FMOS-COSMOS survey of star-forming galaxies at z ~ 1.6

(Progress report on a Subaru intensive program)

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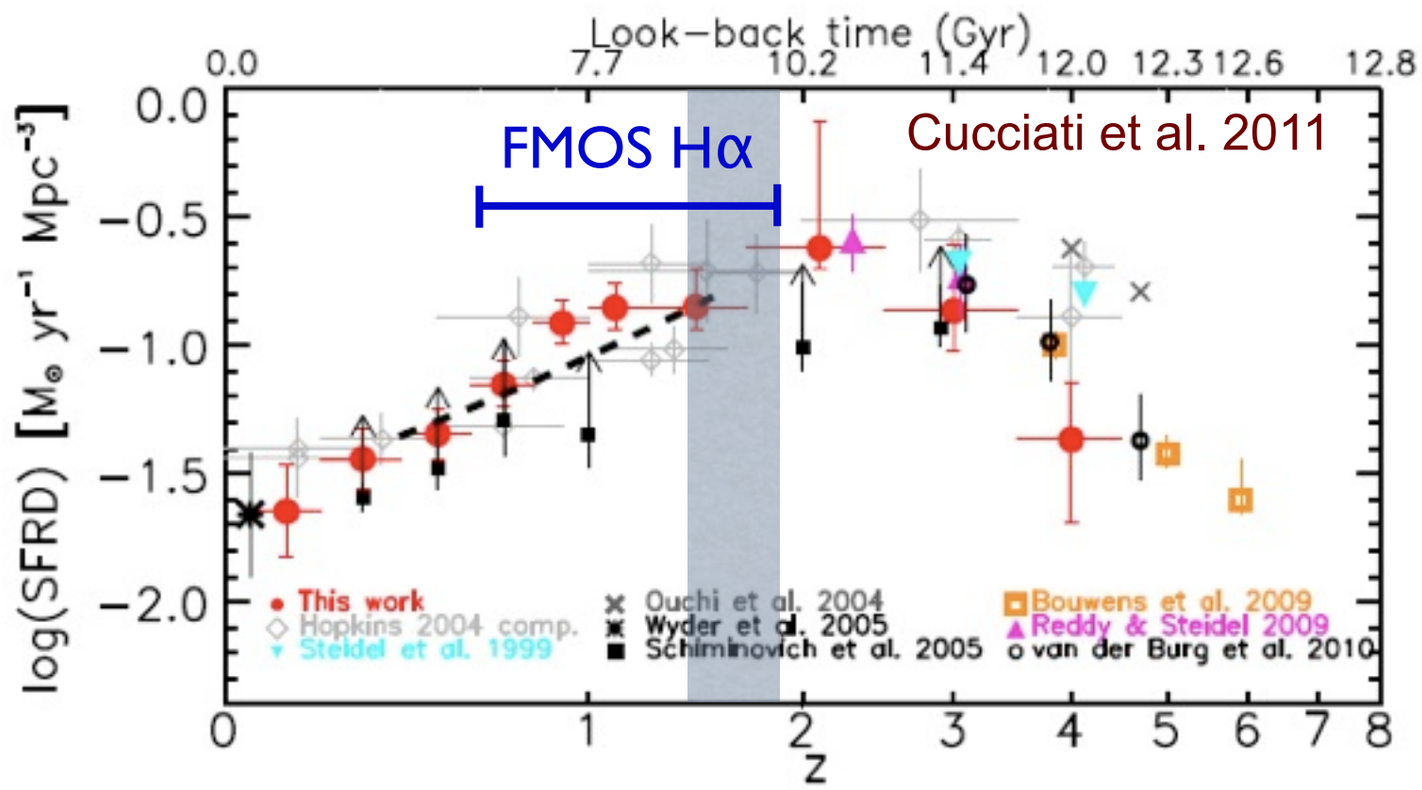
How are galaxies and their supermassive black holes built up with cosmic time?

Galaxy properties: z_{spec}, M_{*}, SFR
ISM: metallicity, M_{gas}, M_{dust}

Central black black hole: L_{bol}, M_{BH}

Environment: δ_{local}, M_{halo}



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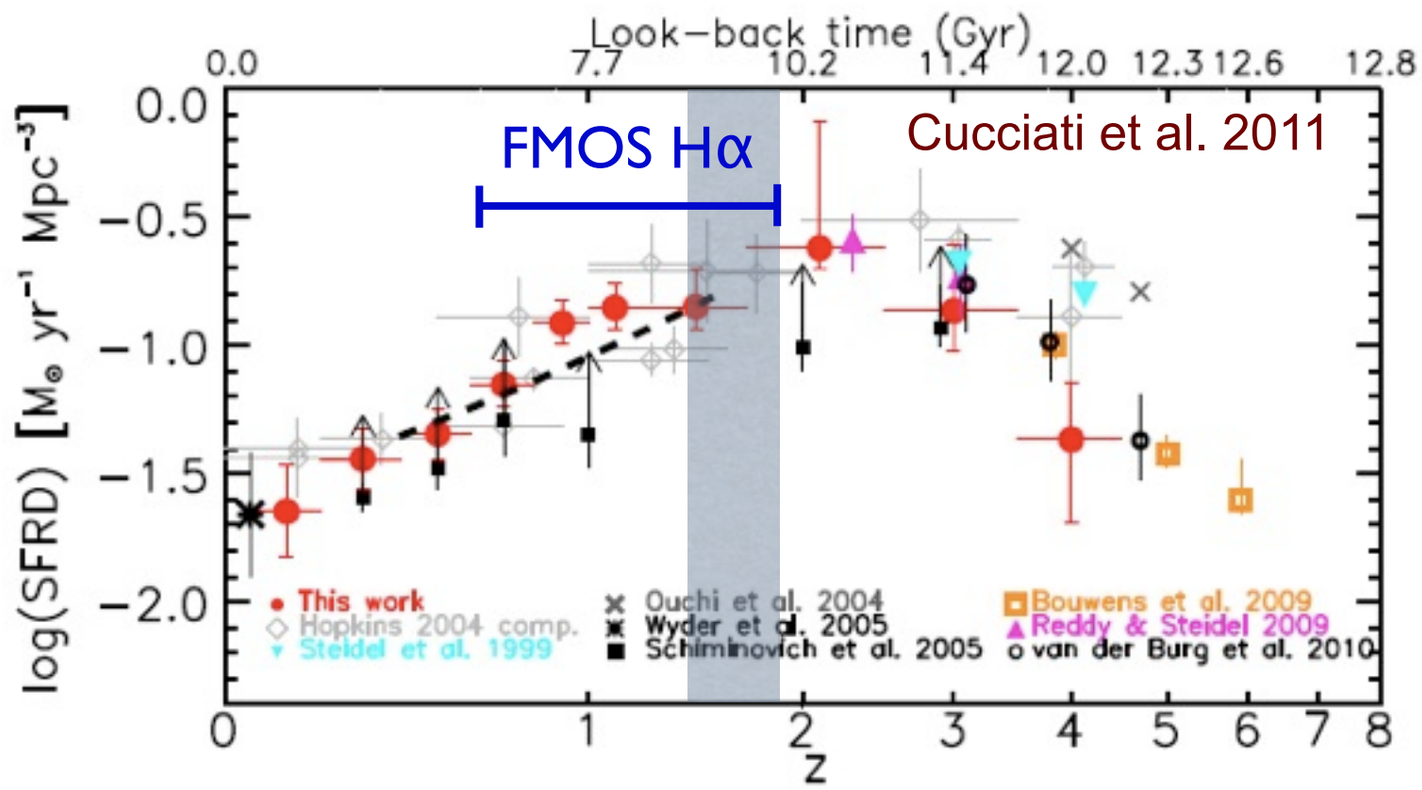
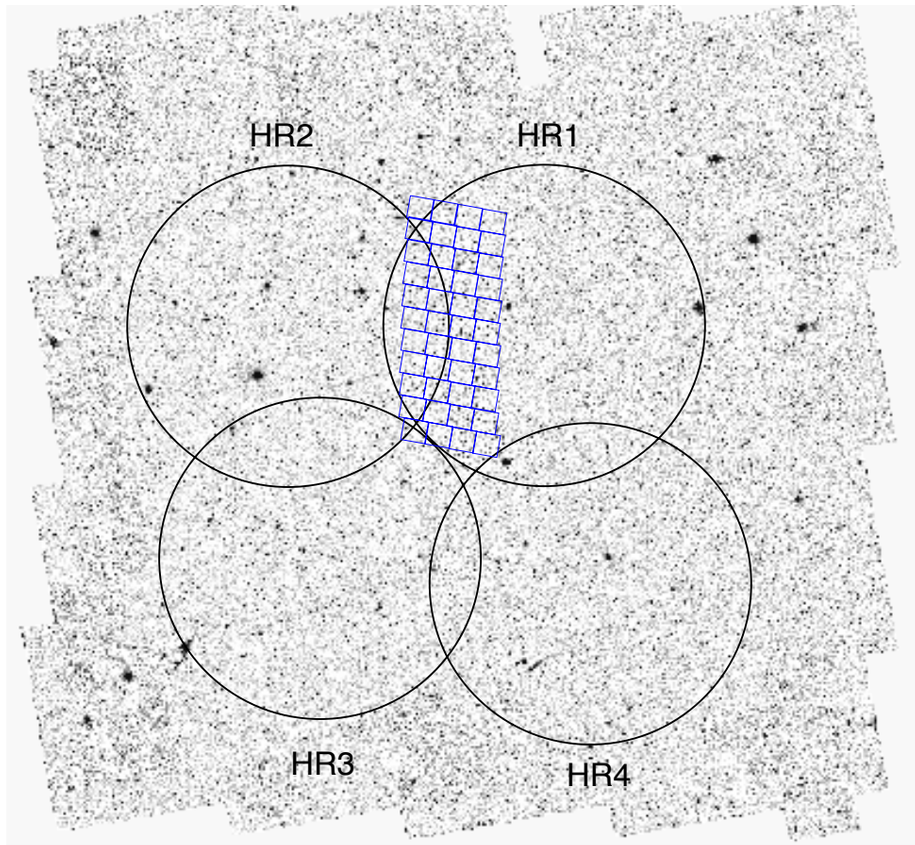


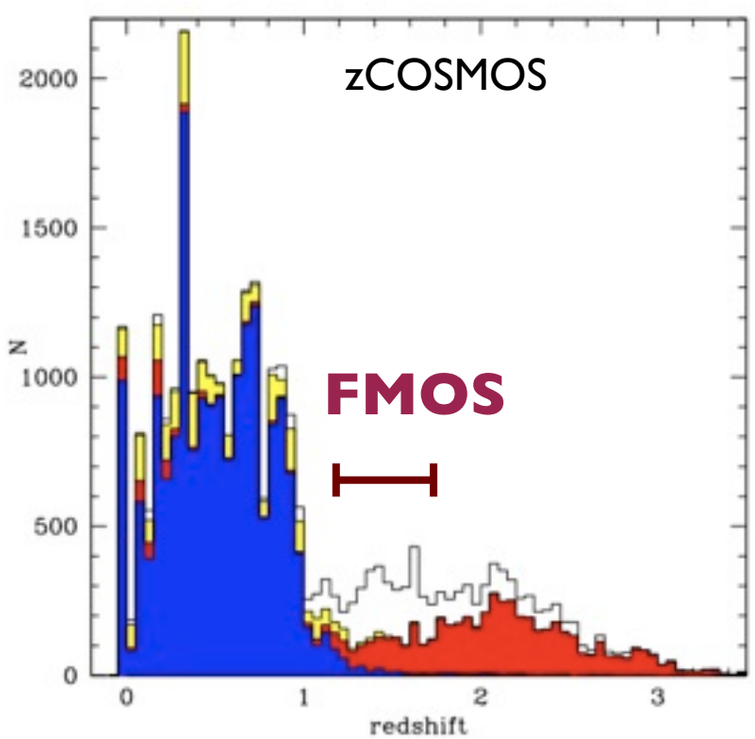
An Hα survey of galaxies in COSMOS with Subaru/FMOS

- large IR spectroscopic redshift survey (> 1000 spectra) with FMOS
  - Effectively ~200 science fibers
  - Resolution ~2200
    - can separate Hα and [NII]
    - high emission-line sensitivity



- accurate SFR
  - measured in the say way at z=0 (i.e., Hα)
  - 1-1.7 μm (Hα between 0.5 < z < 1.8)
  - Hα less affected by dust extinction

than [OII]3727, more responsive to the UV ionizing flux from young stars, not affected by variations in metallicity



