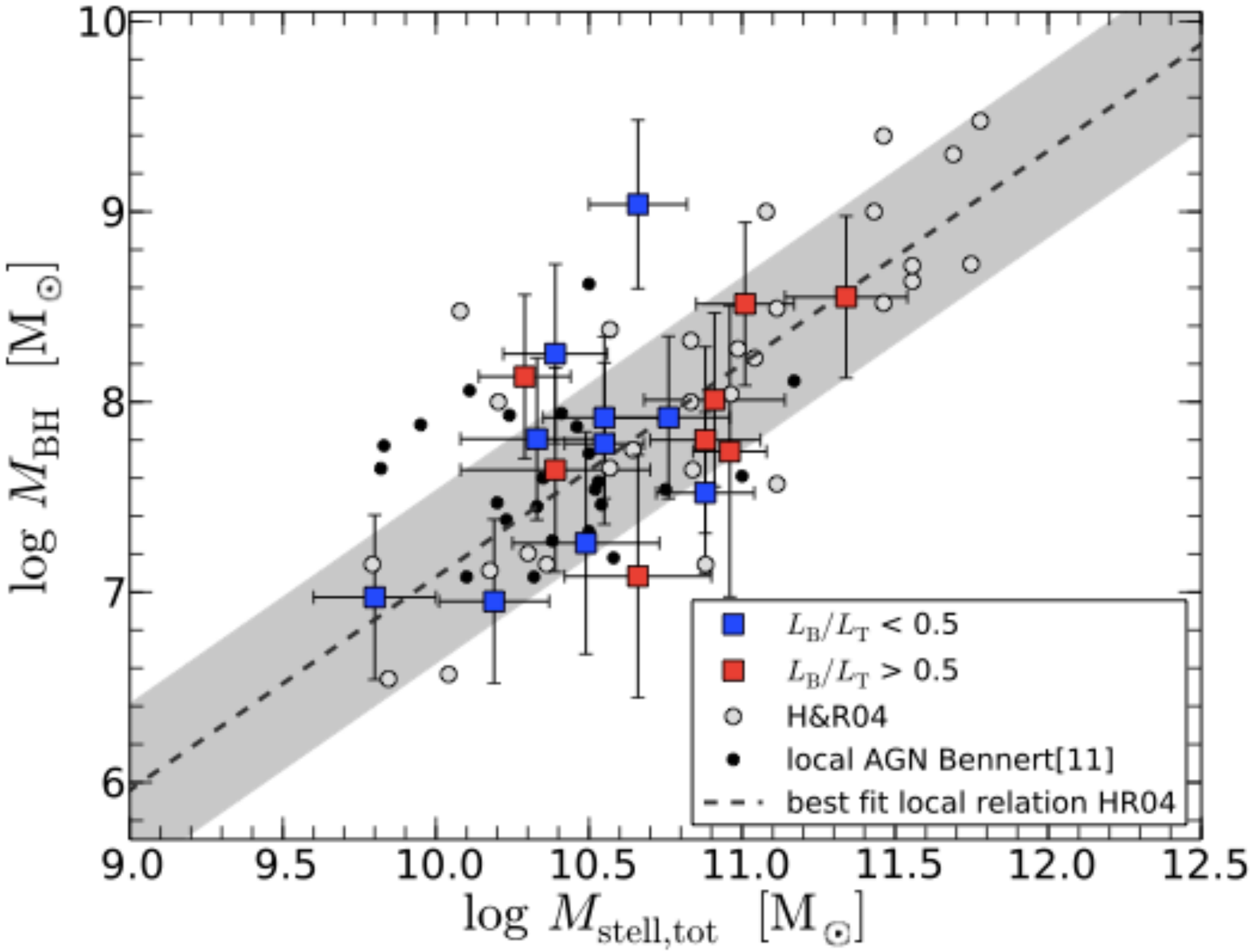
18 type 1 AGNs (0.5 < z < 1.2) in the Chandra Deep Field South Survey

F606W (V-band) and F850LP (z-band)