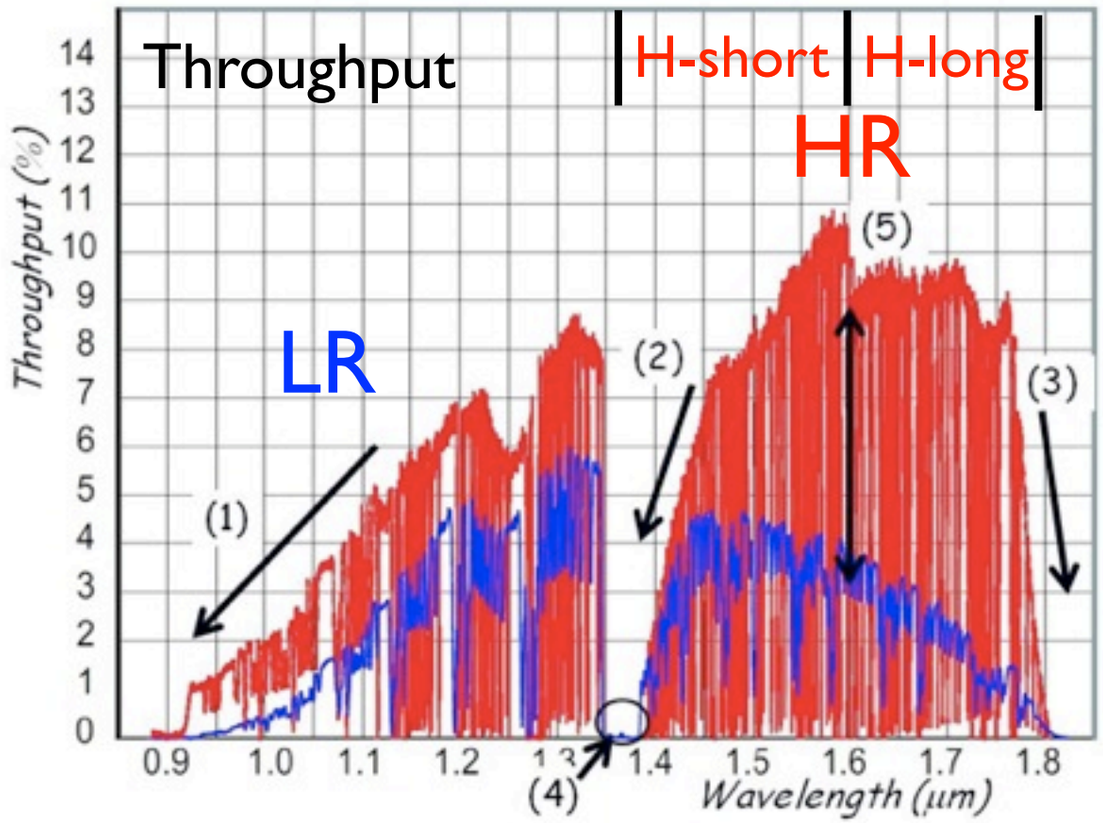
- characterization of the local density field
  - general galaxy population
  - beyond z ~1 for the first time

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
- Echidna fiber system
- 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)

- Initial results (Yabe et al. 2012; Roseboom et al. 2012; Matsuoka, JDS et al. 2013)

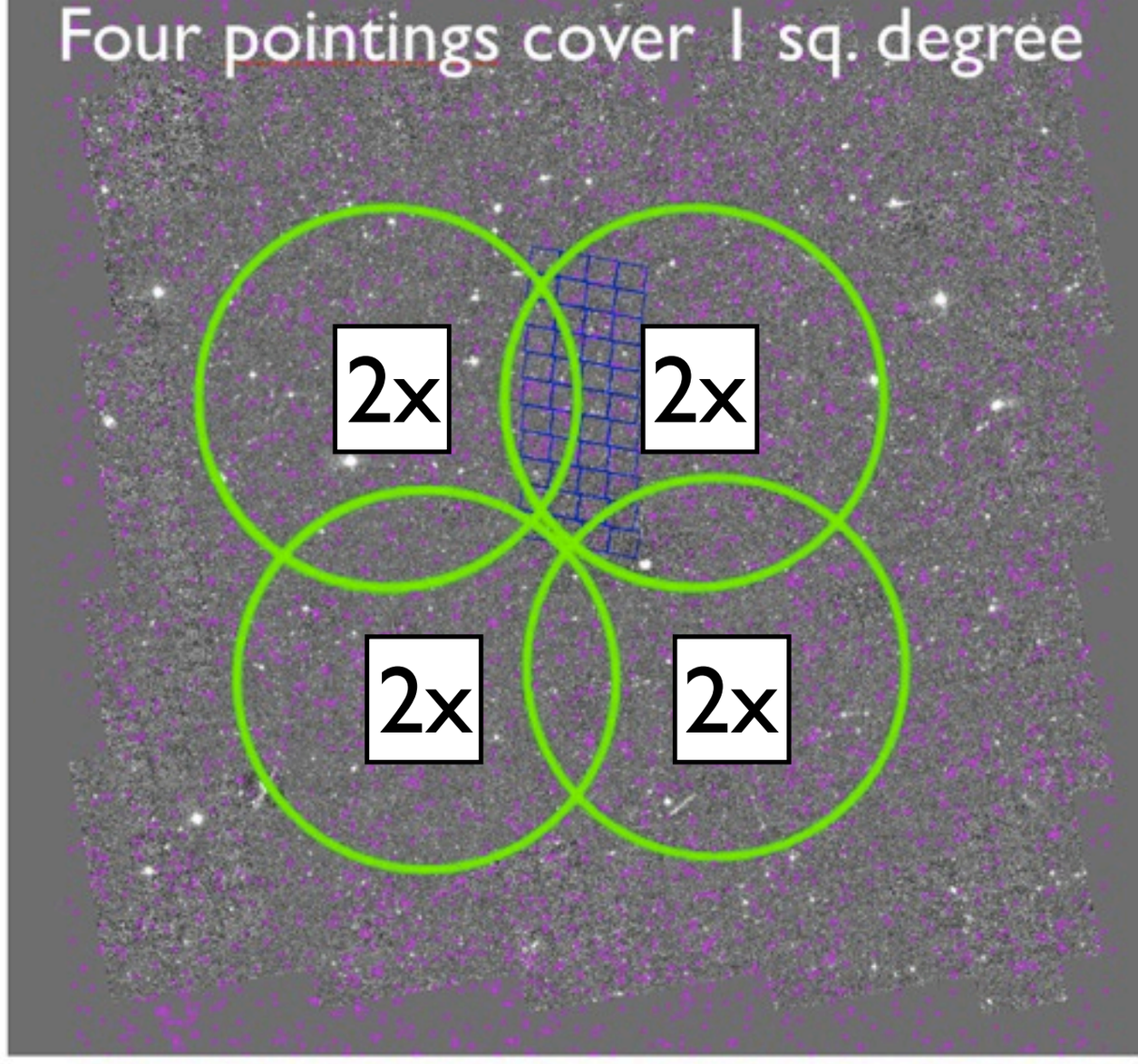


FMOS observations

H-long (Hα)

14 nights (S12A-S14A; Japan time)
[last 7 nights completed in S14A]

- Pilot survey: 5 nights in March 2012
- Additional time through IfA (J. Zahid)
- NAOJ Intensive program (PI: JDS)
  (8 nights awarded)
- 4-5 hour integration time per pointing



J-long (Hβ+[OIII])

14 nights (S12A-S14A; UH/IfA time)

- IfA time (PI: Dave Sanders)

Over 1200 spectra
(H-long; 1.6-1.8um)

50% observations in hand

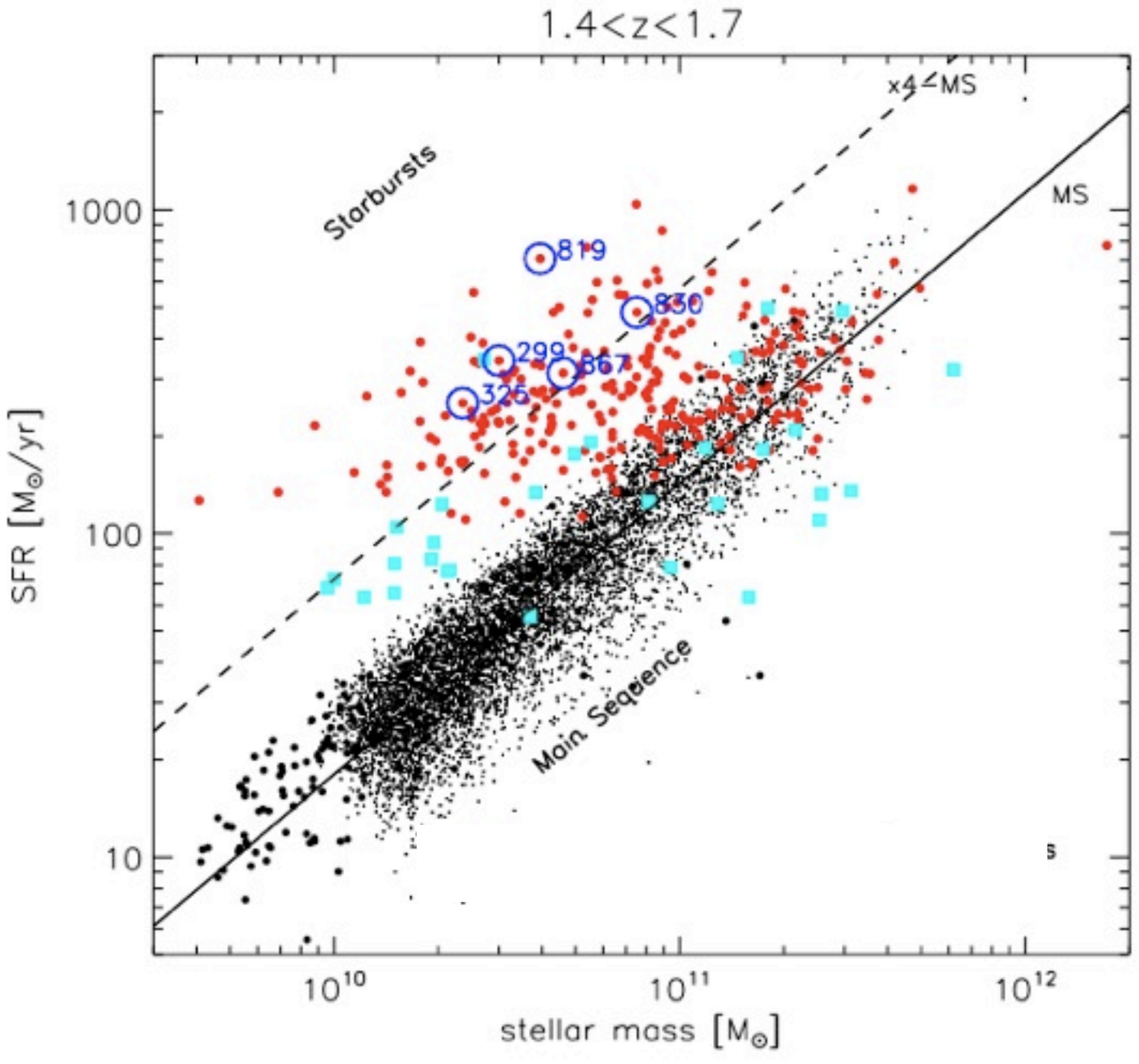
466 with a redshift

Target selection

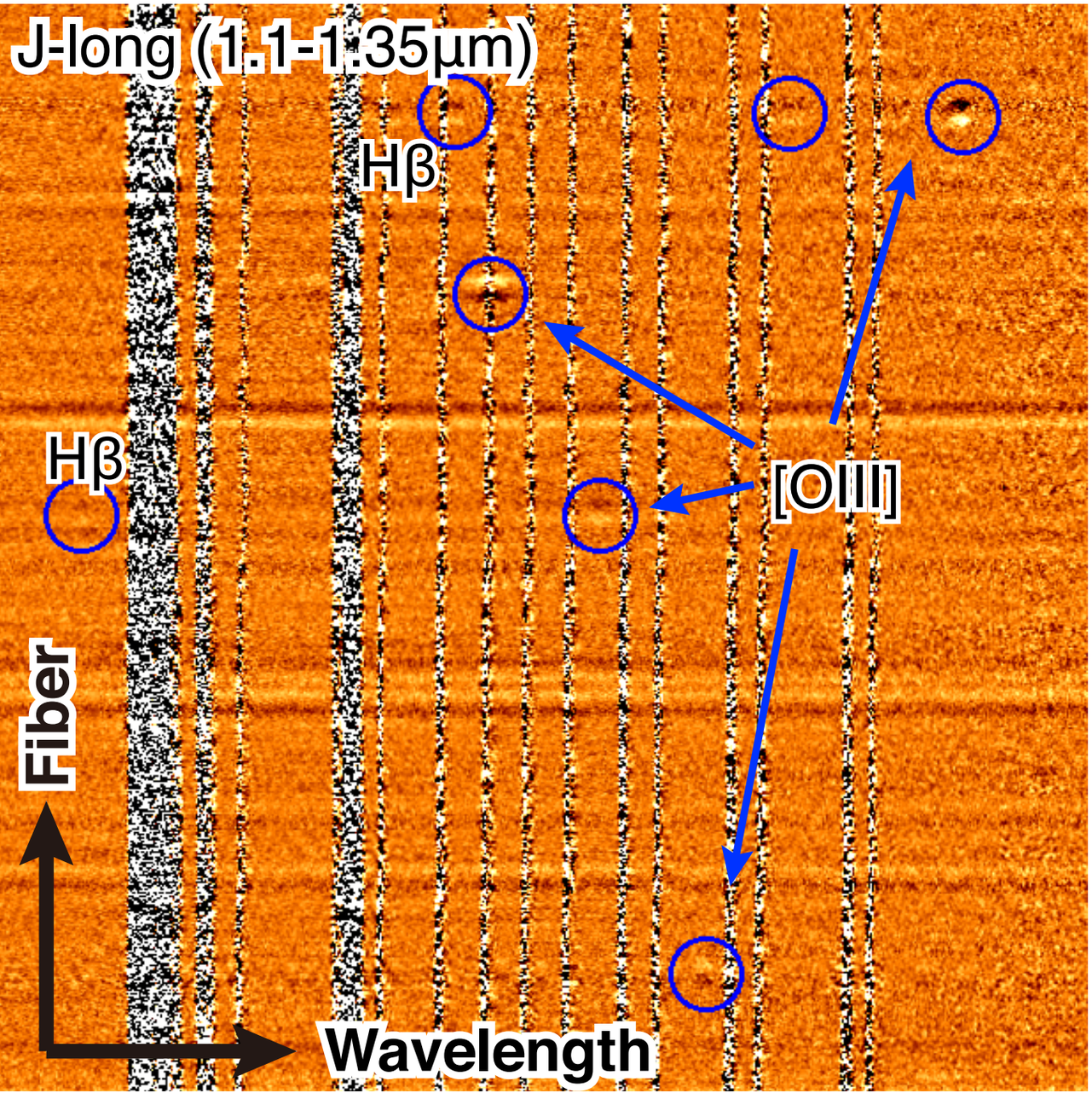
- star-forming galaxies
  - K-selected ($M_* > 10^{10}\ M_\odot$)
  - sBzK
  - along the star-forming main sequence
  - $f_{H\alpha} > 4 \times 10^{-17}$ erg cm^{-2} s^{-1}

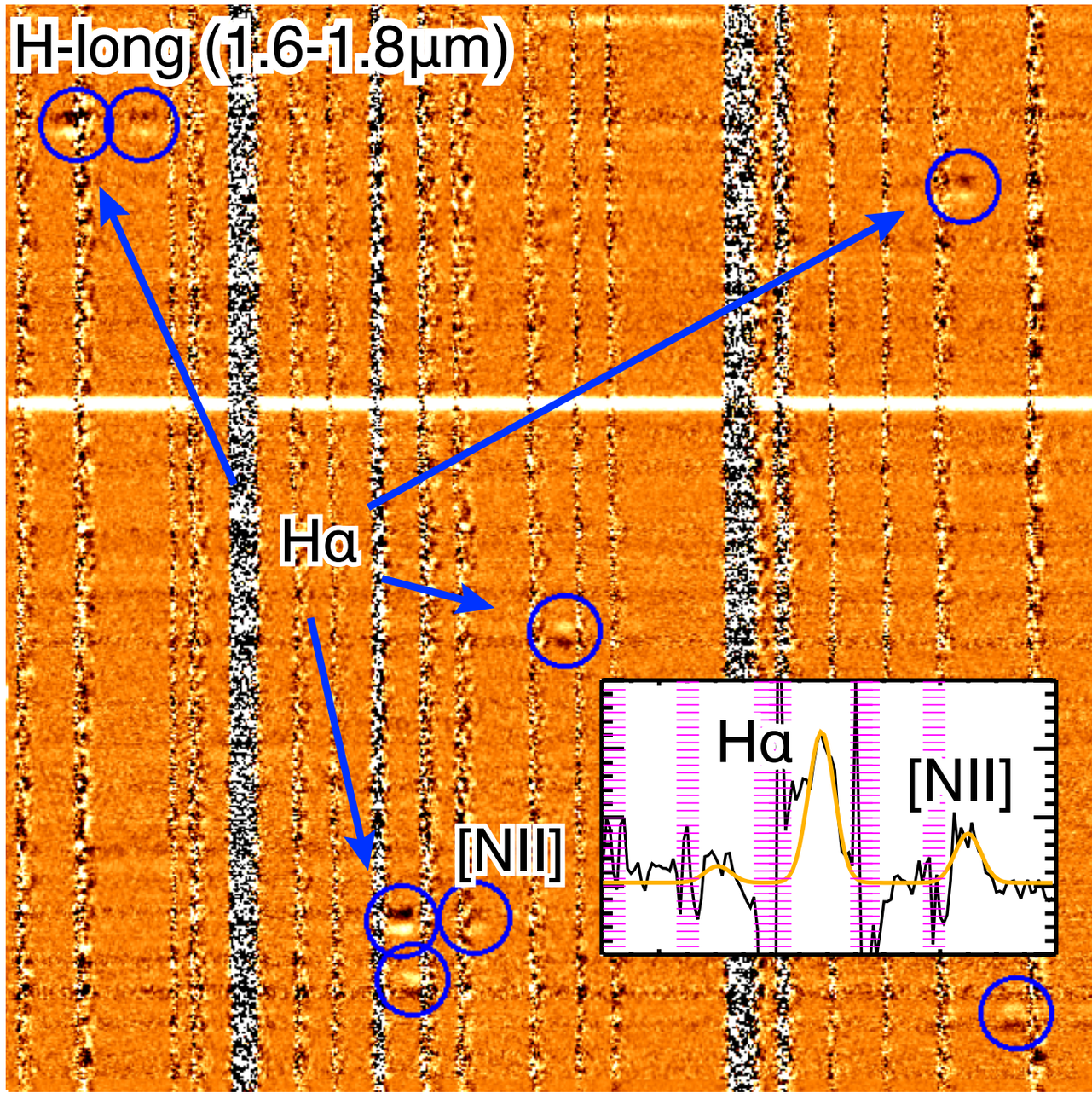
- Herschel/PACs sources
  - highly obscured SF galaxies
  - above or on M-S
  - near bright stars for future IFU/AO observations