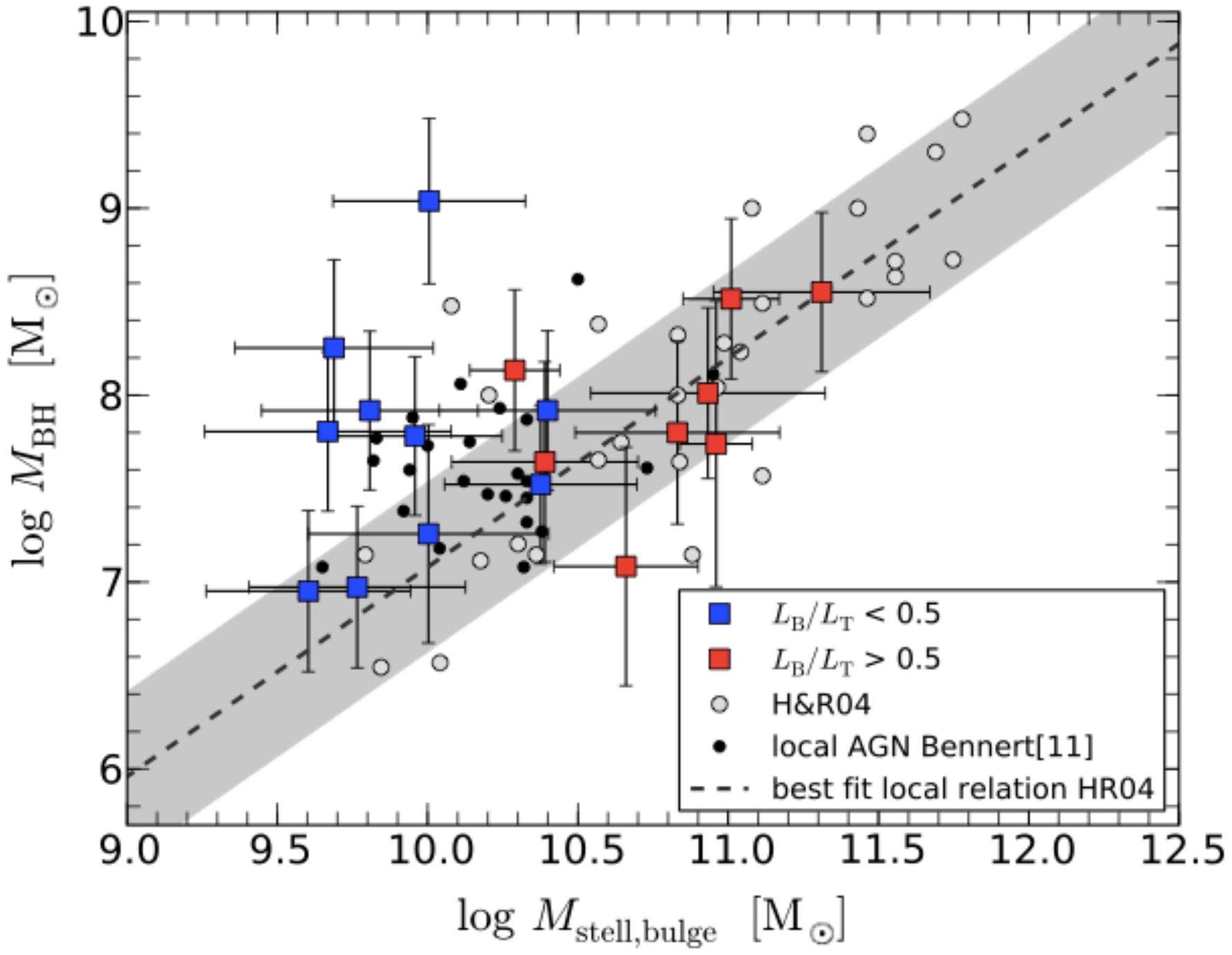


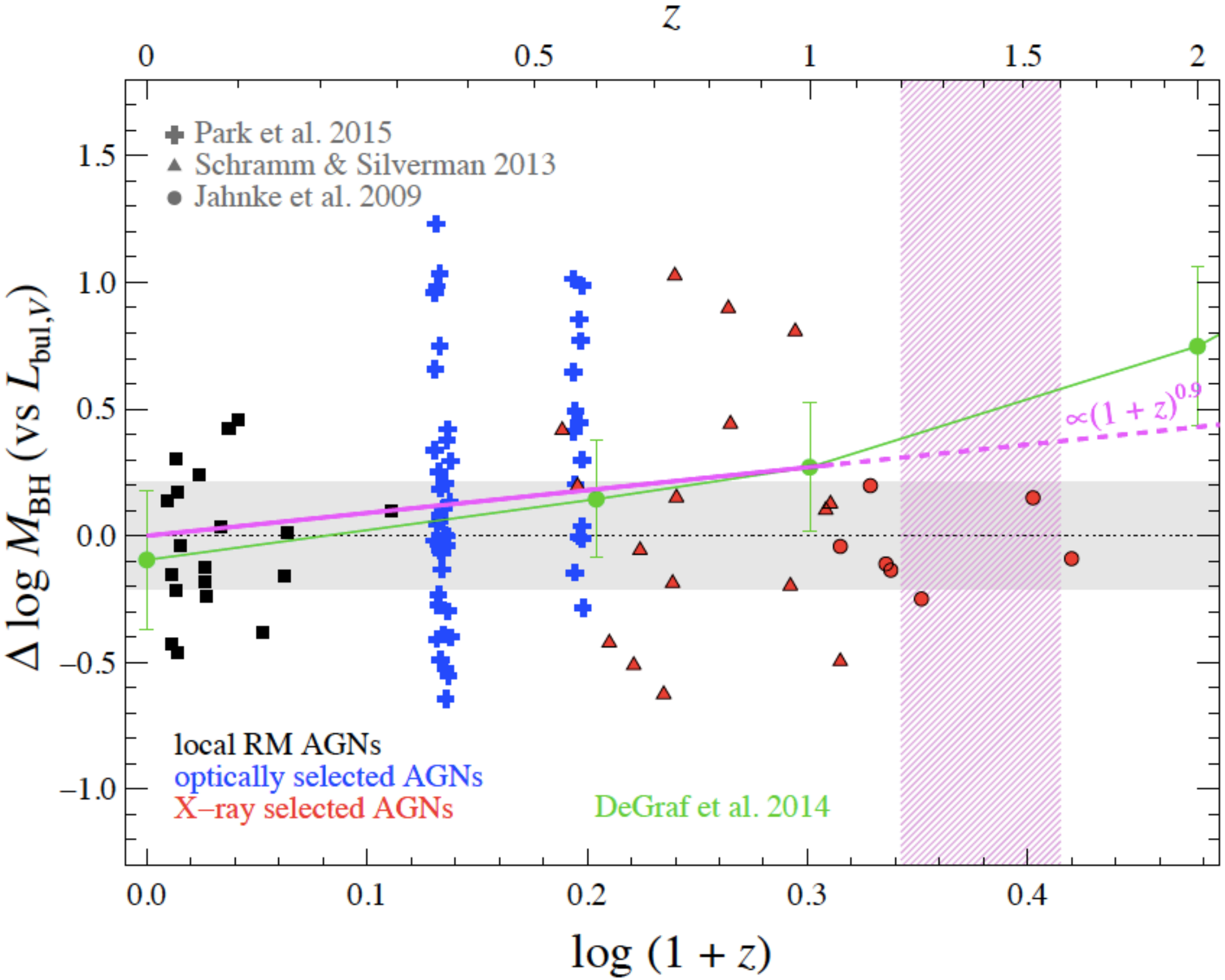


AGN: Black hole - host mass relation at high-z



AGN: Black hole - host mass relation at high-z




z
0
0.5
1
1.5
2
Park et al. 2015
Schramm & Silverman 2013
Jahnke et al. 2009
1.5
1.0
0.5
0.0
−0.5
−1.0
Δ log M_BH (vs L_bul,V)
∝(1 + z)^0.9
local RM AGNs
optically selected AGNs
X−ray selected AGNs
DeGraf et al. 2014
0.0
0.1
0.2
0.3
0.4
log (1 + z)

Use of TAO-SWIMS

Dust-obscured galaxies
(missed by FMOS-COSMOS)

Dynamic properties of proto-groups/clusters

AGN science

Spectroscopic support for HSC SSP