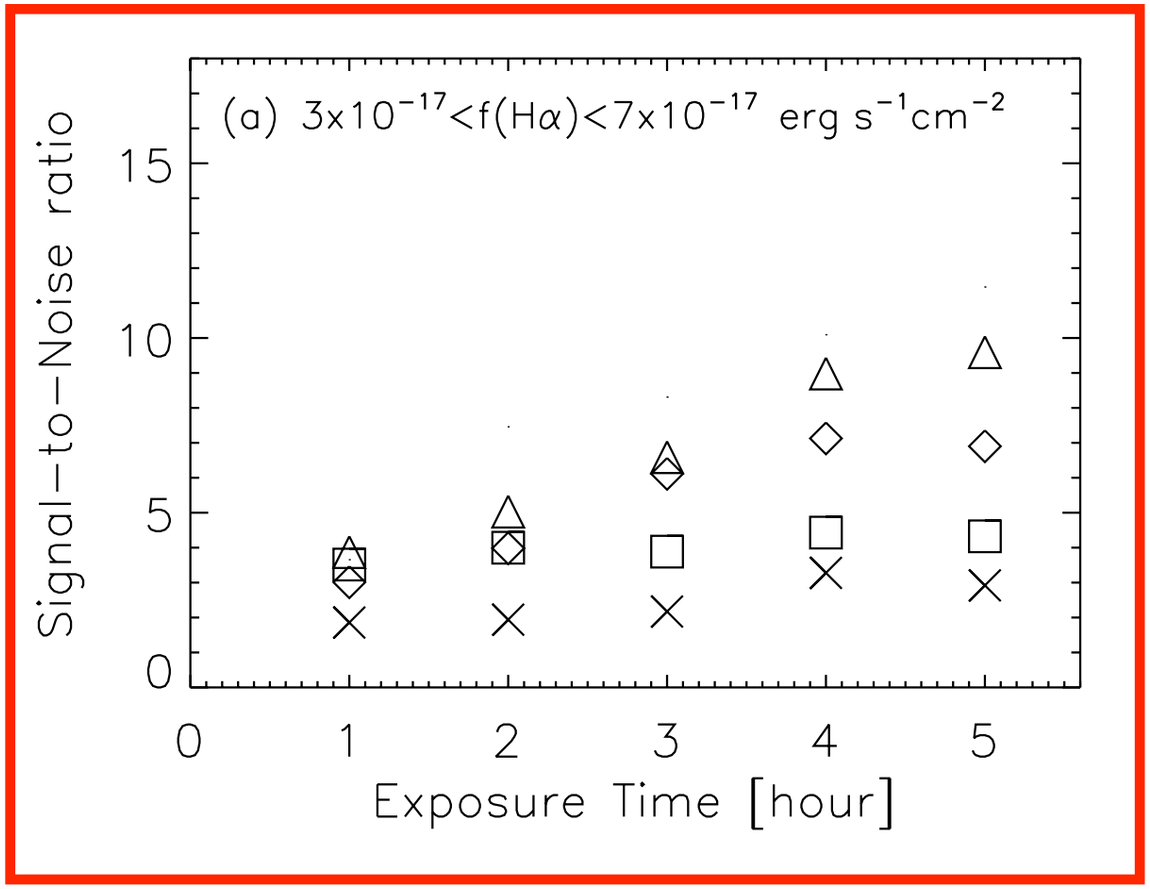
Filler targets: AGNs, low-mass galaxies

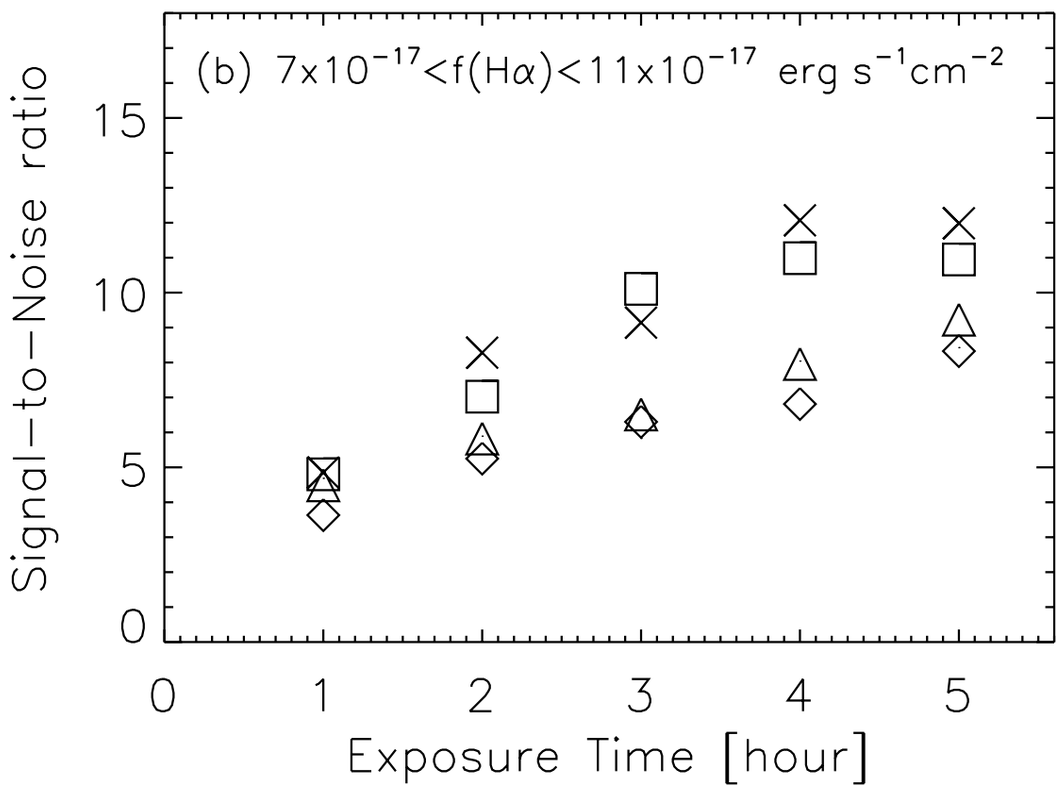


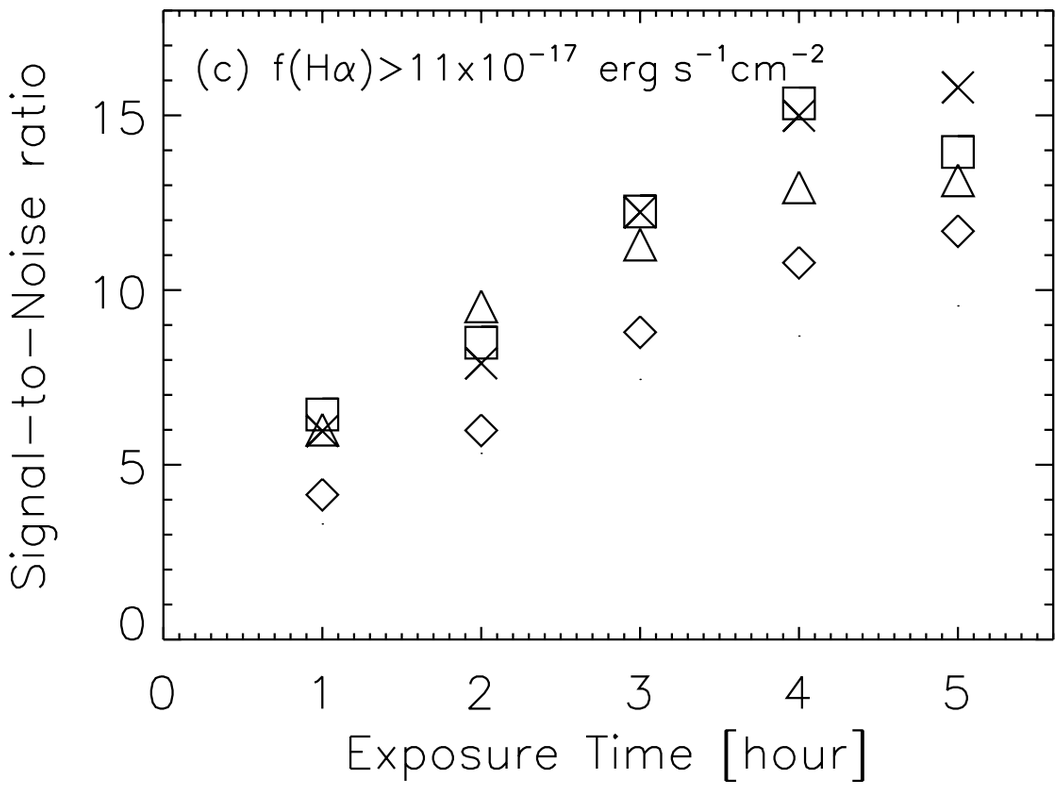
Rodighiero et al. 2010

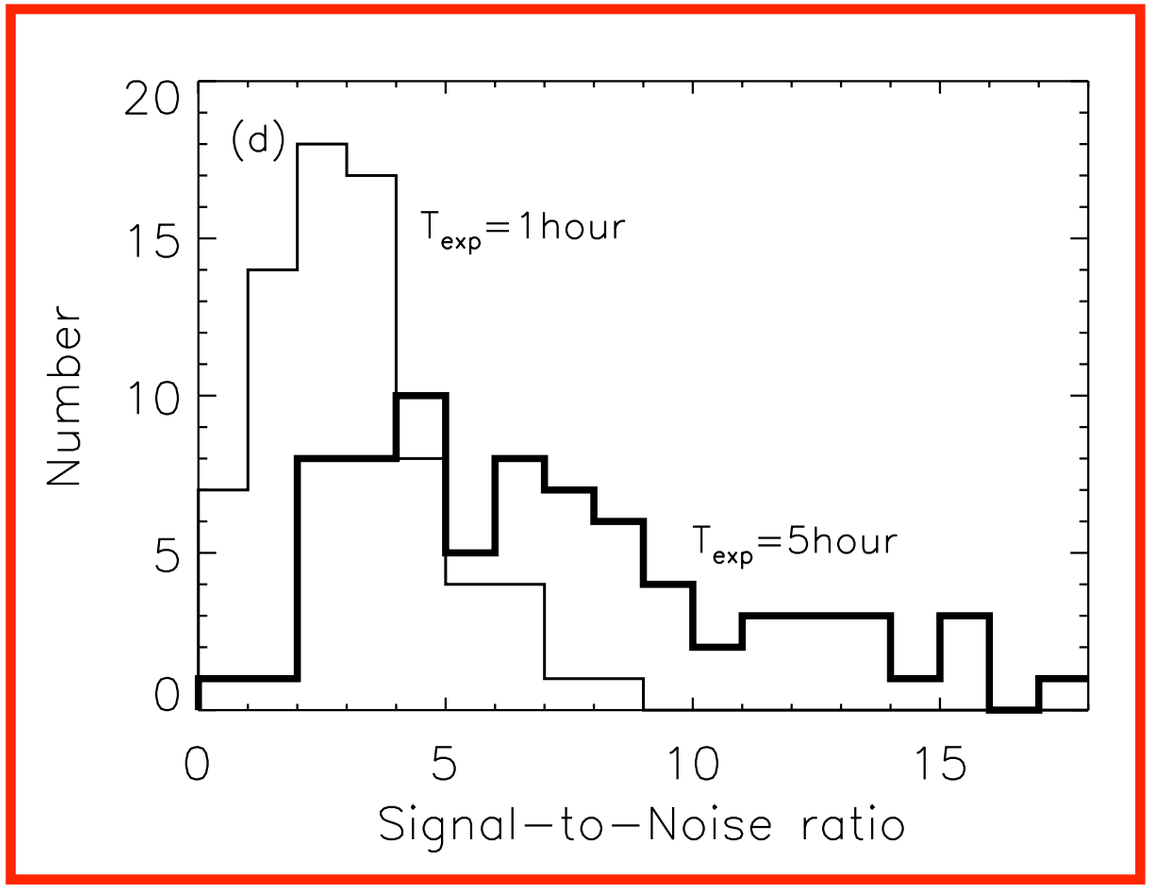

J-long (1.1-1.35μm)
Hβ
Hβ
[OIII]
Fiber
Wavelength

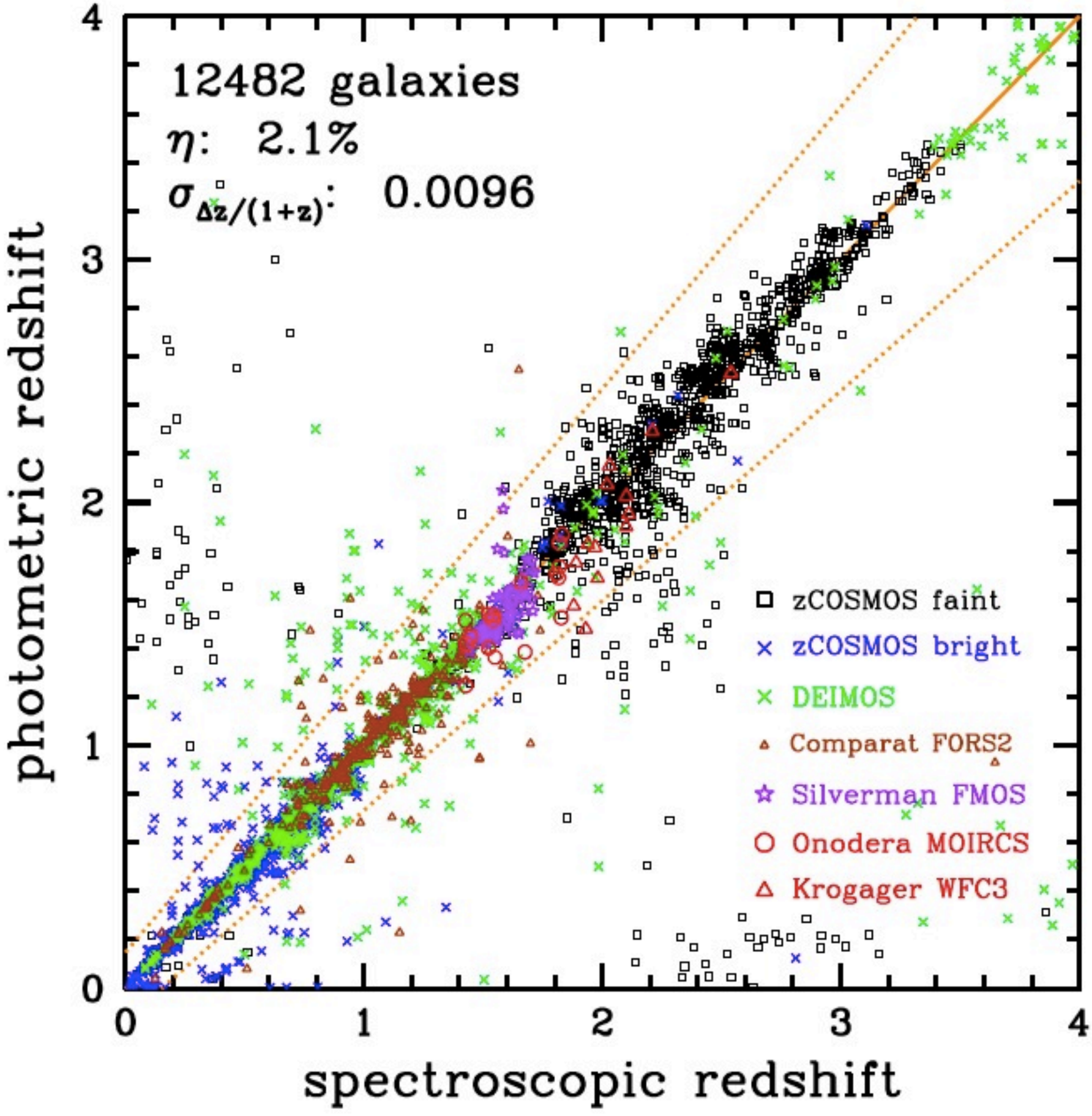

H-long (1.6-1.8μm)
Hα
[NII]
Hα
[NII]


(a) 3x10^{-17}<f(Hα)<7x10^{-17} erg s^{-1}cm^{-2}
Signal−to−Noise ratio
Exposure Time [hour]
0
5
10
15
0
1
2
3
4
5


(b) 7x10^{-17}<f(Hα)<11x10^{-17} erg s^{-1}cm^{-2}
Signal−to−Noise ratio
Exposure Time [hour]
0
5
10
15
0
1
2
3
4
5


(c) f(Hα)>11x10^{-17} erg s^{-1}cm^{-2}
Signal−to−Noise ratio
Exposure Time [hour]
0
5
10
15
0
1
2
3
4
5

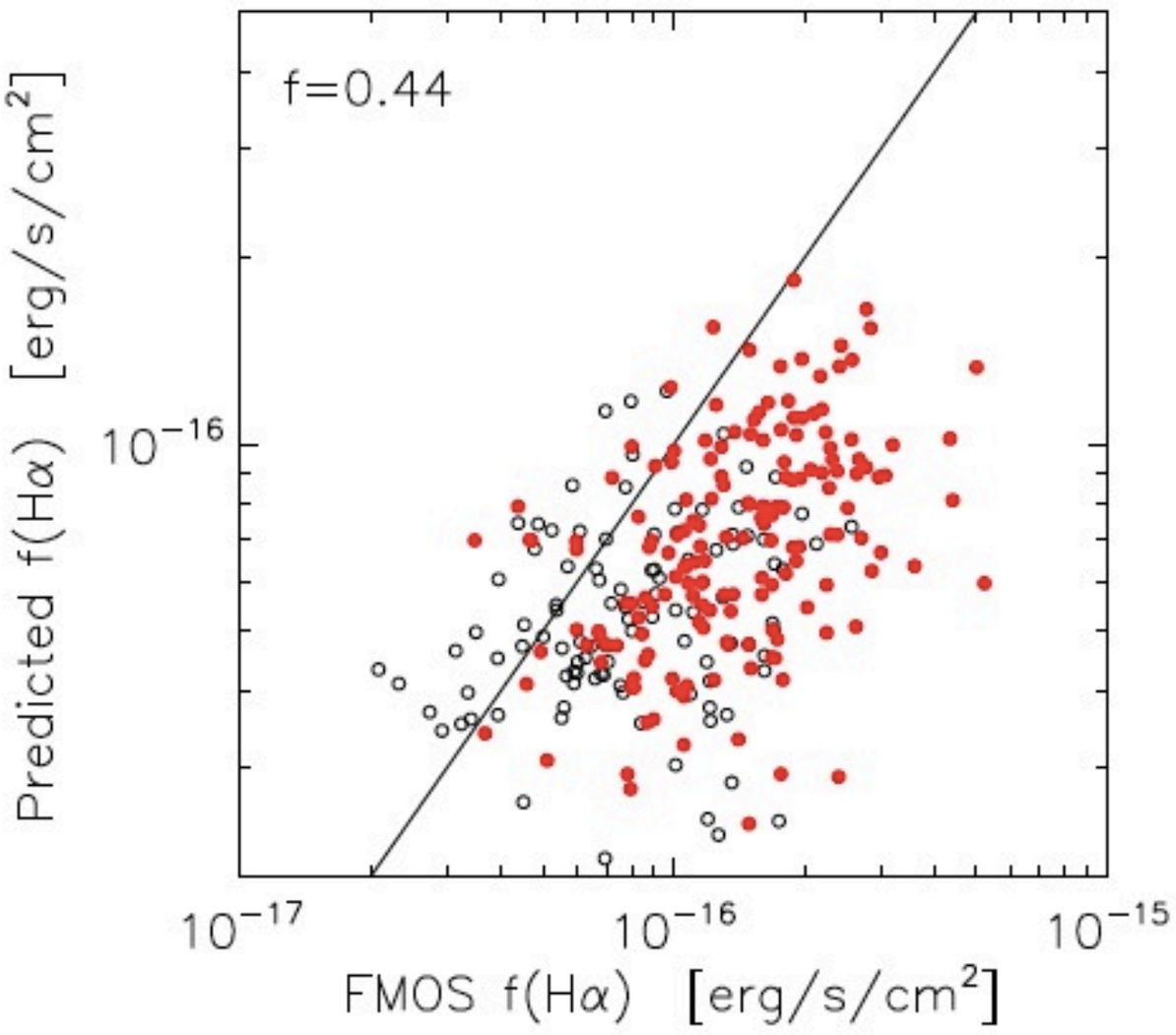

(d)
T_{exp}=1hour
T_{exp}=5hour
Number
Signal−to−Noise ratio
0
5
10
15
20
0
5
10
15

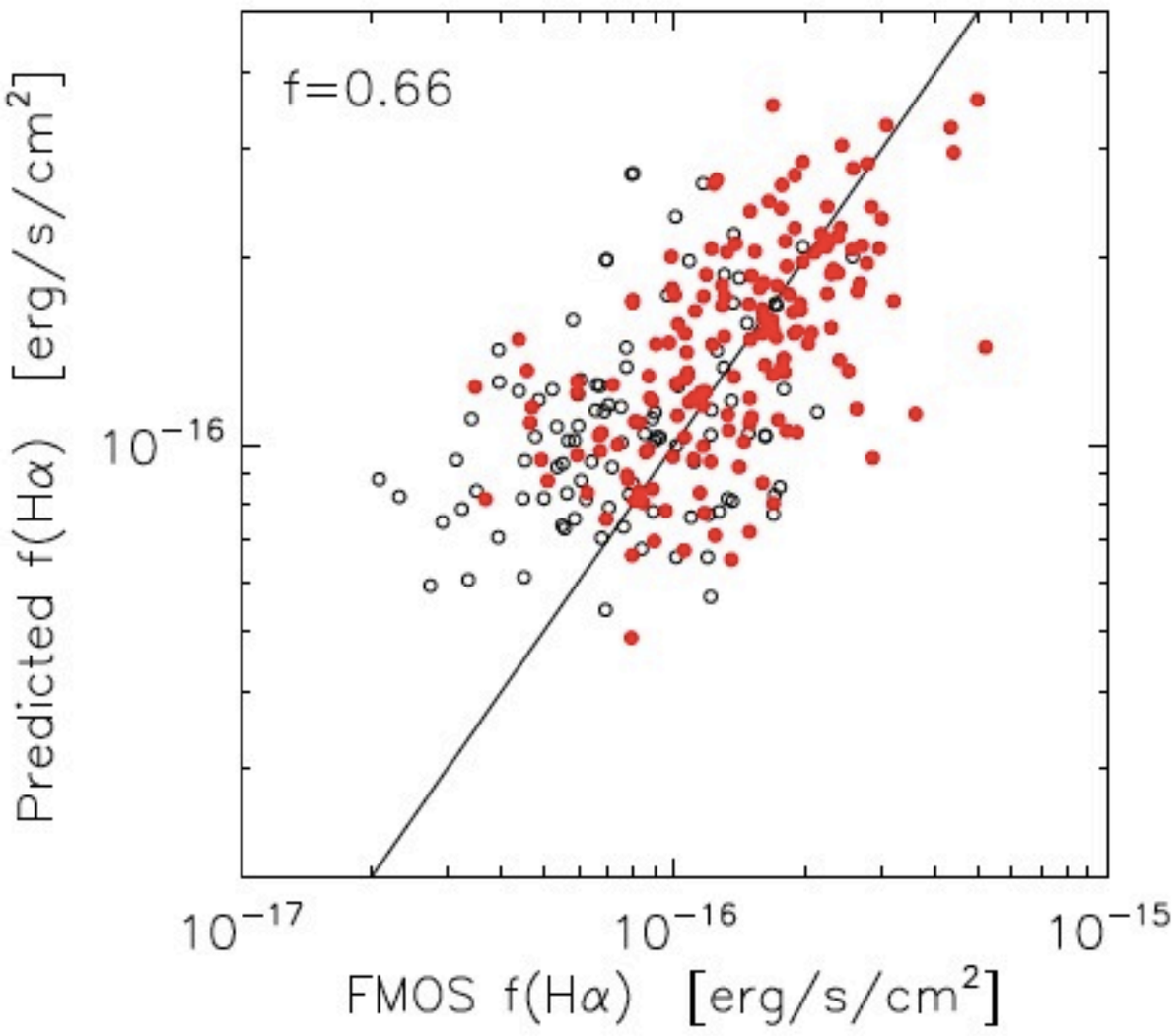


Ilbert et al. 2013

Predicted vs. Observed Hα flux

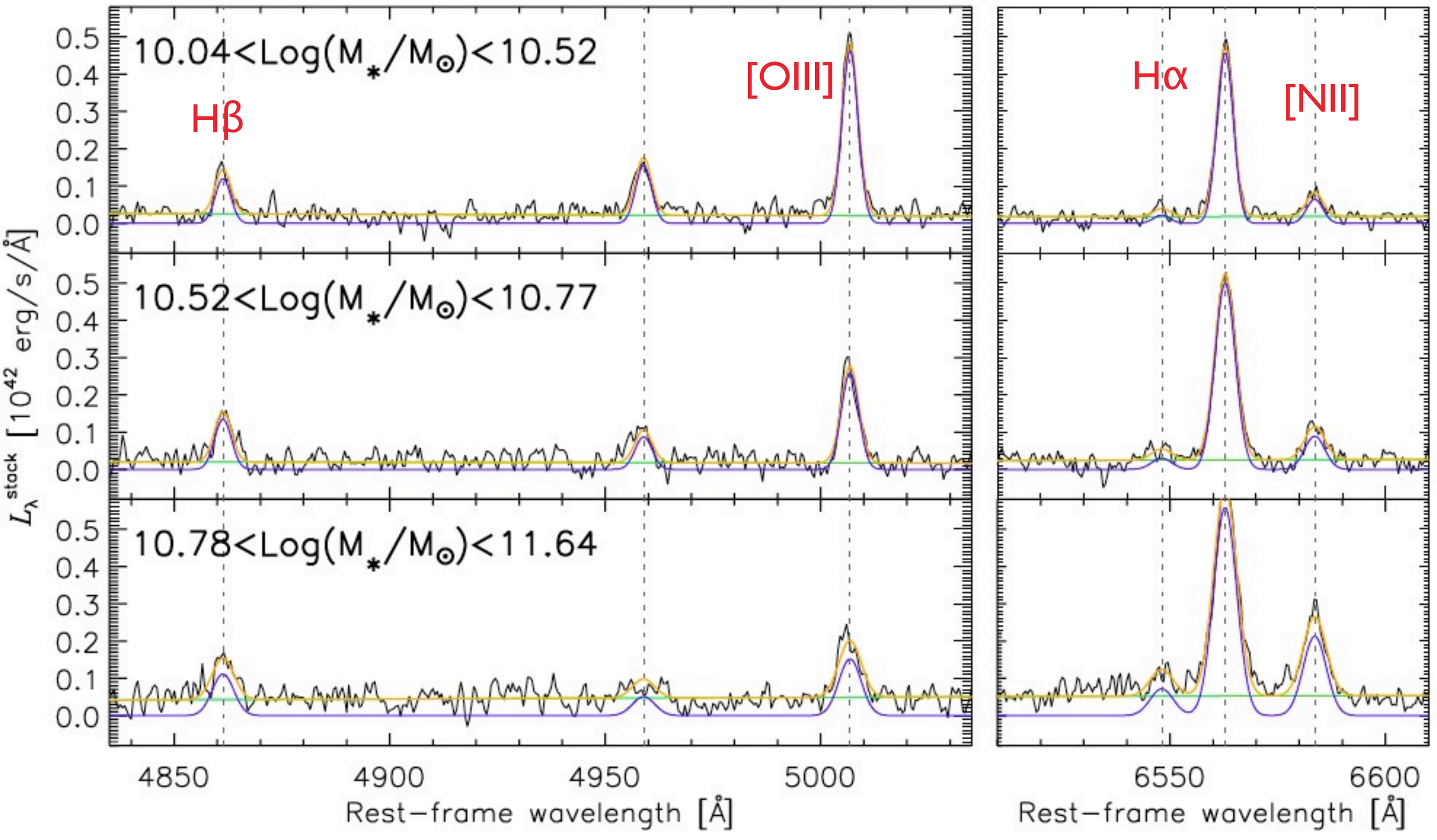
Flag = 2
= 1





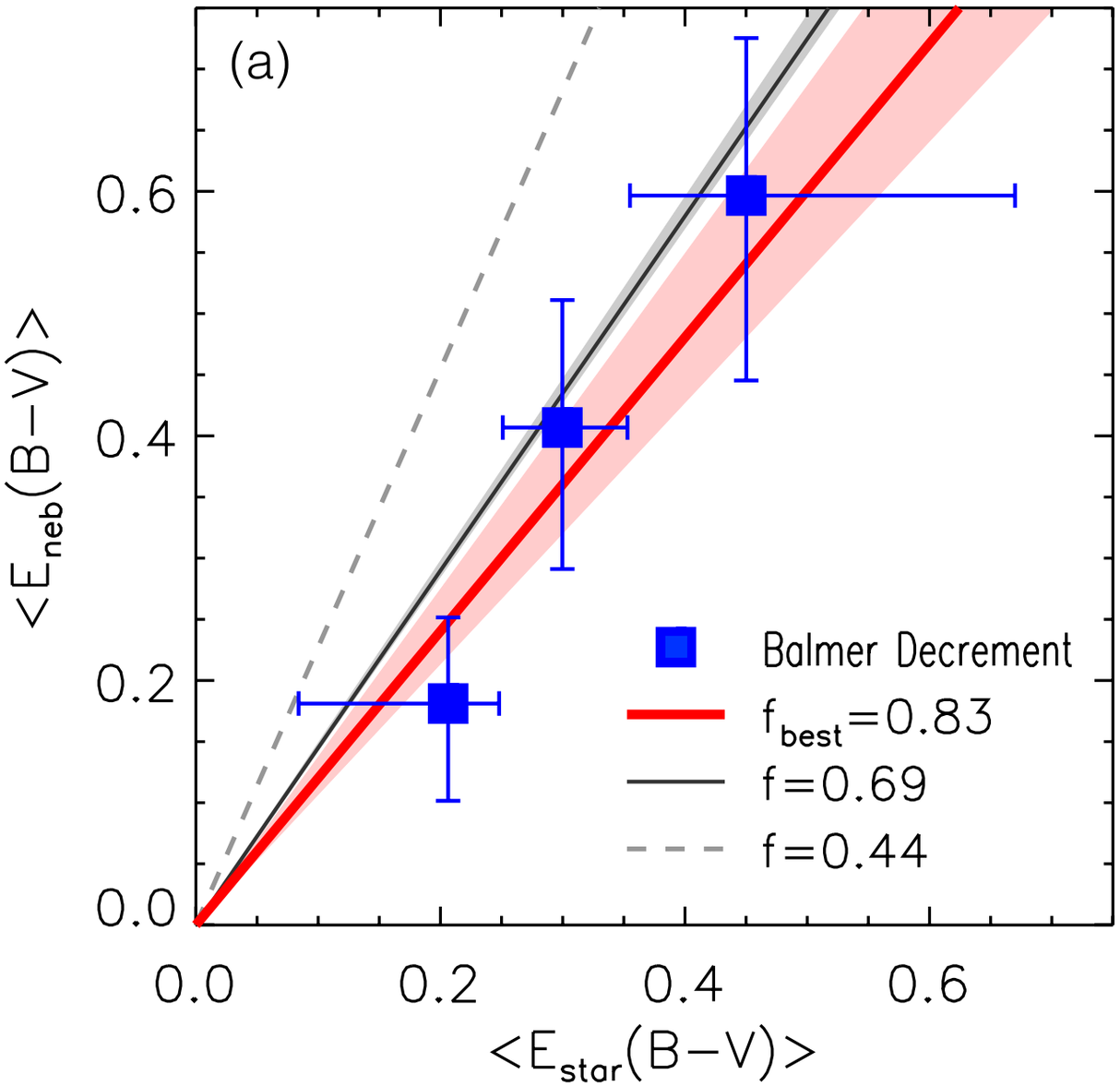
Stacking analysis

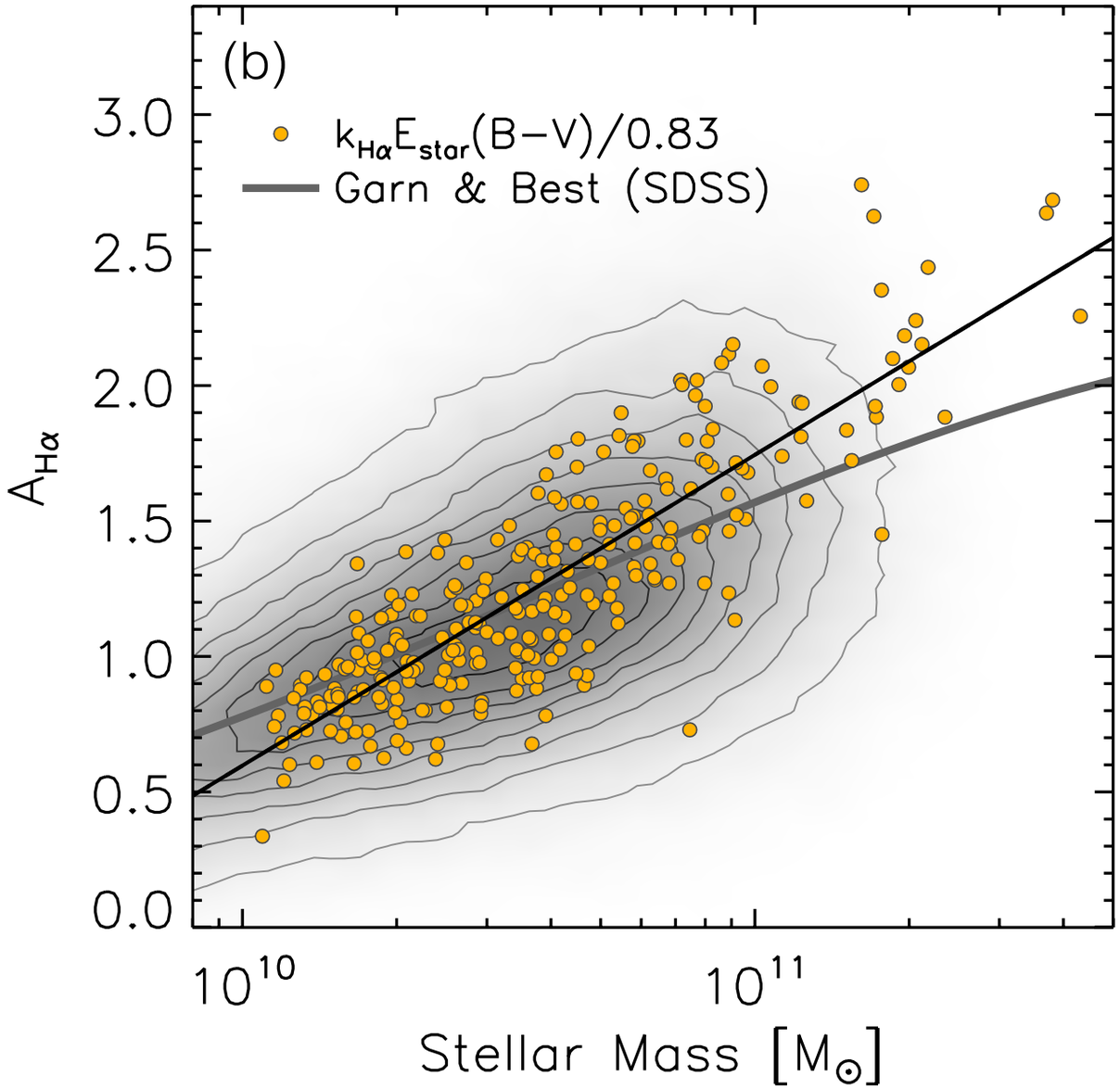
We stacked 34 individual spectra in each three mass bins.
Line properties change clearly with mass.



Kashino et al. 2013

Nebular versus stellar extinction

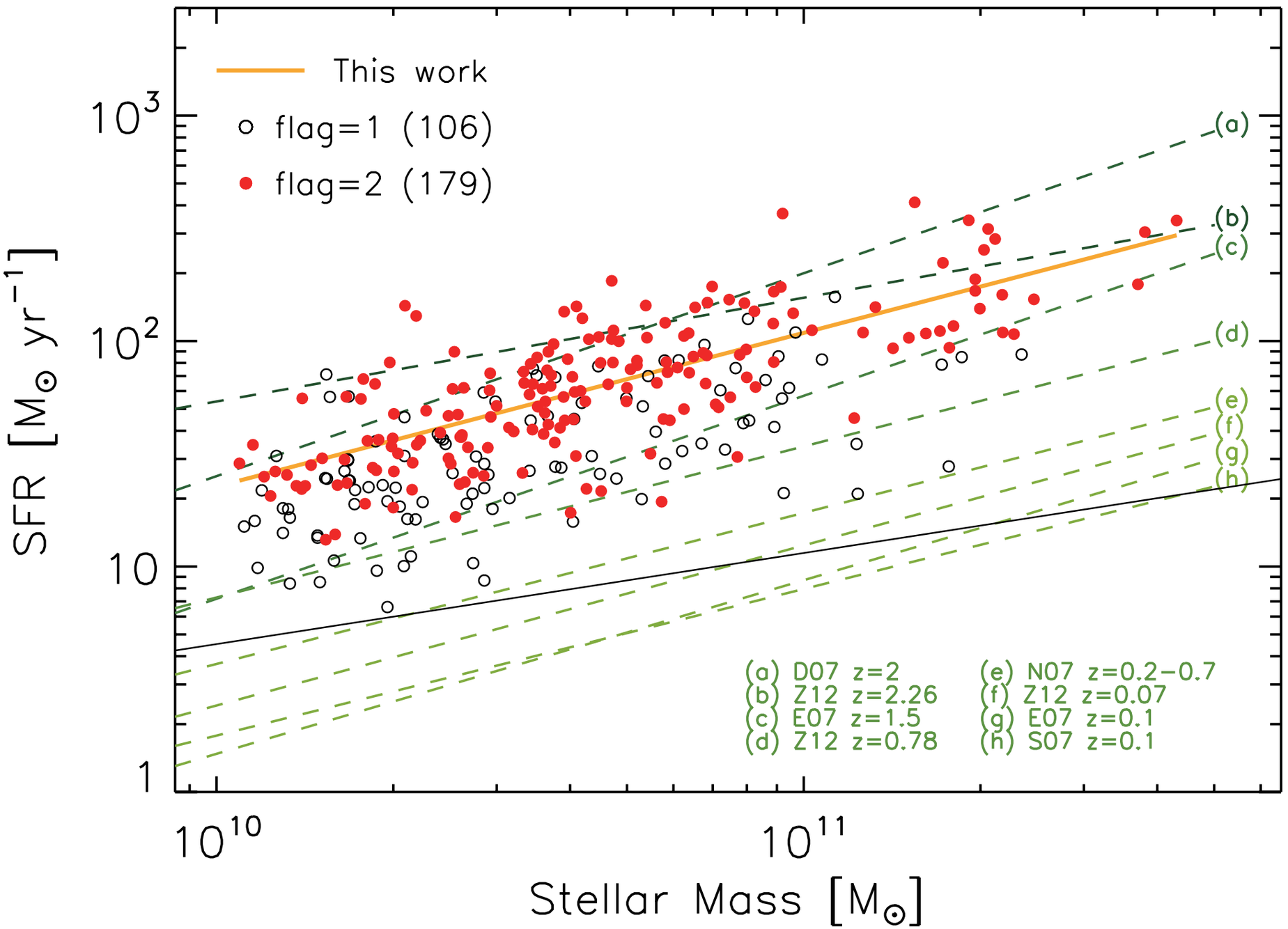




f=E_{star}(B-V)/E_{neb}(B-V)

Kashino et al. 2013

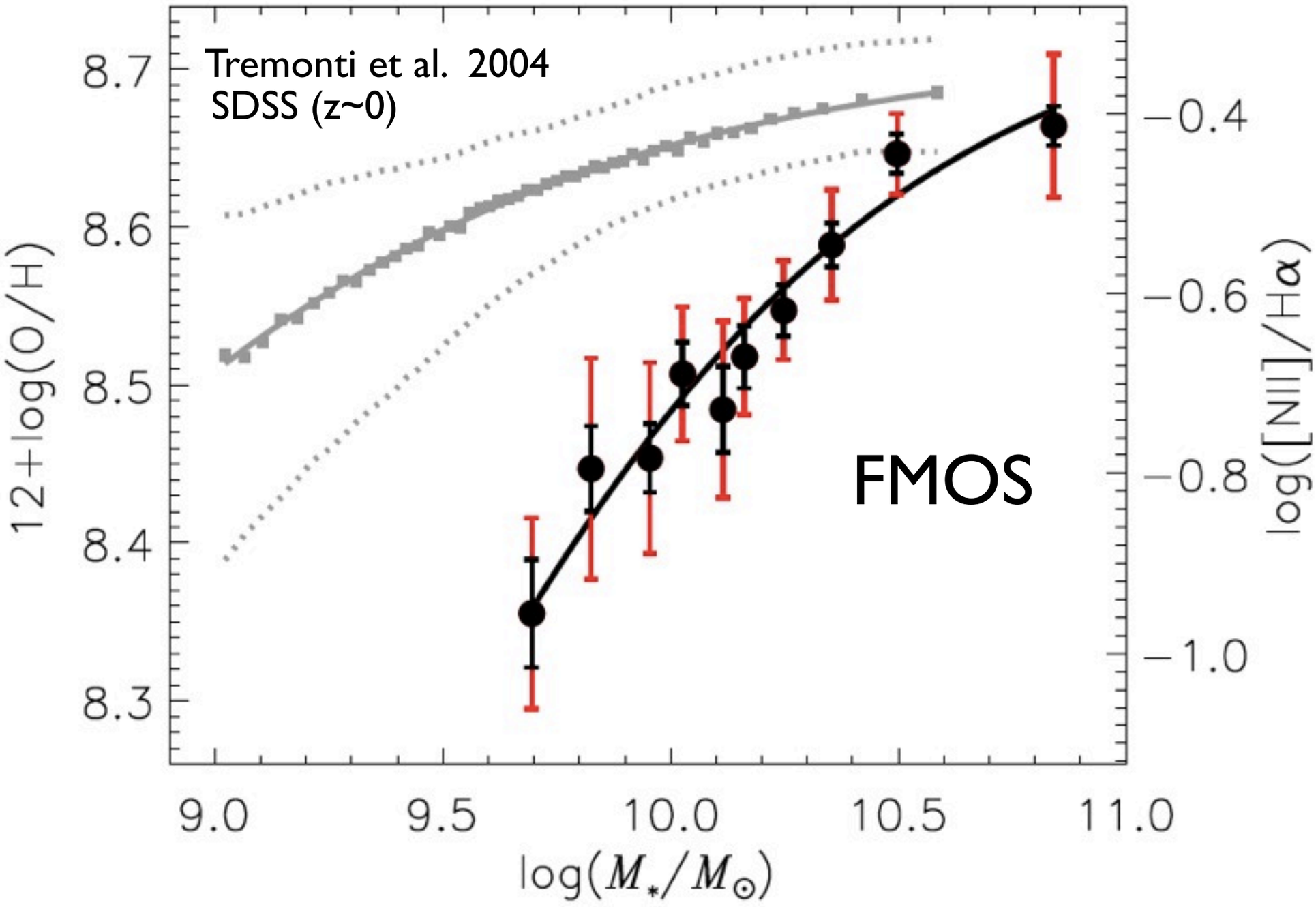
Star-forming main sequence at z ~ 1.6

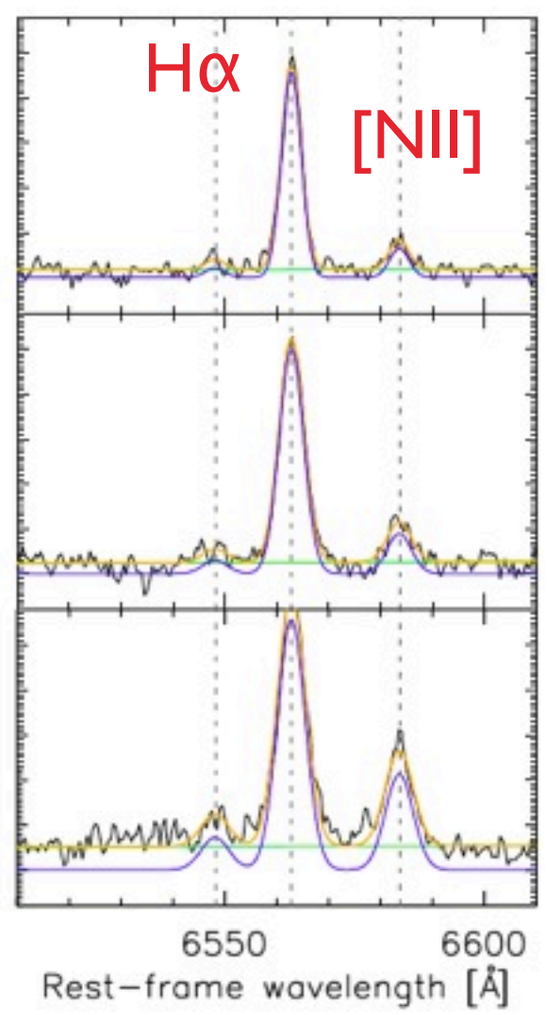


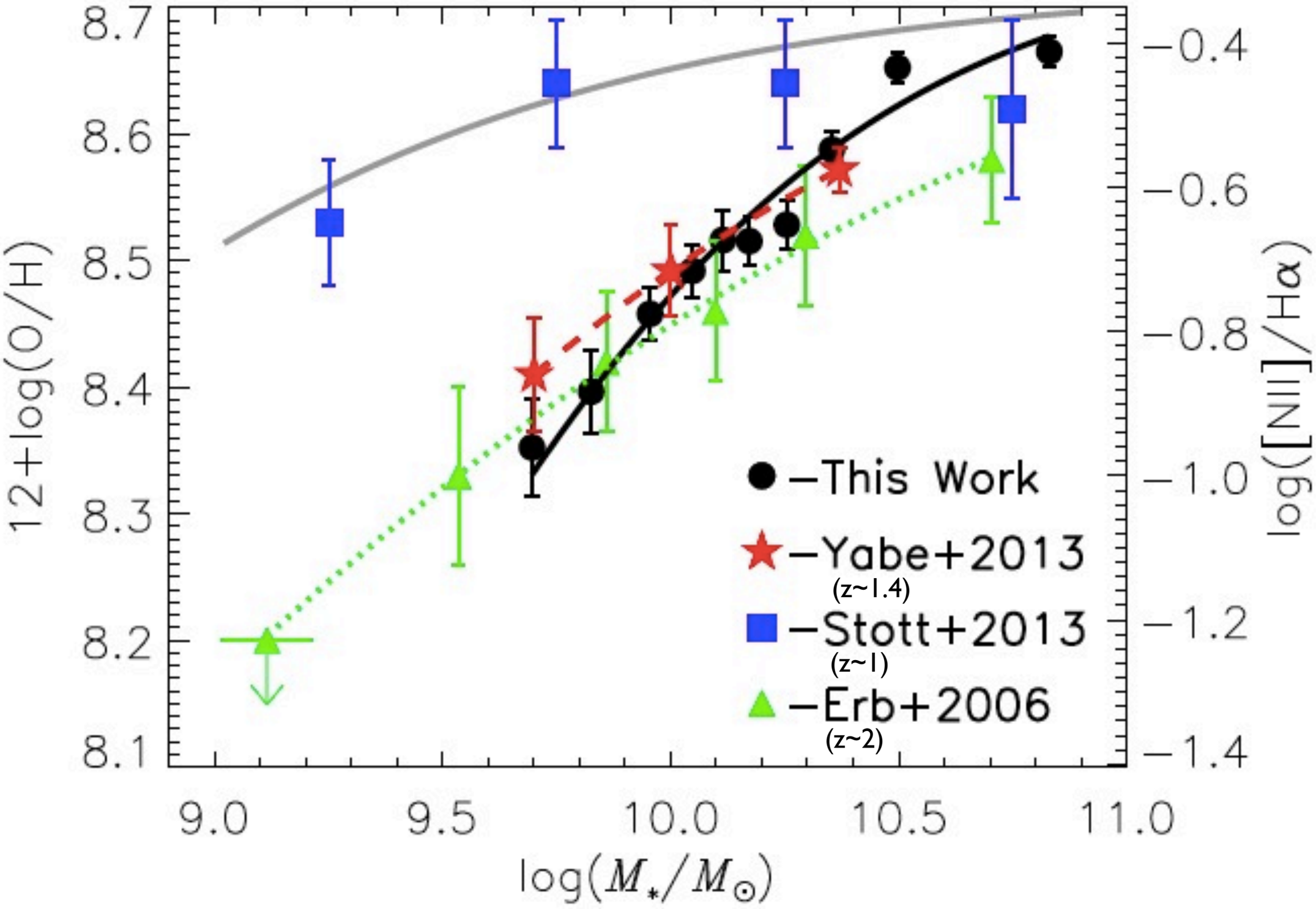
Kashino et al. 2013

Mass-metallicity relation at high-z

Zahid, Kashino, JDS et al. arXiv:1310.4950

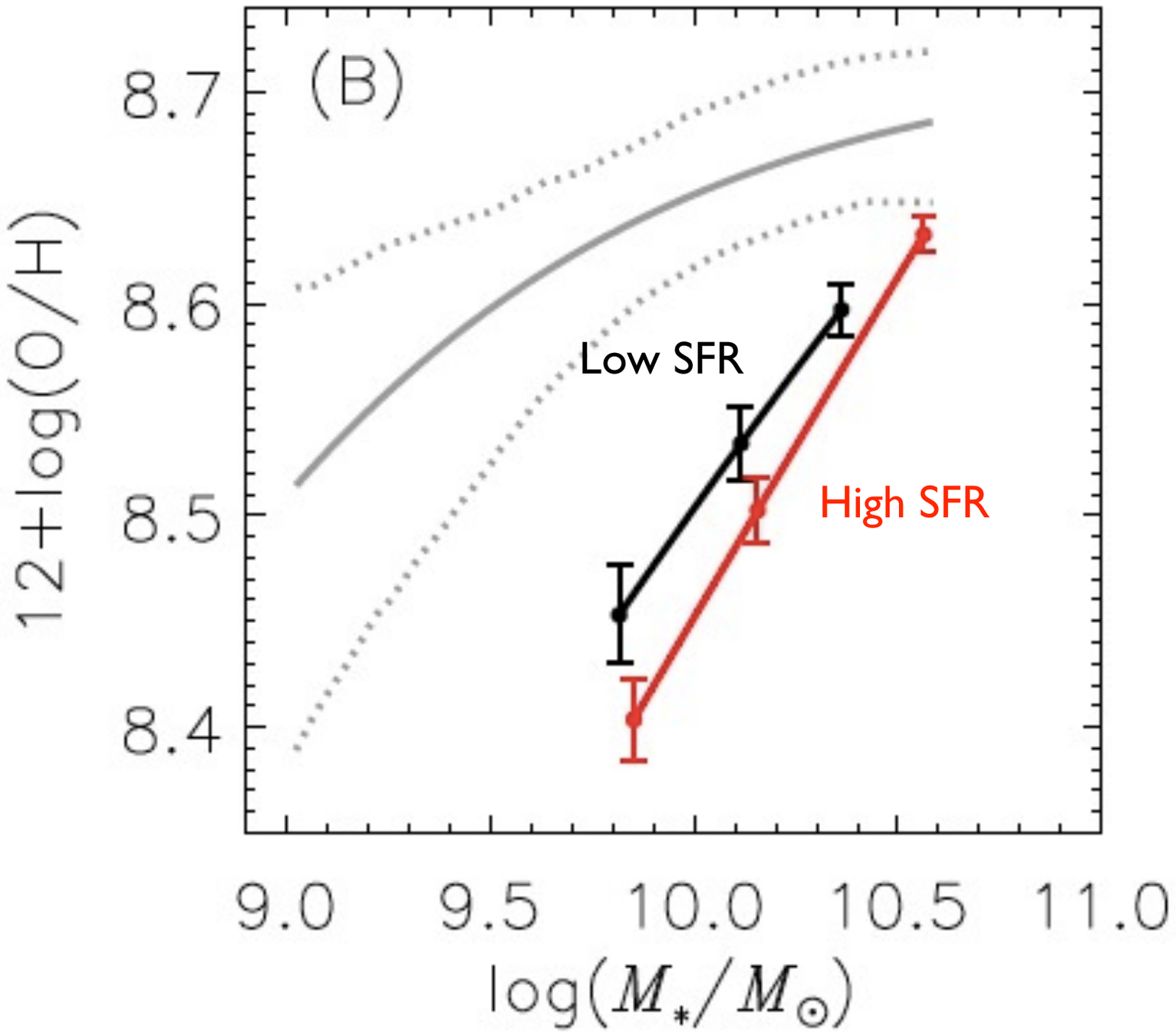




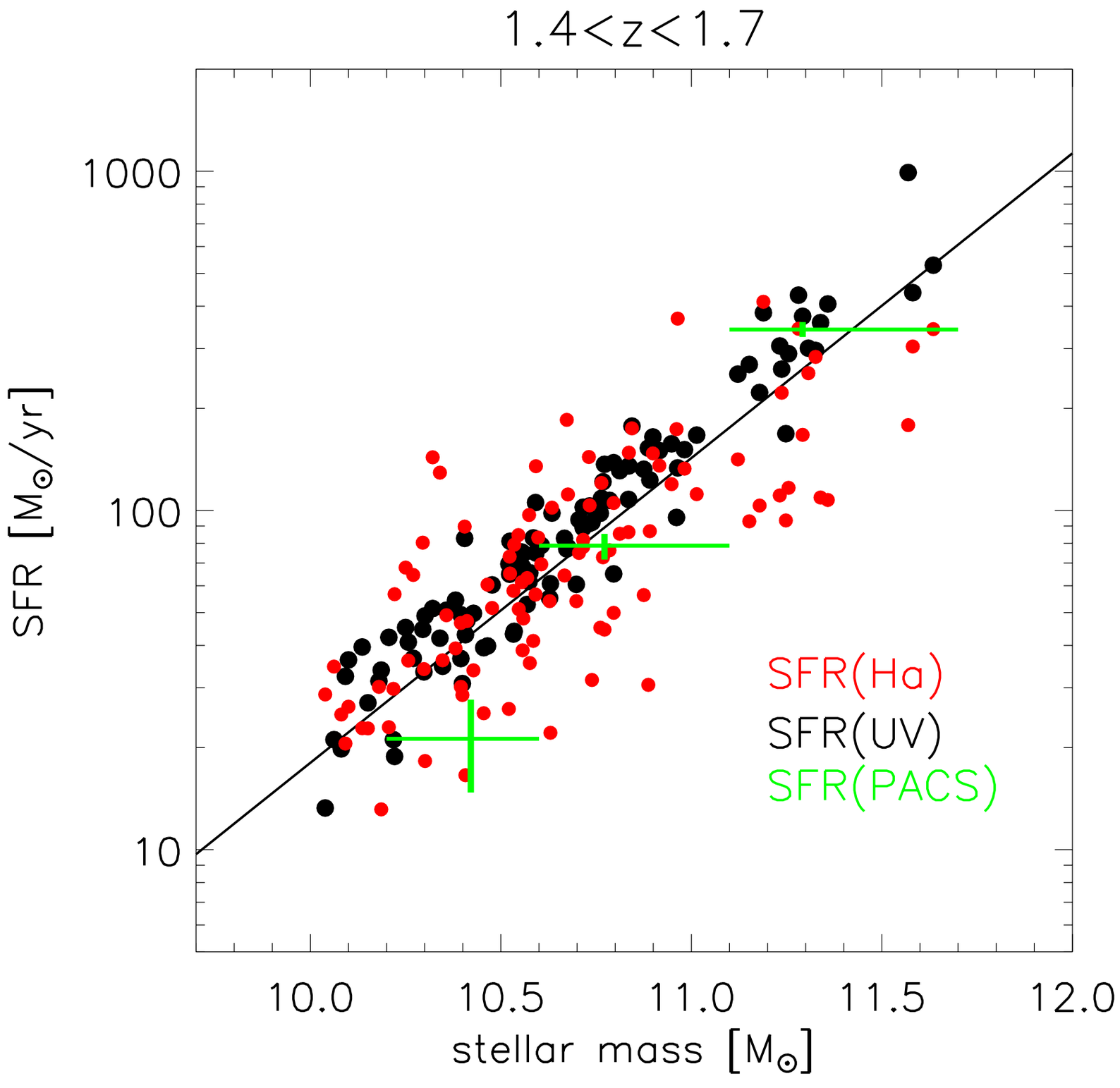

8.7
8.6
8.5
8.4
8.3
8.2
8.1
12+log(O/H)
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
log([NII]/Hα)
9.0
9.5
10.0
10.5
11.0
log(M*/M⊙)
This Work
Yabe+2013
(z~1.4)
Stott+2013
(z~1)
Erb+2006
(z~2)

Mass-metallicity relation at high-z

Zahid, Kashino, JDS et al. arXiv:1310.4950

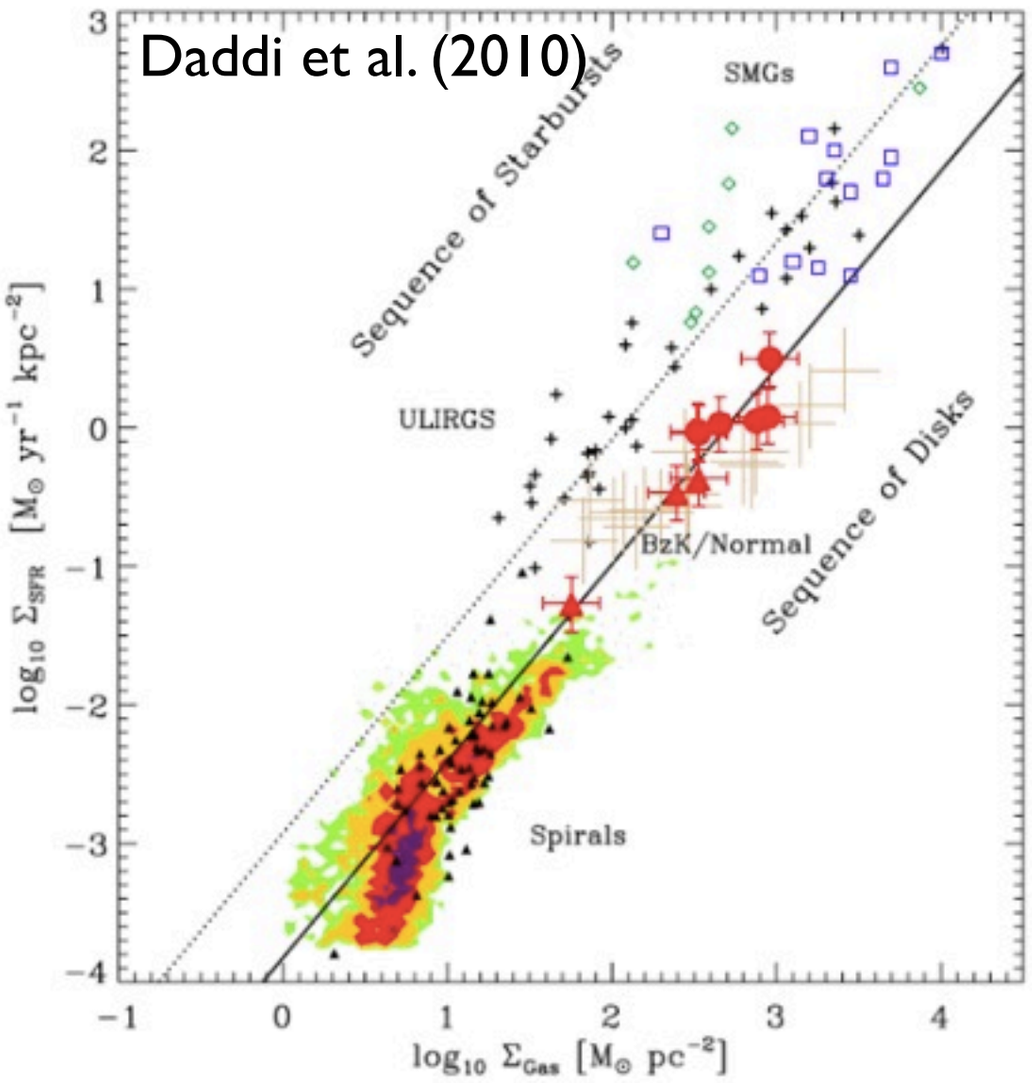


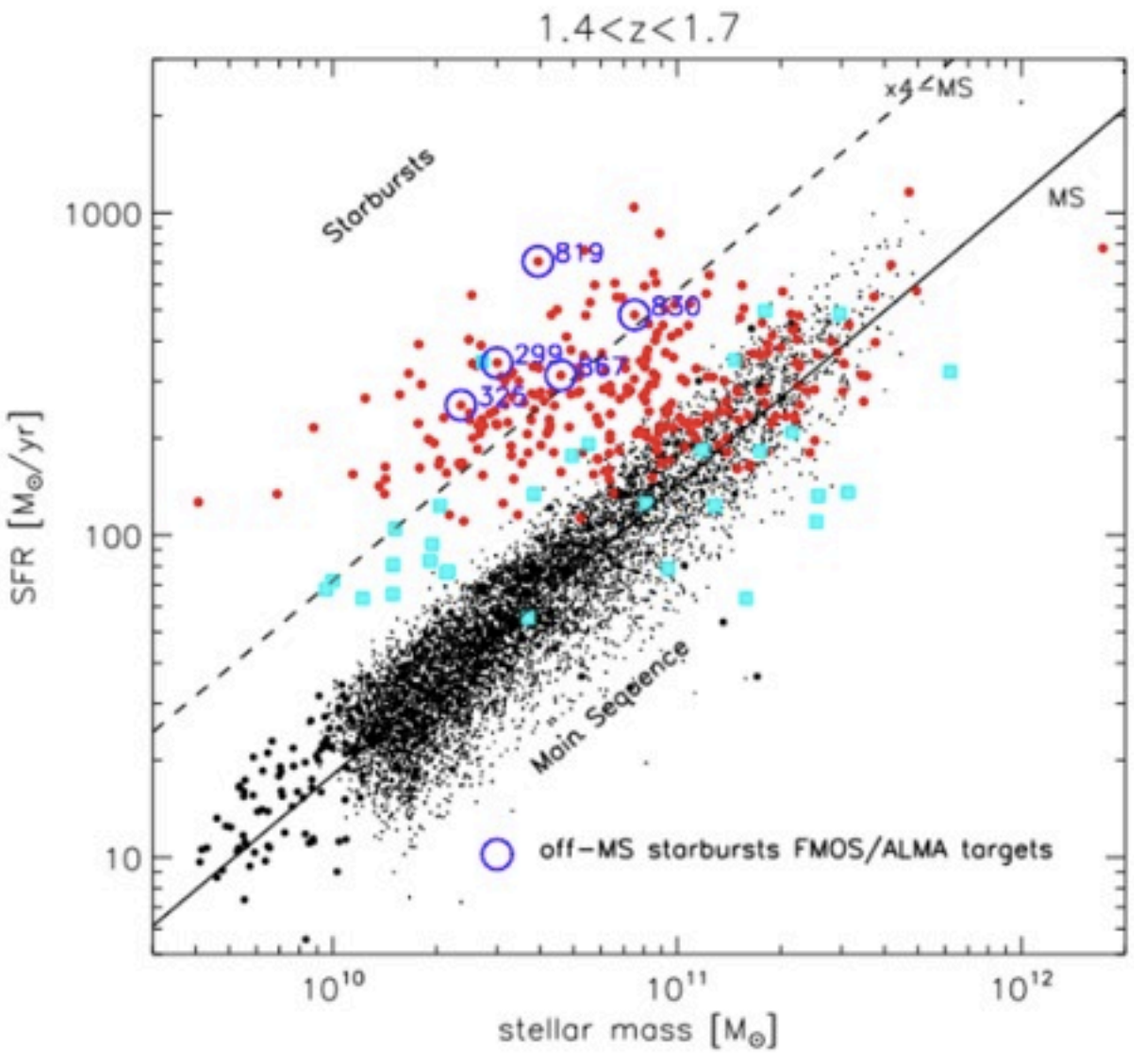
Comparison of different SFR indicators



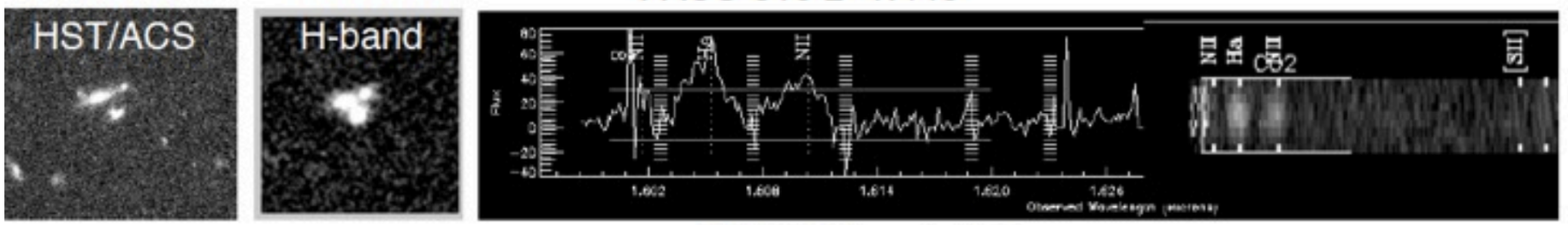
G. Rodighiero et al. in preparation

CO (2-1) masses through ALMA followup (Cycle 1)

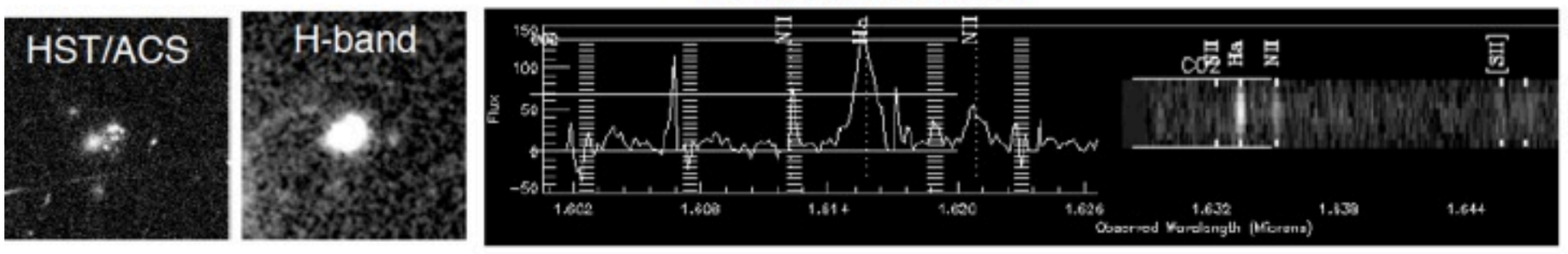




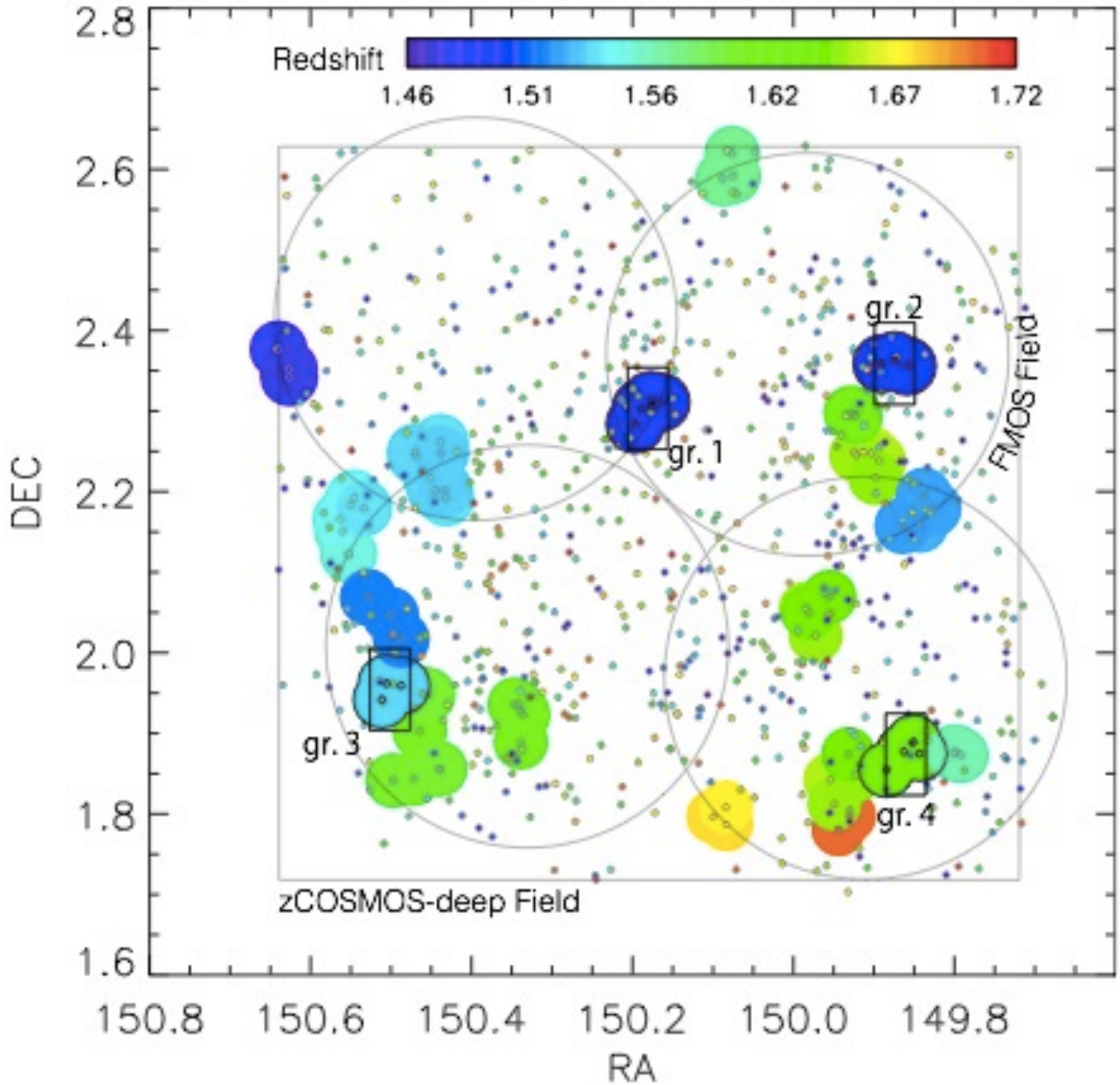
PACS-819 z=1.446



PACS-830 z=1.446



Galaxy associations at high-z



Summary

On our way towards a 1k NIR spectroscopic catalog

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

- SF main sequence in place (intrinsic width ~0.2-0.3 dex)

- Close relation between UV, Hα and FIR SFR indicators (Rodighiero et al.)

- Chemical enrichment (Zahid et al. 2013)
  - ★ High-mass galaxies have metallicities reaching the local relation
  - ★ Steeper mass - metallicity relation
  - ★ mass-metallicity-SFR relation is not so fundamental

Works in progress

- FMOS survey design and sample characteristics (Silverman)
- Comparison of star-formation rates (UV, Hα, FIR; G. Rodighiero, A. Renzini)
- Star formation timescales (E. Daddi)
- SF and metallicities as a function of UV morphology (M. Akhlaghi-Tohoku)
- Outflows using zCOSMOS deep UV spectra (D. Kashino)
- Proto-groups and environmental impact on star-formation (D. Kashino)
- AGN narrow emission-line properties at high-z (J. Chu, D. Sanders, L. Kewley)
- Properties of IR-selected galaxies (J. Kartaltepe, D. Sanders)
- Gas masses and star-formation efficiency with ALMA